Material change for a better environment

MRFs Comparison of efficiency and quality

Materials Recovery Facilities

Written by:

The Dougherty Group LLC on behalf of WRAP

The Waste & Resources Action Programme
The Old Academy, 21 Horse Fair, Banbury, Oxon OX16 0AH
Tel: 01295 819900 Fax: 01295 819911 www.wrap.org.uk

WRAP Helpline: freephone 0808 100 2040

September 2006

An introduction to MRFs and comparison of sorting operations based on site visits to selected facilities in England, Europe and North America

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Disclaimer

Introduction

Advancing the success of kerbside recycling programmes requires a persistent focus on reducing the costs of collection and sorting, while increasing the value of the recovered materials.

WRAP – the Waste and Resources Action Programme – has given considerable attention to understanding the most effective and efficient methods for recovering materials for recycling from household wastes. Further, WRAP's market development programme has made significant strides in increasing the diversity of markets for recyclable materials and hence the value of these materials.

Over the past several years, many local authority recycling programmes have evolved from separating materials at the kerbside to collecting co-mingled materials and delivering them to a central sorting facility. For these schemes, the "Materials Recovery Facility" (MRF) has become integral to both the method of collection and achieving end market requirements for sorted materials.

WRAP has commissioned four pieces of work to broaden understanding of the central role MRFs perform in co-mingled collection programmes:

- Current sorting practices and an initial review of operations at selected MRFs in England compared with selected MRFs operating in Europe and North America – the subject of this report.
- Development of a MRF cost model, an Excel™ spreadsheet which helps local authorities and MRF operators determine capital and operating costs for a sorting facility to handle the tonnage of kerbside materials anticipated for their areas. Materials can be delivered as a single co-mingled stream or as two-streams (fibre plus containers) and with or without glass.
- Review of contractual arrangements held between local authorities and MRF operators.
- Survey of existing MRF capacity in the UK and projections of likely future capacity requirement.

Purpose of this report

WRAP commissioned this report to:

- Describe the role MRFs performs in the recycling programme,
- Describe the MRF's function in sorting kerbside collected recyclables,
- Analyse and compare techniques and technologies currently used to sort materials,
- Identify and describe emerging trends in MRF sorting practices,
- Highlight cost-efficient sorting techniques and technologies,
- Identify techniques that minimise contamination in sorted materials, and
- Highlight successful practices based on existing performance.

This report is intended primarily for members of the UK recycling industry who have a well-rounded understanding of what a MRF is and how it operates. For them, this report highlights some of the sorting practices taking place in MRFs operating in England and in other countries.

For members of the recycling industry who have no first-hand knowledge of MRFs, or who may have limited understanding based on second and third hand information, this report provides information on the sorting techniques currently used, and the relationship of sorting options to the methods of collection.

For the majority of the UK recycling industry, with some knowledge of the sorting facilities operating in the UK, this report may expand that knowledge with details of MRFs in other countries that have reached their third or fourth generation over 15 years of operation.

The information contained in this report is based on a small sample of MRFs, and is intended to provide an initial view of MRF operations and trends in sorting co-mingled kerbside collected recyclables.

The information gained suggests the need for further examination of MRFs, focusing on specific performance issues in order to better inform the UK recycling community on methods to improve sorting efficiency and quality while reducing processing costs.

Study methodology

This study was designed primarily to analyse materials separation practices, technologies and operations at selected MRFs in England, and compare those to current practices at MRFs operating in Europe and North America.

The research team with input from WRAP staff identified a cross section of MRFs for individual case studies and for comparisons of sorting operations. The MRFs selected represent a variety of materials sorting techniques and range of operating capacities.

Site visits and interviews with managers were conducted at the following MRFs between October 2005 and January 2006:

England:
- Onyx MRF in Hampshire (Site Visit 1)
- RU Recycling MRF in Darwen (Site Visit 2)
- WRG MRF in East Riding of Yorkshire (Site Visit 3)
- SITA MRF in Huddersfield (Site Visit 4)
- WRG MRF in Luton (Site Visit 5)
- NEWS MRF in Norwich (Site Visit 6)
- Grundon MRF in Slough (Site Visit 7)

North America:
- Eureka Recycling MRF in St. Paul, Minnesota (Site Visit 8)
- Waste Management MRF in Minneapolis, Minnesota (Site Visit 9)
- Waste Management MRF in Seattle Washington (Site Visit 10)

Additional information was obtained on North American MRF operations through discussions with industry experts and MRF operators in Atlanta, Georgia and in Maryland.

Europe (selected with assistance from the Association of Recycling Cities):
- Triselec MRF in Lille, France (Site Visit 11)
- Onyx MRF in Renne, France (Site Visit 12)
- LIPOR MRF in Porto, Portugal (Site Visit 13)

Summaries of the site visits are available separate to this report.

1 How a materials recovery facility works

1.1 Introduction

The purpose of a Materials Recovery Facility (MRF) is to separate co-mingled materials into their individual material streams and prepare them for sale into the commodity markets.

A MRF may serve other social, economic or environmental objectives such as creating local employment but those are secondary to achieving the primary goal of cost-efficient sorting.

To be cost-effective, the MRF must operate efficiently, have minimal residues, and result in sorted material that meets the desired market specifications.

MRF processing has changed dramatically from early sorting practices which used equipment from other industries and relied heavily on manual sorting. Today, sorting equipment that has been designed specifically to enable different materials to be sorted from each other is used.

Although the efficiency of MRF technologies and techniques has greatly improved, there are significant advancements that can still be achieved.

1.2 Relationship between collection systems and the sorting process

There are various methods for sorting co-mingled recyclables, and there is no single best method. The most appropriate sorting technique for any given recycling programme depends directly on the:

- number of different materials recovered in the collection process,
- volume of materials to be sorted,
- degree to which materials are co-mingled,
- types of materials to be sorted, and
- end market specifications for the sorted materials.

A MRF may be designed to handle materials collected from a single kerbside collection system, or more typically, to sort materials from a number of kerbside collection programmes, as well as recyclables from commercial and industrial sources.

Naturally, a MRF is required only when the collection system employs some form of co-mingled collection of dry recyclables. Otherwise the need for sorting is minimal.

Methods of collection

The two most common methods of co-mingled collection are:

- Single-stream co-mingled (or fully co-mingled) – all dry recyclables are co-mingled and collected in a single compartment of a collection vehicle. The recyclables are collected from a wheeled bin, box or sack.
- Two-stream – either fibre is collected separately from the other co-mingled materials (typically glass, plastics and cans i.e. containers) or glass is collected separately from the other materials. Typically, collection vehicles have two compartments to keep the materials separate.

Sorting materials at the kerbside and transporting them in a vehicle with multiple compartments/stillages is common practice in the UK. This type of collection system does not require a central sorting facility, and hence is not one of the collection systems discussed in this report.

Local authorities and waste contractors often prefer the convenience and potential lower **collection** costs of the single- and two-stream co-mingled collection systems.

On the other hand, most reprocessors purchasing the recovered materials prefer that materials be sorted at kerbside as this minimises the potential for cross contamination and generally produces higher quality materials. The challenge of two-stream, and more so single-stream MRFs, is to meet the specifications required by the materials markets/ reprocessors.

Flexibility to sort materials from various collection methods

MRFs tend to receive and sort materials from a variety of different local kerbside collection programmes. Should the various local collection programmes collect different materials, or collect the same materials in a different manner, the MRF must have sufficient flexibility to efficiently accommodate these variations.

It is important to note that a MRF designed for single-stream co-mingled materials can also receive and efficiently sort materials from a two-stream collection scheme and even from source separated collection programmes (where some materials can be collected mixed e.g. plastic bottles and cans).

While a two-stream MRF can process both two-stream and source separated materials, it is not designed to process single-stream co-mingled recyclables.

A bulking facility used for source separated collection systems typically has minimal sorting capability and does not have the flexibility to process materials from other collection systems.

Integration of collection and sorting

For greatest effectiveness, the method for sorting materials should be compatible with the way in which materials are collected. This optimises the efficiency of sorting and lowers overall costs.

Equipment

Processing equipment and systems are designed to separate recyclables based on a variety of material characteristics including:

- Size
- Shape
- Weight
- Other e.g. colour, magnetic properties, etc.

These must be used in combination with other sorting techniques to achieve the necessary separation of materials. For example, a system designed to sort materials by surface size will discover, that shredded paper will follow glass fines through the sorting process.

A system designed to sort two-dimensional from three-dimensional materials, will discover that alterations to the dimensions at either the household or in the collection vehicle will affect how the material is sorted. For example, if a householder crushes a plastic or metal container, that container may behave more like a two-dimensional material and follow the paper stream through the sorting process.

In-feed lines

In-feed lines are different points in the overall sorting process where various materials may enter the system. It is important that a MRF processing materials from various collection programmes has adequate in-feed lines so as to avoid unnecessary sorting steps.

Some collectors deliver fully co-mingled materials to the MRF while others also deliver certain materials sorted at the time of collection. It is important that the materials sorted prior to delivery to the MRF are able to enter the sorting system at the appropriate point, thus avoiding the costs of passing through unnecessary sorting stations.

Some MRFs take in materials from commercial and industrial sources and sort those materials along with the kerbside materials. In many cases the commercial/industrial materials are already highly sorted. “Clean” commercial loads (e.g. office paper, old corrugated card (OCC), etc.) are processed at many MRFs to make use of the unused processing capacity and supplement revenue.

1.3 The sorting process

There are three primary phases in the MRF sorting process:

- Receiving and preparing materials for the sorting process
- Sorting the materials into their individual material streams
- Inspecting, baling, storing and shipping sorted materials

Receiving and preparing materials for the sorting process

Receiving incoming materials

Incoming loads of co-mingled dry recyclables are off-loaded in a large space called the "tipping floor". The tipping floor has a hard, concrete surface, allowing the unsorted materials to be stored before being introduced into the processing system via a loading shovel or other similar equipment.

The space dedicated to incoming materials should be a weather-protected area, of sufficient size to hold 1.5 to 3 days worth of delivered, unsorted materials. Although it is best practice to sort all materials on the day received, that is often not possible for a variety of reasons, e.g. mechanical break-down, change in collection patterns, increased loads following public holidays, etc.

Recyclables are transferred from the tipping floor onto a conveyor system that moves the materials toward the sorting stations. This conveyor system can either be at the bottom of a pit in the floor and equipment used to push the materials onto the conveyor, or a floor-level conveyor where a front end loader or similar equipment is used to lift the materials onto the conveyor.

Splitting collection bags

Some local authority collection programmes provide householders with designated recycling bags, typically made of film plastic.

To facilitate the movement of materials to the sorting stations, an automated bag splitter is required at the point materials move from the tipping floor to the metering station. The bags are split open allowing the contents to fall free. In most cases the plastic film bags are retrieved at the pre-sort station.

Metering the flow of material

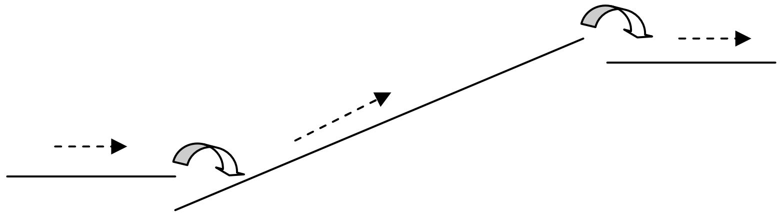
An uneven flow of materials on the conveyor reduces the efficiency of both manual and automated sorting processes. Thus, it is typical to employ a method for levelling out the flow of materials through the sorting stages are four basic methods for metering the flow of material:

- Slowly feed materials onto the conveyor

A simple, basic approach is to require the operator of the loading shovel to slowly tip the materials onto the conveyor belt, thus spreading them out.

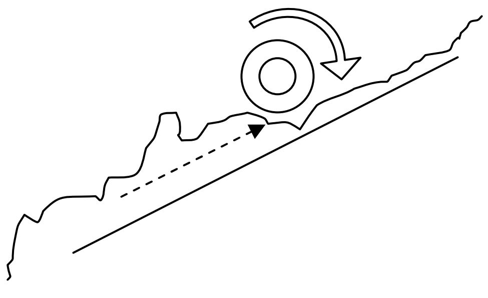
- Series of conveyor belts of progressively increasing speeds

A typical system would consist of three belts, each operating faster than the previous one. The first conveyor can move materials at a rate of 2-10 feet per minute, the second at 20-60 feet per minute, and the third at 60-100 feet per minute. The progressively increasing speed causes materials to spread more evenly over the conveyor belt.



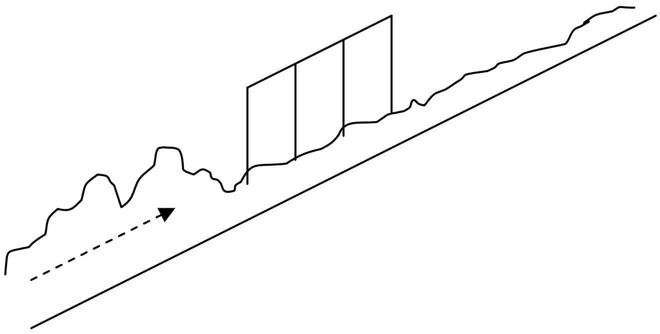
- Metering drum

This is a large steel drum that rotates in the opposite direction to the materials as they travel up the inclined conveyor. As the drum turns, it levels out the materials on the conveyor system, forcing the excess materials to tumble back down the incline.



- Gates or curtains

Steel gates or curtains are placed at specified heights above the inclined conveyor. As materials move up a steep incline, they pass under the gate or curtain. Those materials unable to fit under the gate/curtain fall back down the belt and occupy a space that has fewer materials. This will continue until all the materials pass under the gate/curtain.



Pre-sorting materials

Irrespective of whether the MRF primarily is a manual or an automated sorting facility, there typically is an initial stage, called the pre-sort, at which workers spot and manually remove any non-recyclable materials (e.g. wire, wood waste, etc.).

The pre-sort station is critical to the efficiency of the entire system. Removing contaminants at this stage avoids unnecessary costs being incurred as a result of these materials passing through the various sorting stations and allows the sorting technology to operate at optimal efficiency.

The pre-sort station is also used to remove any recyclable materials that may be allowed by the kerbside collection programme, but for which the sorting system is not designed to segregate. For example, some MRFs may not be designed to sort film plastics, textiles, large OCC.

Local authorities that include film plastics (LDPE, LLDPE) in their kerbside collection schemes often require the householder to place all of the plastic film into one plastic bag. At the pre-sort station, the bags of film plastics are manually removed and sent to a baler.

Similarly, large pieces of corrugated cardboard can cover up other materials, in effect hiding them from both manual and automated sorting. Many MRFs pull the OCC at the pre-sort station. Some MRFs which sort large volumes of OCC may have an OCC screen installed.

Sorting into individual material streams

As is typical with many sorting processes, larger items are separated out at the front end of the process and smaller items toward the back end.

The primary sorting step separates fibre (newsprint, magazines, office paper, OCC) from containers. Advanced sorting steps may then be used to segregate paper by fibre grade and containers by material type.

Sorting paper from containers

Separating the two-dimensional (paper) from three-dimensional (containers) early in the sorting process allows easier access to the materials for further sorting.

With automated sorting, this initial sorting is done using either a trommel screen or a disc screen.

- Trommel screen

A trommel screen consists of a large rotating cylinder with holes of various sizes through which materials fall. The cylinder is set on an incline, the smaller holes being located at the upper end.

As co-mingled materials enter the cylinder, the larger fraction materials pass through the screen first. As the holes become progressively smaller along the length of the cylinder, gradually smaller materials sort out.

Typically, containers pass through various sized holes along the sides of the cylinder while paper passes through last.

- Disc screen

Disc screens have become more popular in recent years in a variety of sorting applications:

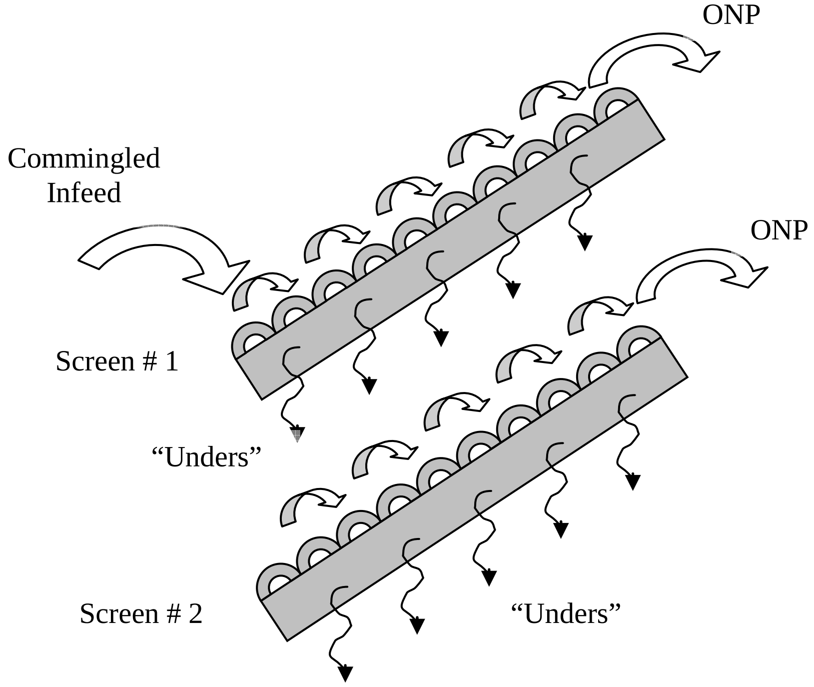
  - In single stream MRFs they are used to perform an initial separation of fibre and container materials.
  - In fibre sorting applications, they are used to separate OCC or newspaper and magazines from other fibre grades.
  - In co-mingled container sorting systems, they serve as an alternative to vibratory screens and trommel screens for removing fines, debris, broken glass, etc. from the larger containers.
  - In co-mingled container sorting systems, they are used to sort containers from miscellaneous fibre contaminants.

The disc screen has several inclined rows of oblong steel discs which spin in the direction of the material flow. Larger surface size (or two-dimensional) materials move up the incline of rotating discs while smaller materials are bounced in the air and knocked off the top. There is sufficient space between the conveyor belt and the disc screen, as well as space between the rows of discs, to allow the smaller surface size materials to fall below onto another conveyor system.

Typically, the disc screen is used to sort three fractions:

- newspaper and magazines over the top of the screen, referred to as “overs”;
- mixed paper and lighter containers through the middle of the screen, referred to as “unders”; and
- heavier material (primarily glass) at the bottom of the screen.

The screens can be designed as single, double or triple screens depending on the function.



ONP = old newspapers

Sorting paper into grades (advanced grading)

Two methods are used for further sorting the mixed paper into various market-grade specifications:

- Disc screens

A series of two disc screens is often employed. The first disc screen has wider spaces between the conveyor and between the discs, allowing for only large and ridged materials, specifically OCC, to move up the screen while all others fall below onto another belt.

At the second disc screen, which has smaller spaces between the discs, the newsprint is sorted from mixed papers.

At two of the MRFs visited (Eureka Recycling, St. Paul, and Waste Management, Seattle), a third disc screen, with even narrower spacing, sorts low grade card (wetpak) from mixed paper.

- Optical scanning

Optical scanners are capable of identifying fibre grades and sorting targeted grades using reflective near infrared (NIR) sensors. The sensor module can be placed on top of the sorting conveyor and once sensed, air jets (or air knives) at the end of this conveyor sequentially eject the target material, separating it from the remainder of the materials. This technology is used successfully for sorting various grades of paper and plastic resins at several MRFs in North America and Europe.

Optical scanners can be used to identify and sort various grades of paper as well as to separate paper from other materials.

Whether using manual or automated sorting techniques, the sorted paper stream should pass through one final inspection station where individuals remove any remaining contamination before the paper is baled and/or shipped to market. This last inspection stage is referred to as the **paper inspection or "buffing" station** and is key to ensuring that the sorted paper meets the specifications/quality standards required by the reprocessors e.g. the paper mills.

Sorting containers by material type

There are a variety of mechanical techniques to separate different container types based on the size, shape, density and conductivity of the material.

Technologies commonly used to sort by type include eddy currents for aluminium and overband magnets for ferrous metals.

Screens and discs are also used to sort larger containers from smaller ones (plastic from glass, aluminium and steel), or the lighter-weight fractions (plastics, aluminium and steel) from the heavier-weight fractions (glass).

There are different schools of thought on the optimal sequence for sorting containers. Some prefer to remove the plastic early in the process while others find it more efficient to remove metals early so as to optimise the efficiency of plastics sorting later in the process. Notwithstanding the selected sequence, the sorting techniques and technologies are similar

Large-capacity North American MRFs such as those in Seattle and Minneapolis operated by Waste Management Inc. have installed a “crusher” that breaks glass and flattens plastic, aluminium and metal. Once fractured, a trommel screen is used to sort the smaller fraction (glass) from the larger (plastics, metals and aluminium).

Sorting plastic containers

Due to their size and volume, plastic containers are often removed early in the sorting process. This facilitates identifying and sorting the remaining aluminium and steel cans.

Sorting plastic containers is done either manually or by means of a near infrared optical scanning system (NIR) which can identify plastic from other materials. Once identified, an air jet separates plastics from other materials on the conveyor.

The plastic containers pass through an inspection or quality control station where any lingering contaminants are manually removed.

Advanced sorting of plastics containers

Plastics commodity markets require clean streams of specific resins. At some point in the process, plastic containers must be sorted by resin, and often by colour, prior to reprocessing.

Manual sorting is sometimes used to carry out this process. However, more common is the use of near infrared (NIR) technologies to identify each resin and colour, and an air jet to lift the sorted containers into the appropriate bunker.

Advanced sorting can occur at the MRF or at a separate location. In determining whether to carry out advanced sorting on site, MRF operators should compare the costs of sorting to the market price for mixed vs. resin-sorted plastic containers.

Sorting metal

Magnets are used to pull steel cans from the conveyor belt. This is an inexpensive and accurate way to sort the metals. Once pulled from the belt they are dropped into a storage bunker and then baled.

Sorting aluminium

Aluminium cans tend to be removed at a point in the sorting process where they are the dominant material, or at least one of only a few remaining materials on the conveyor belt. Eddy current separators are placed at the end of the sorting process where aluminium is separated from a plastic mix, or after positive sorting of plastics takes place. This ensures that the eddy current separator operates at maximum efficiency and that aluminium cans do not get “buried” under other containers (and that other materials don’t get pulled off with aluminium cans).

An eddy current has a slight electrical charge which passes through other materials (paper, plastic, metals, and glass) but is resisted by aluminium, causing the cans to lift or bounce off the conveyor.

Due to the very stringent specifications and the high value of aluminium, manual quality control is often employed to remove any remaining contamination before the sorted aluminium falls into the bunker.

Sorting glass

Both manual and automated systems are used to sort glass from other containers.

Manual sorting:
Manual sorting of glass occurs after the containers are separated from the fibre. Typically it occurs early in the sorting process so as to not block the eddy current and overband magnet from efficiently removing aluminium and steel containers.

Automated sorting:

- Disc screens or trommel screens may be used early in the process.
- The container line passes through a crushing system which flattens plastics and breaks the glass containers. A trommel screen can then be used to sort the glass cullet from larger containers (plastic, aluminium and ferrous metals).

The broken glass is often sorted into two main size categories – particles larger than, and smaller than 0.95cm (3/8th inch). The larger size glass particles can be sorted by means of an optical scanner. The smaller size cullet tends to be sold to the sand blasting or aggregates markets.

Advanced sorting:

Optical scanning technology can be used to sort glass by colour. However, to achieve optimal efficiency, glass cullet must be at least 0.95cm in size to be identified by the near infrared sensors (NIR).

MRF operators should evaluate the market value for mixed cullet compared to colour separated, to determine if there is sufficient price margin to justify the advanced colour sorting of glass either at the MRF or at a separate location.

1.4 Baling, inspection and shipping

Baling and storing

After materials are sorted, they are transferred from their respective storage bunkers to the baling system by one of two methods, a “walking floor” or a loading shovel.

Large-capacity MRFs typically have two baling systems, one for fibre and plastics and another for metal and aluminium.

It is preferable that sorted, baled materials, particularly paper, are stored in a weather-protected area prior to being shipped to market.

Inspection and quality control

To receive optimum value for the sorted materials, MRF operators need to build market confidence that their sorted materials meet or exceed the market specifications.

There are several techniques employed to control the quality of the materials shipped from MRFs. These include:

- Quality control or inspection stations at the end of each sorting line
- Visual inspection of the materials at various levels in the storage bunkers
- Random sampling of bales prior to shipment
- Quality control feedback systems between the market and the supplier

Quality control or inspection stations at the end of each sorting line

Once materials have been sorted into individual material streams, whether manually or using automation, they pass through a final “inspection” phase. Typically, this involves a conveyor belt with one or more sorters who watch for any lingering contaminants in the material. These are manually removed from the conveyor before the materials fall into the storage bunker.

Visual inspection at various levels in the storage bunkers

Storage bunkers holding the sorted materials are usually situated below the sorting shed. A visual inspection of the sorted materials is carried out as the bunker fills. The frequency of inspection varies; typically it occurs at half-meter intervals as the bunker fills. If significant contamination is spotted, immediate feedback and adjustments should be made to the sorting process.

Random sampling of bales prior to shipment

Some MRFs carry out random sampling of baled materials prior to shipping. This is typically carried out by breaking open bales and analysing the level of contamination. Increasingly this may be undertaken by external bodies representing the end market purchasers of the materials or by the reprocessors.

Quality control feedback methods

A wide variety of objective methods are used to provide feedback on the quality of materials shipped to market.

For example, LIPOR in Porto, Portugal brushes paint on the baling wire. The colour used indicates the day the material was baled and the shift working when the material was baled. A different paint colour is used for each day on a weekly rotation. If the MRF receives complaints about shipped materials, the MRF manager can trace the contamination to a specific day and shift and address any problems.

Many MRFs use far more elaborate systems, with random bale sampling and feedback from buyers, particularly those MRFs supplying paper to mills in various parts of the world. Some of these systems are described later in the report in the chapter on market specifications.

1.5 Residue management

Residues include both *non-targeted materials* which households place in their recycling containers, and *recyclable* materials which were not properly sorted at the MRF. Dealing with residues incurs additional costs. First, the cost of collecting them along with recyclables, then the cost of sorting them, and finally the cost of transporting and disposing of them. And, in the end, they will not generate any revenue to offset these costs. Hence, high-performing MRFs seek to minimise the percentage of residues in their systems.

Non-targeted materials

MRFs carry out periodic audits of incoming collections and advise the respective local authorities of the level of contamination being received. This information helps focus the education/ communication campaigns of the local authorities. Some MRFs are beginning to charge local authorities for the cost of disposing of residues.

Residues from the sorting process

Sorting systems do not operate at 100% efficiency at all times. Inevitably, a percentage of recyclable material is not properly sorted. The quantity of residues will vary depending on the type of MRF and its management and the level of contamination in the incoming feedstock.

To improve recovery rates some MRFs process residues for a second time by putting them back through the sorting system.

2. Factors affecting MRF efficiency

One of the aims of this study is to identify factors that contribute to a MRF being able to achieve high quality sorted materials in a cost efficient manner.

Prior to considering individual MRFs, it is important to examine the broader issues that affect the costs of sorting kerbside collected recyclables and some recent trends.

2.1 Key factors affecting efficiency

Several factors affect the cost of sorting materials recovered from kerbside collection programmes. Some are facility design features while others are operational.

Design and development factors:

- Quantity of materials sorted
- Range of materials, and the level to which they are sorted
- Efficiency of the process design and the equipment selected (discussed in chapter 2)

Operational factors:

- Manual vs. automated sorting techniques
- Productivity of individual manual sorters
- Level of residues
- Degree of contamination in the sorted materials

Design and development factors

Quantity of materials sorted

Conventional wisdom has held that the sorting facility should serve a relatively small geographic area, allowing collection vehicles easy access to unload their materials during collection rounds.

However, Waste Management in North America has closed and merged most of its smaller MRFs (under 50,000 tpa) and in some cases are transporting collected kerbside materials over 100 miles to be sorted at larger facilities.

The reason for ‘abandoning” smaller MRFs was based on the economies of scale in sorting. Processing larger quantities enables the operator to fully utilise the system’s processing capacity and justifies the higher capital cost of equipment.

The MRF cost model developed for WRAP, allows users to determine the costs of sorting based on a range of factors, including different volumes of materials. It demonstrates that lower unit costs (cost/tonne sorted) can be achieved by operating larger capacity facilities. For the MRF configurations considered, it shows a sharp drop in the cost per tonne of sorting materials once the volume exceeds 50,000 tonnes per annum.

Range of materials and the level to which they are sorted

Some MRFs may take in eight different co-mingled materials and sort them into five categories, while others may take in the same eight materials, but sort them into eight categories. Typically, the greater the level of sorting, the higher the per-tonne processing costs and the higher the revenue received for the sorted materials.

Examples of the range of materials and level of sorting are shown below:

Example 1

<table>
<tr><th>Eight Materials Collected Co-mingled</th><th>Five Sorted Materials</th></tr>
<tr><td>OCC – corrugated card</td><td>OCC – corrugated card</td></tr>
<tr><td>Newsprint</td><td rowspan="3">Mixed paper</td></tr>
<tr><td>Magazines (PAMS)</td></tr>
<tr><td>Mixed paper</td></tr>
<tr><td>HDPE plastic bottles</td><td rowspan="2">Mixed plastics bottles</td></tr>
<tr><td>PET plastic bottles</td></tr>
<tr><td>Aluminium containers</td><td>Aluminium</td></tr>
<tr><td>Ferrous metal containers</td><td>Ferrous metals</td></tr>
</table>

Example 2

Eight Materials Collected Co-mingled	**Eight Sorted Materials**
OCC – corrugated card	OCC – corrugated card
Newsprint	# 7 News
Magazines (PAMS)	# 6 News
Mixed paper	Mixed paper grade
HDPE plastic bottles	HDPE plastic bottles
PET plastic bottles	PET plastic bottles
Aluminium containers	Aluminium
Ferrous metal containers	Ferrous metals

Depending on the quality of sorted materials and market conditions, the level of sorting occurring in example 2 can significantly increase the revenue received for those sorted materials.

More mature recycling programmes involve MRFs that will take in 15 to 20 different materials co-mingled and sort them to meet market requirements (see Site Visit 10, Seattle MRF).

Operational factors

Manual vs. automated sorting techniques

There are two fundamental approaches to sorting co-mingled materials into individual material streams. One uses personnel to manually pull out specific materials as they pass through the various sorting stations. The second uses automation, or mechanical sorting systems.

Most commonly, a MRF will use a combination of manual and automated sorting techniques. Some steps in the sorting process are best handled manually, while other steps will be more accurate and less costly using automation.

The following summarises the preferred techniques at various sorting stages:

- Pre-sort

Manual sorting tends to be the preferred option for pre-sorting incoming materials. This step removes non-recyclables and any recyclable materials the system is not designed to process, e.g. film plastics (LDPE, textiles).

- Ferrous metals and aluminium

There are automated sorting technologies with high degrees of accuracy that are relatively inexpensive, e.g. eddy currents to sort aluminium and magnets to remove ferrous metals.

- Other materials

For other materials commonly included in kerbside collection programmes, (PET, HDPE, newspapers, magazines, office paper, mixed paper, and glass), the choice of employing manual sorters versus investing in automated sorting technologies is less clear cut and often dependent on the size of the facility.

The existing and projected quantity and variety of materials to be sorted at the MRF, as well as market requirements, affect the costs of sorting and level of investment in automated sorting.

Due to the wide range of materials being sorted and the variety of technologies which can be employed, it is difficult to provide definitive statements on manual vs. automated sorting in all instances. Some general benefits of manual sorting include:

- Capital investment in equipment is less
- MRF has greater flexibility in changing the sorting techniques
- Creates local jobs

The successful use of automated sorting lies in determining how each material stream responds when introduced to certain technologies or techniques.

The key is locating the right technology at the right stage in the sorting process to cause a single material stream to behave differently than the others. By its different behaviour that material is sorted from the others.

Level of residues

As noted earlier, residues are those materials remaining at the end of the sorting process that require disposal. Residues consist of both non-targeted/non-recyclable materials delivered to the MRF in the incoming material stream, and recyclable materials that were missed at some point in the sorting process.

It is essential that both MRF operators and local authorities minimise the level of residues as the costs of handling and disposing of residues can be significant. The level of residues reported by the MRFs visited is 1% to 3% at the low end, and 15% to18% at the high end.

Several reasons for the high percentage of residues were offered by MRF managers interviewed for this study:

- Not cost effective to process materials through their system more than once in an effort to reduce the amount of residues.
- Poor design, poor choice of equipment, and lack of staff training and supervision.
- Access to treatment/disposal options can reduce the incentive to minimise residue levels.

Degree of contamination in sorted materials

One of the growing pains experienced by the recycling industry around the world has been the development of industry specifications or standards that a MRF must achieve in sorting various materials. Over the past 20 years of recycling, no other issue has been debated at greater lengths.

With the use of eddy currents and band magnets, the efficiency of sorting metals and aluminium is relatively high. However, the high value of aluminium and the tight specifications suggest that quality control stations are necessary for inspection of materials prior to bulking and baling. Plastics in particular must be removed from the aluminium stream.

Plastics are sorted into different polymers. The plastics commodity markets are based on single polymers. Each polymer carries a different value. The MRF managers interviewed as part of this study indicated that the plastics markets will accept up to 1% contamination

However, sorting paper to various market specifications is more complex. There are different types of contaminants (moisture, prohibitives (non paper items), out-throws (i.e. wrong type of paper), that can be accepted at various levels by various mills. In many countries, the recycling industry and the pulp and paper industry have developed clear standards, and procedures for testing individual loads to determine if they meet the required standards.

3 Comparison of MRFs visited

3.1 Material recovery facilities in England

The increase in co-mingled kerbside collections has resulted in an increasing number of MRFs in England.

Preliminary WRAP survey data indicates there are around 61 MRFs operating in England processing recyclable materials from kerbside collection programmes[1]. Nearly half (25) of these MRFs have been commissioned in the last six years. A number of proposed new facilities are in the planning process, and more are being considered as part of longer term strategies.

The design capacity of these MRFs range from less than 10,000 tpa to over 100,000 tpa [2]:

- Under 10,000 tpa 14 MRFs
- 11,000 - 25,000 tpa 20 MRFs
- 26,000 - 50,000 tpa 13 MRFs
- 51,000 -100,000 tpa 6 MRFs
- Over 100,000 tpa 2 MRFs

Many of the facilities in the planning process (or recently received planning consent) anticipate a large capacity facility of 100,000 tpa or above.

This apparent trend towards larger MRFs follows the trend in other countries where the cost efficiency of sorting larger volumes of material at a single MRF, operating two or three shifts a day, is recognised.

Most of the 61 existing MRFs receive papers, magazines, steel and aluminium cans and plastic bottles (HDPE, PET). However, only a very few facilities accept glass as part of a co-mingled stream, but glass is delivered as a separate stream to several MRFs for bulking.

[1] *This data was obtained in early 2006 and currently is being updated.*
[2] *The survey was unable, for a number of reasons, to confirm the design capacities of 6 facilities*

3.2 Selection of case study MRFs

Seven MRFs in England were selected and agreed to provide case studies for this review. Three MRFs in North America and three in Europe also were selected.

A standard set of questions was asked of each MRF visited. The aim of the questions was to gather similar data for each site and to carry out some direct comparisons of different sorting techniques and technologies, their costs and their efficiency.

The initial study design was to focus on direct comparisons of capital and operating costs between MRFs in England and MRFs in other countries based on size and volume of materials sorted. The initial thinking was to analyse MRFs sorting less than 10,000 tpa; 11,000 – 25,000 tpa; 26,000 – 50,000 tpa; and 50,000 – 100,000 tpa. However, the research team found it difficult to locate small scale MRFs (below 50,000 tpa) in Europe and North America as most of the MRFs are in the 50,000 tpa or above range.

The MRFs visited in England were mainly smaller facilities (under 50,000 tpa). Although it was desirable to include larger capacity MRFs, it did not happen for two reasons. Firstly, not all MRFs contacted agreed to participate, in some cases because they were new facilities and still going through the commissioning stage. Secondly, although several large MRFs are planned for coming years, the majority (81%) of the existing MRFs are below 50,000 tpa.

The study team considered it appropriate to focus the international case studies on larger scale MRFs, believing this to be the likely trend in the UK.

Notwithstanding the disparity of size, the site visits gathered information on capacity, physical plant characteristics and volumes of materials processed. This information was useful in drawing some conclusions and suggestions.

Information on the materials received at each MRF and the level of sorting carried out for each individual material was available and useful for some comparisons.

Other information relating to costs per tonne for sorting, revenue from sale of sorted materials and specifications were less available.

3.3 Comparison of MRF characteristics

Facility size and processing capacity

Table 1 compares facility size to anticipated tonnage processed and shows current tonnage processed to number of sorting staff employed at each facility. It also shows whether the sorting process was highly automated or primarily carried out through manual sorting.

Table 1: Capacity, facility size and number of sorters required

MRF	Design capacity (per year)	Current tonnage processed	Building (square meters)	Automated or manual sort (primarily)	Sorting staff per shift	# of shifts	Tonnes processed per sorter	Tonne per hr per sorter
Luton – WRG	25,000	10,400	200	Mostly Manual	15	1	693	0.33
East Riding-WRG	14,000	7,500	670	Mostly Manual	9.5	1	789	0.38
Norwich NEWS	60,000	45,000	5,000	Mostly automated	26	2	1,428	0.68
Darwen - RU Recycling	40,000 (containers only)	40,000	2,415	Mostly automated	10	2	2000	0.96
Slough – Grundon	100,000	90,000		Mostly Manual	20	1	4500	2.16
Huddersfield -SITA	25,000	25,000		Mostly Manual	17	3	490	0.23

MRF	Design capacity (per year)	Current tonnage processed	Building (square meters)	Automated or manual sort (primarily)	Sorting staff per shift	# of shifts	Tonnes processed per sorter	Tonne per hr per sorter
Hampshire – Onyx	85,000	84,000		Mostly Automated	19	2	2236	1.08
Seattle – Waste Management	120,000	180,000	8,618	Mostly Automated	30-35	3	1875	0.9
St. Paul Minn Eureka	80,000	40,000	5,500	Mostly Automated	17.5	1	2285	1.09
Minneapolis Waste Mgmt	160,000	160,000	11,150	Mostly automated	32	2	2312	1.10
Lille France Triselec	60,000	90,000		Mostly Automated		2		
Renne France Onyx	25,000	24,000		Mostly Manual	12	3	666.6	0.32
Porto, Portugal, LIPOR	35,000	35,000	4.00	Mostly Manual	32	2	546.88	0.26

With regard to comparing the design capacity (stated capacity according to the MRF operator) to anticipated tonnage, it is difficult to draw any conclusions due to the wide range of operations observed. Some facilities were operating at capacity and were anticipating a move to a larger site (e.g. MRFs at Slough and Darwen). Other facilities were new and had additional space available for expanding their operations.

Similarly it is not possible to draw any direct correlation between the number of sorters employed by each MRF to sort a specific tonnage of material without including variables relating to the level of separation conducted and the level of automation used.

Materials flow – incoming, outgoing and baling

Apart from the actual sorting process, there are certain physical features of a MRF that must be of adequate size to accommodate the volumes of materials anticipated. This includes the capacity for receiving materials, the size of the tipping floor, the number of balers, the capacity for storing sorted materials and space for loading sorted materials.

Table 2 examines three potential bottlenecks – capacity to hold delivered materials, baling capacity, and capacity for loading sorted materials for shipping.

The capacity of the tipping floor is dependent on three key factors:

- Throughput capacity
- Number of balers
- Number of shifts

Table 2: Materials Flow

MRF	Design capacity (per year)	Current tonnage sorted	Capacity of tipping floor	Number of balers	Transport bays
Luton – WRG	25,000	10,400	3 days	1 baler	1 inside 1 outside
East Riding-WRG	14,000	7,500	5 days	1 baler	2 loading bays
Norwich NEWS	60,000	45,000	3 days	3 balers	6 loading docks
Darwen - RU Recycling	40,000 (containers only)	40,000	.5 days volume	1 baler	3 loading docks
Slough – Grundon	100,000	90,000	1-2 days	1 baler	2-3 loading docks
Huddersfield-SITA	25,000	25,000	5 days volume	1 baler	1 loading dock
Hampshire –	85,000	83,000		1 baler	

MRF	Design capacity (per year)	Current tonnage sorted	Capacity of tipping floor	Number of balers	Transport bays
Onyx					
Seattle – Waste Management	120,000	180,000	1.5 days volume	2 balers	8 loading docks
St. Paul Minn Eureka	80,000	45,000	2.5–3 days volume	1 baler	2 loading docks
Minneapolis Waste Mgmt	160,000	160,000	1.5 days	4 balers	9 loading docks
Lille, France	60,000	90,000	3 days	2 balers	4 loading docks
Renne, France	25,000	24,000	3 days	2 balers	3 loading docks
Porto, Portugal	35,000	35,000	3-4 days	2 balers	2 loading docks

Balers

Eureka and RU Recycling, which each have just one baler, mentioned that they require significant capacity to store unsorted materials as a contingency in case the baler is out of action. In the case of Eureka, the facility has capacity to store unsorted materials on the tipping floor for up to three days.

The managers at both these facilities recognised this “bottleneck” in their system and indicated that a second baler was one of their more immediate needs.

MRFs with back-up balers are able to minimise the tipping floor capacity. For example, the tipping floors at the larger Waste Management MRFs in Seattle and Minneapolis have 1 to 1.5 days capacity.

The need for back-up baler capacity is less critical in England than in other countries because much of the newspaper and magazines are shipped loose (rather than baled) to UK mills or paper merchants. Baling, however, is required if fibre is to be exported.

Number of Shifts

The number of shifts operating also affects tipping floor capacity. In most communities, kerbside materials can only be collected and delivered to the MRF during the working day. If the MRF operates two or three shifts daily to sort the material, the tipping floor must have sufficient capacity to hold the materials until the three shifts have completed their processing.

Degree of sorting and costs per tonne

A third broad comparison examines the level or degree of sorting at each MRF.

Table 3: Level of sorting achieved

MRF	Incoming Materials	Sorted Materials
Luton – WRG single stream, no glass	Newsprint Magazines HDPE bottles PET bottles Aluminium cans Ferrous metal OCC (8 materials)	Mixed paper Mixed plastics OCC Aluminium Ferrous metal (5 categories)
East Riding - WRG single stream, no glass	Newsprint Magazines OCC Aluminium cans Steel cans HDPE bottles PET bottles (8 materials)	News and Pams Mixed plastics Aluminium Steel OCC (5 categories)
	Newsprint Magazines OCC	News and Pams

MRF	Incoming Materials	Sorted Materials
Norwich - NEWS single stream, no glass	Boxboard HDPE bottles PET bottles Mixed paper Other plastics Aluminium cans Ferrous metal Aerosol cans (11 materials)	Mixed paper OCC Mixed plastics Ferrous metal Aluminium (6 categories)
Darwen - RU Recycling two stream, paper separate	OCC, Newpaper Magazines, Old Box Board, HDPE bottles PET bottles Green glass Clear glass Amber glass Mixed paper, Ferrous metal Aluminium (12 materials)	OCC OBB Green glass Clear glass Amber glass Aluminium Steel Mixed paper PET – natural HDPE – natural (10 categories)
Slough – Grundon single stream, no glass	Newsprint Magazines OCC Mixed paper HDPE bottles PET bottle Aluminium cans Steel cans (8 materials)	Mixed Paper OCC Mixed plastics Aluminium cans Ferrous metal (5 categories)
Huddersfield - SITA single stream no glass	Newsprint Magazine OCC Mixed paper Ferrous metals Aluminium cans	Mixed paper Mixed plastics Aluminium Steel OCC

MRF	Incoming Materials	Sorted Materials
	HDPE bottles PET Bottles (8 materials)	(5 categories)
Hampshire – Onyx single stream, no glass	Newsprint Magazines Mixed paper OCC PET bottles HDPE bottles Aluminium cans Steel cans (8 materials)	Mixed paper OCC Mixed plastics Aluminium Steel (5 categories)
Seattle – Waste Management single stream	Newspapers Magazines OCC Paperback books Telephone directories Gable top cartons Tetra-pak HDPE Plastics PET Plastics All other plastic containers PVC PS Green glass Amber glass Clear glass Aluminium cans Steel cans Aerosol cans Aluminium foil (19 materials)	# 7 News OCC Mixed Paper HDPE PET Mixed plastics Tetra-pak Steel Aluminium Glass** (10 categories)
	OCC Newsprint Old Magazines	6 grades of fibre - News and Pams - Kraft paper

MRF	Incoming Materials	Sorted Materials
St. Paul Minn Eureka two stream, paper separate	Old Boxboard Telephone directories Wet Pak Mixed paper Ferrous metal Aluminium cans HDPE Bottles PET Bottles Textiles Green glass Clear glass Amber glass (15 materials)	- Boxboard - Wet strength - OCC - Office Pak 4 grades of glass - Green - Clear - Amber - Mixed HDPE PET Mixed plastics Aluminium Ferrous metal Mixed textiles (16 Categories)
Minneapolis Waste Mgmt single stream	Newsprint Old Magazines OCC Office paper Mixed paper HDPE bottles PET bottles LDPE All plastics Glass bottles Aluminium cans Aluminium foil Steel cans Aerosol cans (14 materials)	# 8 News #6 News OCC Mixed paper HDPE PET Mixed plastics Mixed glass Aluminium Steel (Glass and plastics sorted at sister plant) (10 categories)
	Newspapers Magazines Cardboard Mixed Paper	News and Pams Cardboard Mixed paper Mixed glass

MRF	Incoming Materials	Sorted Materials
Lille, France	Glass bottles PET HDPE Aseptic containers Aluminium cans Metal cans (10 materials)	PET HDPE PVC Aluminium cans Ferrous cans (9 categories)
Renne, France	Cardboard Newsprint Magazines PET HDPE Metal cans Aluminium cans Aseptic containers Shredded paper Books Office paper LDPE (13 materials)	Cardboard News and Pams Mixed paper HDPE – natural PET – natural PET – coloured LDPe Aluminium Ferrous metals (9 categories)
Porto, Portugal	OCC Magazines Juice box Newsprint Mixed paper Ferrous metal Aluminium cans HDPE – bottles PET – bottles PVC – plastics LDPE plastics Aerosol cans (12 materials)	OCC Newsprint Mixed paper Ferrous metals Aluminium HDPE PET PVC LDPE (9 categories)

**Seattle Waste Management – glass is sorted by colour at a sister plant in Seattle.

Comparing materials sorted

As Table 3 illustrates, most of the MRFs visited receive eight different materials:

- Newsprint
- Magazines
- Mixed paper
- OCC
- Aluminium containers
- Steel containers
- HDPE bottles
- PET bottles

These eight materials are sorted into 5 categories:

- Mixed paper
- OCC
- Mixed plastic
- Aluminium
- Ferrous metal

Most plastics reprocessors are unable to use mixed plastics bottles and most of the higher value paper mills can only accept a small percentage of mixed paper. Therefore, these material streams are often shipped to other facilities to be sorted by resin and by fibre grade prior to use by the reprocessor.

Probably the most significant material common to most local recycling programmes, but not processed at the MRFs visited in England, is glass containers. Six of the seven MRFs visited do not accept glass containers in the incoming material streams. The only MRF visited that accepts and sorts glass is RU Recycling. RU Recycling is the UK distributor for the Andela Glass Pulverizing Equipment, which is used extensively in North America to process glass for a variety of end market applications.

However, several of the newer MRFs (as well as planned MRFs), particularly in the London region, accept single-stream co-mingled material including glass (e.g. Greenwich MRF operated by Veolia and Crayford MRF operated by Grosvenor).

In the rest of Europe, as across most of the UK, the primary method for collecting glass containers is the "bring bank" system. A recent survey by the European Association of Recycling Cities found that of the 30 cities responding to the survey:

- 28 offer bring bank systems
- 12 provide kerbside collection
- 15 collect glass at civic amenity sites, and
- 1 (Porto) provides on-demand collection systems.

All MRFs visited sort aluminium and ferrous metals, using relatively inexpensive, automated sorting technologies – eddy currents and magnets respectively.

Comparing processing costs per tonne

The cost per tonne for sorting materials should include for all capital costs (land, building and equipment), and all operating/variable costs (labour, fuel, utilities, etc). However, as there is no standardised accounting system, direct comparisons of MRF sorting costs can be misleading.

Variations that make standard cost accounting difficult include:

- Land, facilities and/or equipment may be provided by the local authority at no or reduced costs.
- Some facilities and equipment are financed through government grants.
- Each organisation has its own accounting system - handling of capital costs/cost of capital varies as do items included as direct costs e.g. some do not fully account for the costs of residues
- A basic system of weights and measurements associated with incoming and sorted materials does not exist at most of the MRFs.

Several of the MRFs did provide an indication (at the time of the site visits) of their processing costs per tonne, but for the reasons outlined above and as this information was provided in confidence in some cases it is inappropriate to comment further.

Residues

Residue rates at MRFs visited in England range from 1.5% to 20% (of total input tonnage by weight) with most averaging approximately 12% to 15%.

Non-targeted materials
All the MRFs visited carry out periodic audits of vehicles arriving at the facility and provide feedback to local authorities on the level of non-target materials in the dry recycling stream.

Process residues
Of the MRFs with higher residue rates, visual inspection of the residues indicates that they appear to contain a significant percentage of process waste – recyclables that are not being properly sorted by the MRF sorting system - possibly about 40-60% of total residues are from processing.

Market specifications and quality control of sorted materials

Two aspects were examined: quality control systems to monitor levels of contamination in sorted materials, and specifications required by each materials commodity market.

At each site visited, the MRF managers were asked to explain the system in place for monitoring the quality of sorted materials, and their understanding of the level of contamination acceptable for each sorted material.

Specifications used by MRFs

Appendix 2 contains the market specifications staff indicated they followed for the various sorted materials.

There are clear standards for aluminium and metals with regard to contamination (1% contamination), and the MRFs visited, both in England and elsewhere, reported being able to meet this standard. This is largely due to the automated sorting system for metals that assures accuracy in separation. However, it should be noted that moisture is a serious concern to the aluminium industry as is plastic contamination.

Similarly, plastics markets were reported to accept up to 1% contamination.

However, the complexity of the pulp markets and the paper making process requires more complex sets of specifications to assure a quality of feedstock that is suited for the specific product manufactured at a particular mill.

In most cases, the MRFs visited in England use much broader and more general specifications than the MRFs visited in other countries. This may in part be a reflection of the relative immaturity of the recycling sector in the UK compared to many parts of Europe and North America.

For most materials, the English MRFs visited followed a general rule of up to 1% contaminants. The following is a summary of the standards for sorted materials provided to the study team during the site visits.

Luton

- Most materials can have up to 1% contamination

NEWS

- Fibre: 1% contamination – but less for OCC
- Containers: 1% contamination (plastics are exported to Asia)

East Riding

- Paper must be not more than 6 months old
- Maximum of 1% of contraries such as metal, plastic, string.
- Maximum of 12.5% moisture
- Maximum of 2.5% coloured newsprint
- Maximum 1% telephone directories/envelopes
- Maximum 10% catalogues

SITA – Huddersfield

- Most markets accept up to 1% contamination

ONYX – Hampshire

- Paper – typically up to 1% contamination, although they do have an agreed specification for paper with one of the UK mills

RU Recycling - Darwen

- Mixed paper is bulked and sent to Aylesford (not sorted at the MRF – collected separately as part of a 2-stream co-mingled collection)
- Plastics sorted by resin and colour less than 1% contamination

Material specifications reported by MRFs in Europe and North America

The study team found that MRFs operating in Europe and North America tend to operate to a much tighter set of specifications. In most cases these specifications were negotiated between the industry and the MRF operators.

In Europe, the producer responsibility organisation defines the specifications required for each sorted material. Appendix 2 includes the specifications required by Eco-Emballage in France. Similar specifications are set by Sociedad in Portugal.

Many MRFs in Europe, (including the UK) ship paper to the Stora Enso mill in Gutenburg, Sweden, one of the largest pulp mills in Europe. The Gutenburg mill has developed exacting specifications for paper and a robust, objective system for carrying out quality testing on a periodic basis.

Gutenburg's accepted levels of contamination for paper are:

- Moisture – 10% or less
- Out-throws – 5% or less (fibres different than those purchased i.e. wrong type of paper)
- Prohibitives – 0.05% (materials that can destroy pulping equipment)

(Appendix 2 defines items considered prohibitives and out-throws.)

Quality control at MRF

The quality control system at most of the MRFs visited in England is carried out through visual examination of the sorted materials in the bunker or when they are moved to the baling system. Although, it is noted that sampling bales of sorted materials prior to shipment is becoming more standard practice at many of the newer facilities.

At the MRFs visited in Europe and North America, more specific inspection techniques were used including:

- Inspection station after the sorting process to remove any contaminants
- Inspection of the sorted materials in the bunkers, prior to baling
- Sampling bales of sorted materials prior to shipment

4 Efficiency, quality and processing costs

This review of MRFs together with discussions with MRF operators has highlighted a number of factors that are critical to achieving cost effective and quality sorting operations. The key findings are summarised in this chapter.

4.1 Proximity of MRF to point of collection

Companies, mainly in North America, in their third and fourth generation of collection and sorting have evolved in their thinking regarding the proximity of a sorting facility to the point of collection.

The issues differ between sorting facilities in or near large urban areas and sorting facilities in semi-urban and rural areas.

MRFs in urban areas

Staff interviewed at MRFs serving more urban areas e.g. in Hampshire, Minneapolis and Seattle, highlighted the importance of locating their facility near a dual-carriageway. In each of these cases, the driving time between the carriageway and the MRF was under 5 minutes.

Collection vehicles need to be able to offload the collected materials and return to their scheduled routes without delays. Inasmuch as collecting materials at kerbside is the most expensive part of recycling, reducing travel time for collection vehicles becomes a critical cost savings measure.

MRFs in semi-urban and rural areas

The trend in North America has been to close many of the medium and smaller size MRFs and transport the collected materials up to 100 miles to larger facilities. The waste companies doing this have found the cost of transporting the materials to be less than the cost of sorting smaller volumes (below 50,000tpa) at multiple sorting facilities.

Whilst there is some evidence of co-mingled materials being transported similar distances for sorting in the UK, this appears to be due in part to a lack of suitable MRF capacity locally. The costs and benefits of bulking up and transferring materials to larger facilities for sorting should be considered against the costs of operating smaller capacity facilities.

4.2 MRFs serving multiple collection programmes

Many of the MRFs visited process materials collected by more than one local authority. Given the capital costs involved, having one MRF to serve a number of kerbside collection schemes is likely to be the most cost effective. However, there are some significant issues to be considered as the trend towards larger regional/sub regional MRFs evolves. These include the need to:

Ensure competition

If one company establishes the sole facility in an area for sorting materials collected from several local authorities often by different contractors (possibly including the company that operates the MRF), the MRF may in fact gain dominance in the area and apply differential charging to other contractors / local authorities.

This dominant position can mean that MRF operators make the decisions as to which materials will be accepted for sorting and which will not. This leaves local authorities responding to decisions made by one part of the overall recycling system.

To ensure fair competition and equal access to quality sorting for collected materials a number of local authorities in northern California determined it was in their best interest to own the MRF and contract out its operation.

One of the North American programmes visited as part of this study (Minneapolis, Minn.) has achieved a break-even point in their recycling programme whereby all the direct costs associated with collection and sorting of recyclables are covered by the revenue obtained from the sale of materials. They achieved this by generating competition amongst the collection and sorting companies, as well as the marketplace for the recovered materials.

Local authorities often pursue separate contracts; one for the collection service and another for the most efficient sorting system (the one offering the highest revenue return due to quality of materials shipped to markets). Without this competition, inefficiencies may go unnoticed.

Design in flexibility to handle materials from different collection systems

In England, as well as North America, several MRFs are receiving materials from numerous collection schemes. For example, some collection programmes in England collect plastic containers, others do not; some collect paper separately from containers, while others collect paper with containers, yet all materials may be taken to the same MRF for processing.

Three of the MRFs visited currently receive a mix of both fully co-mingled materials and sorted materials. One MRF receives materials from local authority schemes that collect very different materials.

In each of these situations, all the incoming materials were processed through all of the sorting stations. The unnecessary sorting of already separated materials adds significantly to the cost of sorting.

To accommodate this, the more efficient MRFs have installed additional “in-feed” lines to enable materials separated during the collection process to enter the MRF sorting process at the appropriate point.

For example, if clean paper or cardboard is collected and delivered to the MRF, there is no need for that material to be processed through the entire sorting system. It can either be introduced at a point in the system where minimal sorting will remove contaminants, or if sufficiently clean, it can be baled directly.

If the paper received is mixed paper, and the MRF can sort paper into two or three different grades, the sorted mixed paper can enter the system after the disc screen. This means the separate mixed paper stream can still be processed into various grades at the MRF.

A similar process can be used for containers collected separately from other co-mingled materials. Plastic bottles can be fed into the system at the point where they can either go straight to the final inspection station, or into the specific material (usually polymer) sorting stage.

4.3 Receiving and preparing materials for processing

Tipping floor

Weather and safety protection

The tipping floor should be protected from weather and be constructed of wear-resistant concrete so that materials can be moved around by loading shovels and other large equipment. The space should be relatively free of columns and other obstructions that can cause safety hazards and limit efficient use of the space.

Adequate capacity

The tipping floor should have sufficient capacity to receive and store two days worth of incoming materials. This level of capacity is critical to allow collections from the kerbside to continue at times when the MRF is unable to process materials due to maintenance or other interruptions in the normal schedule.

In determining the capacity requirements for the tipping floor, the vulnerability of the sorting system to interruptions, as well as the capacity required to enable more than one shift to operate should be considered.

Health and safety

The nature of the materials received requires the MRF to be diligent in protecting the health and safety of workers near the tipping floor. Two practices in particular were observed:

- Daily clearing. It is standard practice to have all the materials received on a given day sorted that same day, and the tipping floor cleaned during the night shift. This practice is not only important to achieve efficiency in the sorting processing, but also reduces the potential for attracting rodents.

- Disinfectant sprays. The East Riding MRF periodically sprays a mist of disinfectant over the materials on the tipping floor to suppress bacteria that may be emitted from the materials.

Metering

A continuous and even flow of materials through the various sorting stations is critical to achieving optimal use of the sorting capability, whether automated or manual. There is no single best method for achieving proper metering of materials.

- MRFs handling smaller volumes of materials (< 50,000 tpa) could use variable speed belts more efficiently and at less cost than other more labour intensive approaches.
- Larger scale facilities should consider more sophisticated methods, such as a metering drum which is positioned above an inclined conveyor to level material flow.

Pre-sorting

Some of the MRFs visited in England did not have a station to carry out the pre-sort function. This can result in a higher level of contamination in the sorted materials, and underperformance of the system. Both result in cost-inefficiencies. New MRFs must be designed to provide adequate pre-sorting of delivered materials.

The pre-sort station is necessary to:

- Remove contaminants that would otherwise move through the sorting stations, taking up space, increasing costs and preventing the sorting stations from carrying out their primary objective of separating recyclable materials.
- Pull out materials that exceed the ability of the sorting process to identify and separate. Examples may include film plastics, textiles and oversized cardboard. These materials should be stored separately and in some cases outlets to recycle these materials may be identified by MRF operators.
- Protect health and safety of sorters further down the sorting line. Appropriate personal protective equipment should be provided to sorters including puncture proof gloves to protect against various sharps and other hazardous and dangerous materials which could be present.

4.4 Sorting specific materials

Sorting paper from containers

Some of the MRFs visited use a “negative sort” for paper. This means that other materials and contaminants are removed, with the objective of leaving just the mixed paper on the conveyor. The MRFs using this approach have expressed some difficulty with the market accepting their product.

Most MRFs use automated sorting equipment to sort paper from containers.

Trommel screens

Based on the MRFs visited, although no sampling was taken, it appeared that the trommel screen was able to successfully sort 70% to 80% of the materials targeted for separation.

A trommel screen is used by several different industries to sort materials by size. However, possibly because of the physical characteristics of news and pams, it appeared that many of the containers were prevented from dropping through the trommel screen, and hence emerged with the paper. In most cases, the paper stream required additional sorting to remove the containers. Typically this additional sorting occurred manually, however, at one MRF, a disc screen was installed following the trommel screen to further remove the containers from the paper.

Disc screens

By comparison, disc screens appear purpose-built to sort the paper from the containers; and it appears they can do so with over 90% accuracy, thereby reducing the amount of further sorting required to remove the other materials. This observation was based on site visits, and closer examination would be warranted.

Inspection station

Having a final inspection station to remove any remaining contaminants is important to ensure the highest quality of material is shipped from the MRF. Inspection stations were observed at the MRFs visited in Europe and North America, but notably, but not at any of the seven visited in England.

Sorting paper into grades

The degree of paper sorting observed warrants further examination.

- Four MRFs sort into two grades – OCC and mixed paper (Luton, East Riding, Slough, Huddersfield).
- One MRF receives the papers separate from containers and ships it on to the mill with no sorting (Darwen).
- Two mills sort three grades of paper – OCC, newsprint and mixed paper, and (Norfolk, Seattle).
- Two MRFs sort paper into four or more grades – OCC, #7 news, #6 news, boxboard, Kraft paper, wetpak, office pak (Eureka Recycling and Waste Management, Minneapolis).

Disc screens

As observed at some of the MRFs visited, sorting mixed paper into two or three grades can be accomplished with the addition of disc screens. Optical scanners
Sorting paper into a wider variety of grades can be accomplished with optical scanning technology.

Optical scanners

Sorting paper into a wider variety of grades can be accomplished with optical scanning technology.

Meeting paper specifications

Typically, the UK MRFs visited indicated that 1% contamination was allowable.

In Europe and North America the MRFs followed rigid standards agreed with the paper industry. These specifications had three categories of contaminants (moisture, prohibitives (non paper) and out-throws (wrong paper) and had allowable percentages for each.

Suggestions for improving the quality of sorted paper include:

- Promulgate clear standards on moisture content and contaminants (prohibitives and out-throws) permitted, an objective testing procedure for sorted paper and continuous feedback from the reprocessor to the MRFs and local collection programmes.
- Use of financial incentives/penalties as part of the quality control system.

A programme that might be adapted to the UK is the SP Recycling programme in Atlanta Georgia (see Appendix 2).

Sorting glass containers

As mentioned earlier, although glass containers are an integral part of most local authority recycling programmes, only one of the seven MRFs visited in England accepts glass. The issue of collecting and sorting glass containers continues to be the subject of some debate in the UK. Some MRFs and collection authorities fear that including glass in a co-mingled collection scheme will lower the market value for the other co-mingled materials collected. Similarly, there is concern that collecting glass separately from kerbside is relatively expensive compared to the value received in the marketplace.

At this point there appears to be no clear trend in the UK that glass containers will be included in co-mingled kerbside programmes or whether local authorities will continue to rely on bring systems as the primary method for collecting glass. To achieve high diversion of glass from the waste stream will require either a higher concentration of bring banks than currently exists in most communities; or a system for glass to be introduced to kerbside collection schemes without significant additional costs to the recycling programmes.

Approaches developed by local authorities in other countries to increasing the collection of glass have included:

- Keep glass separate

Maintain glass as a separate material throughout the collection and processing stages (2-stream collection).

- Provide financial incentives

Provide financial incentives to collection and sorting companies to maximise volume and value of recovered glass containers.

- Pilot new technologies

Conduct pilot demonstrations of new technologies, such as MRF-level optical sorting equipment, multiple screening systems, and other automatic processing technologies that can reduce costs and increase value.

Sorting ferrous metals

Magnets are used to separate ferrous metals from other materials on the container conveyor. Typically the ferrous metal is removed later in the container sorting process to ensure metal containers are not hidden by other materials.

Plastics

Both manual and automated techniques are used to sort plastic bottles from other containers and to sort by polymer (optical scanning technology).

At the Darwen MRF high-speed optical scanning is used to sort plastic bottles into individual polymers for sale directly to the market. The other MRFs visited in England transfer their mixed plastics to separate facilities for sorting into individual polymers.

A comparison of the market price for mixed plastics compared to individual polymers and the costs of sorting plastic bottles at the MRF suggest that larger volume MRFs should consider further sorting of plastics on site.

The level of sorting has a direct effect on the revenues the MRF receives for the sorted materials. The costs of further sorting must be weighed against any increase in price that would be received from the marketplace.
For example, the current UK price for mixed plastics is approximately £145 per tonne. Natural HDPE currently sells in the UK for £250 per tonne.

Aluminium

An eddy current system is typically used to separate aluminium from other materials. The eddy current should be located toward the end of the sorting process, after the plastics have been sorted, to avoid other materials interfering with the ability of the system to properly sort aluminium. Because of the high value of aluminium, quality control is normally required after separation to ensure a high quality product.

4.5 Inspection, baling and shipping

Both manual and automated sorting will not eliminate all contaminants. A final inspection/buffing station is important to ensure a higher quality of material is shipped to the market and potential revenues are maximized.

Most of the materials processed at a MRF typically are baled prior to shipment to market. The decision to bale must be made based on consideration of market requirements, market prices, and the differential transportation costs between shipping materials baled and shipping loose materials.

If a single baler is used and breaks down, the entire sorting process can be compromised. Hence consideration should be given to a back up baler, intermediate storage capacity, or pre-arranged temporary baling at an alternative facility.

Balers should be selected to provide sufficient baling capacity as well as to meet market requirements for bale size, density and weight.

4.6 Residues

With only one exception, the MRFs visited in England reported higher residue rates than those reported by the MRFs visited in Europe and North America. Some of the MRF managers interviewed reported that it is not cost effective to run the materials through the processing system a second time, in some cases because they have access to alternative treatment/disposal facilities.

There is significant expense associated with each tonne of residue, and often these costs are not transparent or directly accounted for. Costs are incurred in collecting the materials in the first place, sorting them at the MRF and then transporting and disposing of them. In addition, if the residues are comprised mainly of recyclable materials (as opposed to non recyclable materials) then revenue from the sale of these materials is lost.

Many MRF operators do recognise that high residue rates result in significant costs and are taking steps to minimise those costs by lowering the residue rates. A variety of approaches are being used:

- Sort non-recyclables at the pre-sort stage - as explained previously this helps optimize the down-stream sorting process by removing materials that the system is not designed to identify and process
- Process materials a second time - if most large non-recyclables are pulled at the pre-sort, then the residues remaining at the end of the process should be recyclables that did not get sorted properly. Materials passing through the sorting process that have not been positively sorted can be passed through the sorting system a second time.
- Conduct audits of the process residues - The results of the audit can be used to determine what steps should be taken to improve MRF operations, such as more manual sorters, better training for staff, air classifiers to separate small paper fractions from residues, etc.
- Conduct periodic audits of incoming loads - Most of the MRFs visited indicated that they do inspect incoming loads on a random basis. Some MRFs carry out more regular inspections and provide detailed reports to local authorities. To be effective, frequent random audits should be carried out with reports issued to the local authority/waste collection contractors immediately. This allows for identification of the problem routes, and corrective action to be taken on a timely basis.
- Charge local authorities for the cost of disposing of non- recyclables collected - Some MRFs charge for the disposal of the non-recyclable residues that enter the recycling stream at the collection stage. This can provide an additional incentive to local authorities

to target their education/ communication campaigns with the aim of reducing the level of non-recyclable contamination.

- Adjust (lower) the recycling rate of the local authority commensurate with the rate of residue - typically, a local authority determines its recycling rate based on the volume of materials collected at kerbside and sent to the MRF (among other factors). The calculation of BVPI 82a (recycling) requires an adjustment to the tonnes collected for recycling to reflect the level of MRF residues.
- Use performance-based contracts to improve quality of collected materials - local authorities/collection contractors have found it important, to train collection staff on collection policies and how to deal with contamination in the recycling stream. Towards that end, some local authorities have entered into performance based contracts that provide financial bonus awards for both an increase in volume/participation as well as a reduction in contamination from households.

4.7. Contractual relationship between MRF and local authorities

Good contractual arrangements and working relationships between local authorities, collection contractors and sorting contractors are essential to ensuring efficient recycling operations. Increasingly many local authorities stipulate levels of performance to be achieved by the MRF contractor and include financial incentives to encourage increased performance. Key issues to consider include:

- **Determine materials to be sorted -** Local authorities should determine the materials to be included in their kerbside collection programme and invite companies to bid on their net costs for sorting the materials received and the revenue that will be generated.
- **Tender the sorting function separate from collection** - To maintain competition and ensure transparency in the costs of each element of the service.
- **Establish acceptable residue rate** - The contract should specify an acceptable level of residues for the sorting process. Efficient MRFs appear to achieve 2 – 5% residues. Financial penalties should be a part of the agreement if the residue rate is to have meaning.
- **Establish cost per tonne for sorting** - Tenders received for sorting kerbside materials should indicate the costs per tonne for sorting the specified materials, the net value to be received from the sale of sorted materials, even though it will vary from time to time, and a proposed revenue sharing plan with the local authority.

- **Specify market price for materials** - The successful contractor should state the price they expect to receive for the value of the sorted materials. Having to offer a competitive market price places pressure on the MRF operator to ensure revenue earning potential is maximised.
- **Establish revenue sharing arrangements** between MRF and local authority - The contract should specify the basis on which revenue will be passed back to the local authority from the sale of the sorted recyclables. This revenue will help offset the direct costs of collecting and sorting the materials. For many local authorities in England revenues coming back to local government are not assigned directly to the waste service. Eureka Recycling and the City of St. Paul Minnesota had this similar constraint and developed a system whereby funds generated from the sale of materials are discounted from invoices received from the contractor. Under this procedure the waste department is able to use unspent funds to support other recycling activities.

4.8 Specifications

Although there is a fairly high degree of clarity on specifications in other countries, the MRFs visited in England seem to be guided by rather broad specifications. Unlike the MRFs in other countries, the team did not detect a well defined set of specifications for supplying the paper industry, nor any evidence that prices fluctuated depending on the quality of the material presented.

The system for agreeing acceptable standards for supplying paper to the mills appears to be in the main a bi-lateral arrangement between individual MRFs and individual mills.

Steps that have been taken elsewhere to set and meet specifications:

- Publish paper standards In North America and Europe, paper specifications are publicised and made available on Mill web sites for all potential suppliers.
- Implement objective testing procedures to determine quality of materials received - straight-forward and inexpensive systems for random sample testing of materials shipped from MRFs and received at mills. This is now adopted at several Mills in the UK e.g. Aylesford, however is no standardised testing procedure
- Implement a continuous feedback system to the MRFs, advising on the quality of materials received during a given month. Results of random tests can be sent automatically by email to the supplier MRF. This allows for quick response by the MRF

manager when the quality shipped is not consistent with previous shipments. Again several mills in the UK are now providing this feedback.

- Differential pricing - financial incentives for materials that significantly exceed the standard and penalties for materials that are below standard.

Appendix 1

Terminology

Understanding specific terminology related to sorting techniques and processes is important to understanding how a MRF works. The following provides an explanation of commonly used terms in this report.

Material streams

Incoming materials are typically collected co-mingled.

Single-stream co-mingled

All dry recyclables are co-mingled in one container (wheeled bin, box, sack) and typically are collected in a single compartment compaction vehicle and delivered to a MRF for sorting.

Two-stream/glass separate

All dry recyclables are co-mingled in one container and a separate container is provided for glass; these materials are collected in a two compartment collection vehicle in order to keep the glass separate from the other recyclables and delivered to a MRF for sorting.

Two-stream/paper separate

All dry recyclables (glass, plastics, cans) with the exception of fibres are co-mingled in one container (wheeled bin, box, sack) and a separate container is provided for paper; these materials are collected in a two compartment collection vehicle in order to keep the paper separate from the other recyclables and delivered to a MRF for sorting.

Source-separated

The separation of targeted dry recyclables at the point of collection. Materials are placed into one or more containers by the householder and then sorted into separate materials streams at the kerbside. Collections are made using stillage or multi-compartment vehicles.

Recovered materials

Once materials have been sorted into homogenous streams, baled or densified for transportation, they are described as recovered materials.

Sorting stations

As materials move through a MRF, they are sorted at a sequence of stations where specific techniques are used for identifying and separating designated materials from other materials in the co-mingled stream.

Manual sorting

Employees identify and manually pull out material from the stream as it passes in front of their station.

Automated sorting

Machines separate targeted materials in the co-mingled or mixed material stream.

Positive sort

The targeted material is removed from other materials on the conveyor.

Negative sort

Material(s) remaining on the conveyor after other targeted material(s) have been extracted.

Light fractions

Those materials that tend to weigh less than other materials in the co-mingled stream and can therefore be sorted by weight, e.g. plastic from glass.

Heavy fractions

Those materials that tend to be heavier than other materials in the co-mingled stream and can therefore be sorted by weight, e.g. glass.

Residues

Material remaining after the sorting process has been completed. Residue typically is comprised of unsorted recyclables (e.g. small paper, plastic, etc fractions – process residues) and non-targeted materials that are delivered to the MRF. Residues usually require some form of final disposal.

Sorting equipment

Air classifiers

A mechanical device using air currents to separate solid components into "light-fraction" or "heavy-fraction".

Cyclone/hurricane

Large fans inside metal air ducts suck light-weight material (paper) from the co-mingled stream.

Disc screen (also known as a ‘star screen’)

A series of inclined rotating discs used to separate recyclables based on shape and size. The discs rotate on a series of axes. Spaces between the individual discs as well as the rows of discs can be adjusted so as to screen the desired material. Larger, flat materials (e.g. cardboard and newspaper) move up and over the screen in the direction of the rotating discs, while smaller round recyclables (e.g. cans and plastic bottles) fall between the discs onto a conveyor belt.

Eddy current

A device which passes a magnetic field through materials, thereby inducing eddy currents in the non-ferrous metals. The eddy currents counteract the magnetic field and exert a repelling force on the non-ferrous metals, separating them from the other materials.

Magnet separation

A system to remove ferrous metals from other materials. Magnets are used to attract the ferrous metals and to direct them away from the other recyclables.

Metering drum

A large steel drum positioned above an inclined conveyor to level material flow. The drum rotates in the opposite direction of the materials as they travel up an inclined conveyor.

Optical scanning

Optical scanners identify the material passing under the scan at high speed. Air knives sort the scanned material based on definitions set by the operator. Optical scanning is used to sort glass by colour, plastic by resin, and paper by fibre grade.

Trommel screen

A rotary cylindrical screen typically inclined at a downward angle that separates materials of different physical size. Materials that enter the trommel are selectively removed through various sized holes as they move through the trammel.

Vibrating table

A tilted flat surface, which may or may not have holes, that moves the co-mingled materials through vibration. The tilted angle causes the heavier materials to slide downward to the lower end of the table and onto a conveyor for further sorting. The larger lighter-weight materials move forward onto a second conveyor for further sorting.

Appendix 2

Quality Control and Specifications

To be used as industrial feedstock, materials recovered from kerbside recycling collection programmes must be sorted and processed in a manner that will allow them to be traded on a commodities market, sight unseen.

Part of this review of MRFs looked at the extent to which market specifications were defined. And also the extent to which MRF staff were cognizant of those specifications and the extent to which those specifications were used and achieved by each facility visited.

In Europe the market specifications are established by the producer responsibility organisations. The specifications are rigid and the MRFs are acutely aware of the acceptable levels of contamination. Each facility visited had established inspection and testing procedures.

In North America, specifications provided by the MRF staff were fairly detailed. Inspection and testing procedures were in place to monitor the quality of sorted materials in relation to the market specifications.

The staff interviewed at the MRFs in England, presented more general specifications than their counterparts in other countries. Quality inspection systems and quality testing of sorted materials was less prevalent.

The following is a compilation of specifications provided by the MRFs managers during interviews conducted in the course of this study.

Market specifications from selected European recycling programmes

Eco-Emballage specifications

The MRFs visited in Lille and Renne must adhere to the specifications set by Eco-Emballage, the French producer responsibility organisation. These cover:

- Liquid food packaging

- Any type of plastics composed of one material
- Screened glass
- Sorted graphic paper for de-inking
- Recovered corrugated paper
- Mixed papers and cards
- Steel – commercial use only
- Packaging products (cans, aerosols) from a separate packaging kerbside collection
- Aluminium

1. **Liquid food packaging** such as 'tetrapak' and assimilated materials (abbreviated 'ELA' in French)

Criteria: obtain by automatic sorting

C0: Useful materials	C01 ELA	Higher than 95% (**)
C1: Inappropriate materials	C11 Total of inappropriate materials	Lower than 5% (**)
C2: Humidity	C21 Humidity rate	Lower than 12% (**)
C3: Packaging	C31 Weight of bales	Between 400 and 1200kg (**)
	C32 Density	Higher than 0.4 +- 0.05 (**)
C4: Consignment	C42 Bales on trailer	Around 20 tonnes (max 24 t) (**)

2. **Plastic** coloured or not, opaque or transparent, composed mainly of one material

Criteria:

C1: Inappropriate materials	C11 Total of free inappropriate materials	Lower or equal to 10% (**)
C2: Humidity	-	-
C3: Packaging	C31 Weight of bales	To be defined
C4: Consignment	C42 bales	To be defined
	C43 unsorted	To be defined

3. Screened glass of 8-15mm

Criteria:

C1: Inappropriate materials	C11 % of total impurities	Lower than 2% (**)
	C12 Infusible	Lower than 10.000g/t (**)

4. **Sorted graphic paper** for de-inking, mixed leaflets – brochure, comics, catalogues, prints, newspapers, directories, with or without staples and without rigid cover.

Criteria:

C0: Useful materials	C01 Tangled leaflet	Around 95% (*)
	C02 Paper's age	Less than 6 month (***)
C1: Inappropriate materials	C11 Total of inappropriate materials (dirty papers and non pulpable materials)	Lower than 3% (**)
C2: Humidity	C21 Humidity rate	Lower than 12% (***)
	C22 Storage under shelter	Yes
C3: Packaging	C31 Weight of bales	Between 500 and 1250kg (**)
	C32 Bales density	Higher than 0.4 (**)
	C33 Non crossed strapping	Yes
C4: Consignment	C42 Bales on trailer	Around 20 tonnes (max 24 t) (**)
	C43 Unsorted dumpster	Around 9 tonnes (Max 10t) (**)
	C44 Unsorted trailer	Around 20 tonnes (max 24t) (**)

5. **Recovered corrugated card**– used boxes and sheets of corrugated card

Criteria:

C0: Useful materials	C01 Boxes and sheet of corrugated card	around 95% (*)
C1: Inappropriate materials	C11 Total of inappropriate materials (dirty papers and non pulpable materials)	Lower than 5% (**)
C2: Humidity	C21 Humidity rate	Lower than 12% (**)
C3: Packaging	C31 Weight of bales	Between 400 and 1000kg (**)
	C32 Bales density	Higher than 0.4 (**)
C4: Consignment	C42 Bales on trailer	Around 20 tonnes (max 24 t) (**)
	C43 Bales on maritime containers	Around 18 tonnes (Max 19t) (**)

6. **Mixed papers and cards**

Criteria:

C0: Useful materials	C01 Tangled papers and cards	Higher than 50% (*)
	C02 Newspapers, magazines and brochures/leaflets	Lower or equal to 40% (**)
C1: Inappropriate materials	C11 Total of inappropriate materials (dirty papers and non pulpable materials)	Lower than 10% (**)
C2: Humidity	C21 Humidity rate	Lower than 12% (**)
C3: Packaging	C31 Weight of bales	Between 400 and 1000kg (**)

C4: Consignment	C42 Bales on trailer	Around 20 tonnes (max 24 t) (**)
	C43 Unsorted dumpster	Around 9 tonnes (Max 10t) (**)
	C44 Bales on maritime containers	Around 20 tonnes (Max 24t) (**)

7. **Steel** – commercial use only – European classification of high steel reference E8 (March 1995)

Criteria:

C1: Inappropriate materials	C11 Inappropriate free non metals materials	Lower or equal to 10% (***)
C3: Packaging	C31 Unsorted density	Higher or equal to 0.1 (***)
C4: Consignment	C41 Minimum shipment by removable dumpster	Higher or equal to 4 tonnes (***)

8. **Packaging products** (cans aerosols) from a separate packaging kerbside collection

Criteria: *obtain by automatic sorting*

C0: Useful materials	C01 %e in magnetic rate	Higher or equal to 88% -2 (*)
C1: Inappropriate materials	-	-
C2: Humidity	C21 %of water rate	Lower or equal to 10% (***)
C3: Packaging	C31 Unsorted density	Higher or equal to 0.1(**)
	C32 Packaging density	Between 1,2 and 2 (**)
	C33 Bale density	Higher than 0.3 (**)
	C34 Packaging resistance of 5 consecutive 2 cm drops on hard surface	Yes (**)
	Weight of packaging	Between 10 and 100 kg(**)

C4: Consignment	C41 Minimum shipment by removable dumpster	If unsorted, higher or equal to 4 T (**) If packaging higher or equal to 10 T (**)
	C42 Small shipment by trailer	If baled, higher or equal to 20T (**)

9. Screened glass at loading - category C or glass >15mm

Criteria:

C0: Useful materials	C01 Density	Lower or equal to 1 (*)
C1: Inappropriate materials	C11 % of total impurities	Lower than 2% (**)
	C12 Infusible	Lower than 5000g/t (**)

10. **Aluminium** – used packaging, rigid or semi-rigid composed mainly of aluminium

Criteria: *obtain by automatic sorting*

C0: Useful materials	C01 Percentage of aluminium used by industries	Higher or equal to 45% (**)
	C02 Grading	Higher than 10mm (***)
C1: Inappropriate materials	C11 Total of inappropriate materials	Lower than or equal to 10% (**)
C2: Humidity	C21 Humidity rate	Lower or equal to 10% (***)
C3: Packaging	C31 In over compressed packaging with density	Around 0.2 (***)
	C32 In sized bale	Between 1m x0.7m x 0.7m and 1.1m x 1.1m x 1.2m (***)
	C33 Unsorted	-
C4: Consignment	C41 Removal on small shipment by trailer or tray or trailer	Higher than 5 tonnes (**)

Market Specifications from North American MRFs

Eureka Recycling:

Paper

#7 News
In addition to newsprint fibre, the load may also contain:
15% Magazine
10% Office Paper
1% Outthrows (other fibres)
0.5% Prohibitives (materials damaging to the pulping process

Other fibre including Kraft Paper, Boxboard, Wet strength, OCC and Office paper must contain less than 1% contamination.

Glass

- Glass Container Market - 3/8th inch or larger and colour sorted
- Sandblasting Market - 3/8th inch or smaller and not colour sorted

Plastics

- 1% contamination is allowed

Aluminium & Steel

- 1% Contamination

SP Recycling, Atlanta Georgia:

Newsprint's de-ink news specifications:

- Contains sorted, fresh, dry sunburn free newspapers
- Contains no more than the normal percentage of inserts, with samples removed
- May contain over-issue news (polyethylene bags must be removed)
- May contain pressroom scrap without heavy ink sheets or overissue inserts
- Maximum age 3 months
- Moisture content 10% (air dry)
- Total contamination: 0.5%
- Prohibitives: None
- Provide supplier with feedback reports.

Prohibitives are any materials and contaminants other than paper; including:

- Plastic bags, flexible film
- Adhesive tapes
- Carbon papers
- Plastic window envelopes
- Glued magazines
- Waxed paper
- Pressure sensitive tapes and labels
- Ropes, strings, twines, strapping
- Metal, glass, dirt, cloth
- Wood, floor sweepings, beverage cartons

Out-throws are papers (fibre) other than old newspaper.

- Aged newspapers, sunburned newspapers
- Shredded papers,
- Corrugated boxes, kraft bags, folding cartons, junk mail,
- Office, computer, coated or treated papers

Other specifications

- Bales should be dense and solid and be uniform in size within a load
- Bales and loads must be tare free
- Container should be swept clean before loading

Waste Management MRFs, Minneapolis and Seattle

Paper

- 2% Contamination
- 10% Moisture
- No glass

Plastics, steel, aluminium

- 1% contamination

UK Market specifications - examples

The following specifications were reported during site visits.

Norwich MRF

- Fibre: typically 1% contamination, however, the market has less tolerance for cardboard.
- Containers: 1% contamination. Plastics are sorted into individual polymers and exported to Asia.

East Riding MRF

The recycled paper must meet the following general specification:

- All paper must be not more than 6 months old
- Maximum of 1% of contraries such as metal, plastic string.
- Maximum of 12.5% moisture
- Maximum of 2.5% coloured newsprint
- Maximum 1% telephone directories/envelopes
- Maximum 10% catalogues

Luton MRF

Typically the markets accept about 1% contamination in the various sorted materials.

Huddersfield MRF

Most markets accept 1% contamination in the materials

Hampshire MRF

Generally 1% contamination for most materials
Specific criteria have been agreed with a UK paper mill

Darwen MRF

Mixed papers are sent direct to Aylesford (not sorted at the MRF)
Plastics sorted by resin and colour must have less than 1% contamination