The MRF Costing Model provides local authorities and others with a tool to enable better understanding of the total costs of sorting and bulking dry recyclables and the relative costs of different sorting systems.
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Preface

The MRF Costing Model was developed to provide Local Authorities with a tool to enable them to better understand the total costs (e.g. capital, operating and unit costs per tonne) of sorting and bulking dry recyclables and the relative costs of different systems. This tool will assist local authorities and other organisations in the planning and delivery of cost effective collection and sorting schemes for dry recyclables.

The MRF Costing Model and this report were prepared by Entec Consulting Ltd under contract to WRAP. Entec Consulting Ltd. is a specialist consultancy established by Bob Graham to provide advice on a variety of waste management issues.

The MRF Costing Model and User Guide were developed under the direction of a Steering Group assembled by WRAP. The model and guide have been subject to a comprehensive peer review process.

Entec and WRAP would like to thank all of the organisations and individuals who provided their time and information in support of this project.

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Glossary of terms

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

Bag Breaker
A machine used to tear open plastic bags containing recyclables so that the recyclables are released from the bag and the film can be manually sorted from the recyclables.

Baler
A machine used to compress recyclables into bundles to reduce volume.

Disc Screen (also know 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 Separator
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.

Magnetic 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.
Materials Recovery Facility (MRF)
A Materials Recovery Facility (MRF) separates co-mingled (recyclable) materials into their individual material streams and prepares them for sale into the commodity markets.

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.

Old Corrugated Cardboard (OCC)
Bulky cardboard that is typically found in boxes used for shipping and packaging. It is made from 2 strips of cardboard with a “corrugated” strip running through the centre.

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

Source Separation
The separation of specific materials at the point of generation for separate collection. (e.g. residents source separate recyclables from refuse and set these recyclables out for kerbside collection).

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 trommel.
Introduction

The Materials Recovery Facility (MRF) Costing Model was developed to raise the profile of the issues surrounding MRF operations and provide relevant information and good practice advice to Local Authorities (LAs) to enable a better understanding of the role of MRFs in achieving higher recycling rates and providing sustainable quality materials to reprocessors.

There has been a growing need to develop a processing costing tool that allows the total costs (e.g. capital, operating, unit costs per tonne) of sorting and bulking dry recyclables to be determined and to enable direct comparisons to be made between the costs of different approaches to collecting and sorting dry recyclables.

WRAP supported development of the Kerbside Analysis Tool\(^1\) (KAT), which allows local authorities to assess the infrastructure and costs for a wide range of different kerbside collection systems. However KAT does not contain detailed fields for post collection sorting and bulking costs. This MRF Costing Model along with KAT will enable local authorities to understand the total costs of managing the collection, bulking and sorting of dry recyclables and the relative costs of different systems. This tool will assist local authorities and other organisations in the planning and delivery of cost effective collection and sorting schemes for dry recyclables. It is designed to accommodate typical types of MRFs ranging from smaller facilities with primarily manual sorting to large, highly automated facilities and to determine the costs of these facilities at different operating/design capacities.

MRFs will have an increasingly important role to play in the sorting of collected dry recyclates prior to the onward delivery of the sorted materials to reprocessors. The type and level of sorting required is determined by the collection system and the range of materials collected at the kerbside. Advice on collection systems is available under WRAP’s ROTATE programme but the level of advice available on sorting operations, in particular fully automated MRFs that support the co-mingled collection of a mix of dry recyclates, requires further development. Recent interest in the efficiency of sorting operations at MRFs and the quality of recovered materials for reprocessing has further highlighted the need for good quality guidance on the sorting technologies available and their performance characteristics, as well as a need for technical advice and guidance on export classifications for recovered paper in particular. Well designed and operated MRFs add value to the mixed recyclates through increased levels of sorting (e.g. several grades of paper, plastics by polymer type, etc), and if appropriate revenue sharing arrangements are in place then the benefits of additional revenues can be used to offset the costs of collection and sorting.

\(^1\) [http://www.wrap.org.uk/local_authorities/toolkits_good_practice/kat_gets_a_new.html](http://www.wrap.org.uk/local_authorities/toolkits_good_practice/kat_gets_a_new.html)
For reasons that will be explained in more detail later in this guide, it was decided that the MRF models would be designed not based on the composition and quantities of recyclables presently collected and processed, but rather on what might be considered the “best practice” standard that local authorities will likely need to aspire to over the next five years or more in order to meet higher recycling rates. This would include a broad range of targeted household recyclables from programmes with above average householder participation and material capture rates.

Whilst few local authorities are likely to operate MRFs, they are involved in procuring services from private contractors that involve the design, commissioning and operation of MRFs/bulking facilities. Understanding all stages in the process from collection through to sale of materials to reprocessors and how responsibility is assigned under contracts is critical. Many local authorities place the responsibility wholly on the MRF operator/contractor for ensuring material quality and sale to reprocessors, however many contracts ignore material value resulting in little incentive for the contractor or the local authority to improve quality.

Furthermore, Waste Collection Authorities (WCAs) often work in isolation from each other, from the Waste Disposal Authority (WDA) and almost certainly from MRF contractors. Development of the MRF Costing Model is designed to bring together the various interrelating strands to enable WRAP to provide high quality advice on sorting as well as collection, covering cost and performance issues of operating MRFs to the required output standards. This is so that local authorities are better informed of the bigger picture and the consequences of choosing a particular path prior to embarking down the procurement route and preparing service specifications.

Development of the MRF Costing Model has been supported by two other projects commissioned by WRAP:

- A review of MRF practices and operations at relevant facilities in North America, the UK and Europe
- A review of contractual arrangements between UK local authorities and MRF operators/owners.

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2 Reports available on the WRAP website: http://www.wrap.org.uk/localAuthorities/
2. Development of the models

2.1 Background

Early MRFs in the UK were primarily smaller facilities, designed with basic sorting systems. These plants met the needs of the initial household collection programmes where most of the sorting effort took place at the kerbside. In fact, many of the collection programmes were designed with kerbside sort systems so as to avoid the need to sort and process the recyclables collected.

With the expansion of kerbside collections to more local authority areas and to more households, together with pressure to collect more materials for recycling authorities began to look at co-mingling various materials primarily so as to simplify collection operations and increase collection efficiencies.

Many kerbside sort programmes have evolved into collecting two streams of recyclables: fibres (e.g. news and PAMs, cardboard, magazines, etc.) and co-mingled containers (e.g. ferrous and aluminium cans, plastic bottles, etc.). For these schemes, a variety of relatively straightforward mechanical and manual MRF sorting techniques have been used to process these material mixtures.

However more co-mingling at the point of collection meant the need for more sophisticated processing equipment in MRFs. Facilities such as those located in Hampshire, and at Rainham and Ipswich saw the introduction of various types of trommels and screens that are now standard processing components used at the initial stages of separating fibre from containers in a fully co-mingled mixture of all recyclables. More of these larger MRFs are now being designed and commissioned in the UK.

2.2 Types of MRFs Modelled

Two individual MRF costing models were developed in this project to replicate the two most popular forms of dry household recyclables collected: one a fully co-mingled (single stream) mixture and the second, a 2 stream mixture of fibres and containers.
The first model “SS MRFs.xls” deals with a fully co-mingled\(^3\) incoming stream of dry recyclables. These materials are typically collected in local authority recycling programmes in a wheeled bin, box or in a dedicated, one-way recycling sack and are typically delivered to the MRF in a single compartment of a collection vehicle. The user has the option in the model to designate whether glass is included in the incoming co-mingled material and whether the material is bagged or loose (see Section 4.4 for further details on including/not including glass).

The second model “2 Stream MRFs.xls” replicates delivery of two separated streams of recyclables: fibres and containers. These are typically materials that are sorted kerbside into two separate collection vehicle compartments. The user has the ability in this MRF model to designate whether glass is to be included in the container mixture. Since recyclables in this system are usually set out at the kerbside using multiple boxes or reusable sacks (or a combination of both), the use of one-way recycling sacks has not been provided as a form of material delivery. This issue will be addressed in Section 4.

### 2.3 Bulking Facilities

Many local authorities (often with their Waste Disposal Authority) presently operate or contract small sorting facilities that involve minimal processing of recyclable materials. Most of these facilities service collection programmes where extensive sorting is done at the kerbside and the collected recyclables are delivered to the facility as individual materials (e.g. news and PAMs, cans, glass, etc.) Consequently, the need for sorting at the facility is minimal and may consist only of separation of ferrous and aluminium cans, or removal of obvious contaminants once the recyclables are off-loaded onto a tipping floor. In many cases, these facilities either bulk incoming recyclables for delivery to more distant reprocessors, or ship recyclables direct to final markets.

There was initial consideration in this project to providing a model to deal with these “bulking” facilities, however it was decided that this type of facility did not fit the “MRF model” concept. Bulking facilities are low tech in nature and more often are designed to meet existing site and building constraints than are “greenfield” MRFs. Furthermore, because of their responsibilities for civic amenity sites, many local authorities feel more comfortable with the task of designing and costing a bulking facility, regardless of its size.

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\(^3\) This fully co-mingled mixture will also be referred to as “single stream” in this report.
2.4 MRF Sizes

MRF size is typically characterized by reference to the maximum throughput tonnage that the MRF is capable of processing. For the purpose of modeling for this project, four MRF sizes were selected to represent a cross-section of facilities currently operating throughout the UK:

- 85,000 tpa
- 50,000 tpa
- 25,000 tpa, and
- 10,000 tpa.

These sizes were selected with a view to being not only representative of what is currently in place, but more importantly, what many authorities are likely to consider as their recycling programmes expand and mature. As recycling collection infrastructure grows, there is a natural, progressive move to larger, more county-wide and/or regional processing facilities. This is evident in the size of MRFs commissioned over the past 5 years or planned in the UK (e.g. Greenwich, Norfolk, East London Waste Authority, Western Riverside Waste Authority, Alton in Hampshire, etc.).

2.5 Health and Safety

It has been assumed that the MRF costs developed in these models provide for facilities that comply with all applicable English Statutes and subordinate legislation, including the Management (Health and Safety) Regulations 1999, The Supply of Machinery (Safety) Regulations 1992 and all relevant guidance and codes of practice.
3. What is the MRF costing model?

3.1 General

The MRF Costing Model is, in fact, two separate Microsoft Excel™ 2003 workbooks that identify the infrastructure required and the associated costs of processing a wide range of target recyclables:

- SS MRFs.xls
- 2 Stream MRFs.xls

The third workbook “Summary Cost Graph.xls” summarises costs for both of the MRF models, to provide a direct comparison of both systems.

The model is not intended to allow the user to design a MRF. Design of a MRF is very specific to local needs and therefore difficult to incorporate into a generic model. Rather, this tool is intended, to the extent possible, to give the user the opportunity to modify a variety of input data to “tailor” several MRF designs to local conditions, including:

- Specific MRF design parameters such as the capacity of the tipping floor and product storage areas
- Operating conditions (hours, shifts, days/wk, etc.)
- Selecting whether the incoming recyclables are fully co-mingled (single stream) or separated (2 stream), whether they are bagged or loose, if glass is included in the mixture or not
- Designating which materials are to be baled and which are to be manually sorted
- Labour rates for operating and supervisory staff
- Designating recovery rates for targeted recyclables
- Revenue and shipping costs for materials to be marketed
- Miscellaneous other items such as the cost of baling wire, cost per tonne of residue disposal, the unit cost of constructing the MRF building, local charge rates for electrical consumption, etc.

The primary intent of the MRF models is to provide local authorities with a costing tool that can be used in conjunction with the KAT collection model to evaluate various options for collecting and processing recyclables. By using the model for a MRF of a particular design capacity, the user is able to identify:

- the cost of a 2-stream and a fully co-mingled processing system
- the cost of adding glass to the incoming recyclables streams
- the additional costs associated with processing bagged recyclables at a fully co-mingled MRF.
Each of these can be investigated under a wide range of operating parameters and several material marketing options. The model is meant to provide “representative” capital and operating costs for a variety of sizes of MRFs. By changing the variables listed above, the user is able to assess the resulting changes in resources and costs.

### 3.2 Setup of the Models

In both of these models, there are two initial spreadsheets that are used for input data: one dealing with incoming material composition, and the other highlighting various operating and cost assumptions. The next four spreadsheets contain all of the detailed calculations and information pertaining to the range of design throughput tonnages selected – 85,000; 50,000; 25,000; and 10,000 tpa. A graph is then provided to summarize the gross and net costs associated with the MRF design and operation parameters that the user has selected. The last spreadsheet in each workbook summarizes key resource and cost information for each facility.

### 3.3 Default Data

In an attempt to make the models as specific and useful as possible, default data have been minimized. Specific input data have been selected to illustrate how the model operates, but in most cases, the user has the option of changing these parameters to reflect local conditions. Cells in the worksheets that require user consideration and input are shaded yellow.
4. Incoming material composition

4.1 Background

The initial step in designing any processing facility is identifying how much of what material will require processing. It is typical that a local authority tendering for its own MRF will specify to the designer a composition breakdown for recyclables to be processed at the MRF. The majority of recyclables to be processed in these MRFs originates from the authority’s own recycling programmes, including recyclables collected through kerbside, estate, bring and civic amenity sites.

Since the majority of material typically comes from kerbside collection, material composition data often come from waste audits performed on recyclables collected through the kerbside programme. This information might then be adjusted to take into account:

- additional materials that will be added to the programme in the coming years
- any “clean” recyclables from commercial or trade sources (e.g. card, office paper, etc.)
- any other recyclables originating from a neighbouring or partner authority.

Obviously, it becomes very difficult to forecast with precision the breakdown of materials to be processed over the life of the MRF. For this reason, care should be taken to identify how much flexibility the designer needs to build into the design to allow for new materials to be separated and marketed. Very often, an authority will indicate:

- a list of minimum separation requirements – those separations that are definitely required in the MRF design
- a list of “optional” additional materials to be sorted - these are typically reviewed at the tender evaluation stage and decisions to include these are often based on the budget constraints
- a list of “future” materials that might be added at a later date - in these cases, the designer might simply provide additional space if available to be able to process these materials.

The primary difficulty in developing MRF models for this project was selecting a representative composition of incoming materials that represents recyclables collected by a broad range of authorities throughout the UK. Not only is there great variety in materials collected by authorities in different geographical locations, but also great variation in the quantities of each material in the mix, depending on the material arisings and the performance of the individual recycling programmes.
Therefore, it was decided that the focus of selecting both “representative” materials to be included and the composition of those materials should not necessarily be what is presently collected, but rather, what might be considered the “best practice” standard that authorities will likely need to aspire to over the next five years as recycling programmes continue to expand. This would include a broad range of targeted household recyclables from programmes with above average householder participation and material capture rates.

### 4.2 Waste Arisings and Recovery Rates

A number of information sources were researched to identify typical arising data that might be used in this project. Defra provided a number of individual waste audits (household refuse and recyclables) that have been performed for various authorities over the past 5 years. Two studies provided arisings data for Wales and for the UK. Household waste arisings data were generally similar for major material categories in both studies, and in addition to a percentage breakdown by material, the UK study also provided a kg/hh/yr material breakdown. This information was reviewed in conjunction with the Defra audit data as well as two other detailed waste audits, one for Hampshire and the other for Western Riverside Waste Authority (WRWA) in London. A breakdown of this information is presented in Appendix A.

The arisings and recycling performance data from these sources were then used to develop representative recovery rates for use in the MRF costing models. The recommended rates were developed for six different collection and processing system options, namely:

- **A**: Single stream co-mingled with glass, bagged collection
- **B**: Single stream co-mingled without glass, bagged collection
- **C**: Single stream co-mingled with glass, loose collection (using a wheeled bin or box)
- **D**: Single stream co-mingled without glass, loose collection (using a wheeled bin or box)
- **E**: 2-stream collection (fibres and containers) with glass (using boxes and/or reusable sacks)
- **F**: 2-stream collection (fibres and containers) without glass (using boxes and/or reusable sacks).

Collection of fibres using (single use) recycling sacks was not deemed a common practice in UK kerbside programmes and therefore was not included as an option for 2-stream collection.

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4 Waste Composition Analysis – Guidance for Local Authorities; Entec UK Ltd with Eunomia Research & Consulting Ltd for DEFRA; 2004
5 Analysis of Household Waste Composition; Dr. Julian Parfitt, WRAP; Dec, 2002
The projected recovery rates shown for each system represent “best practice” for that type of programme. The recovery rates are higher than presently experienced in many UK collection programmes and are meant to reflect recovery rates that local authorities should be aspiring to achieve. They have been developed with due consideration of the performance of some of the leading recycling programmes in the UK and refined to project what is considered high level (but practical) householder participation and material capture rates. Variations in assumed recovery rates across each of the systems are highlighted in yellow. For instance, glass recovery is higher in those systems where glass is a designated material (Systems A, C and E).

In addition, experience shows that a fully co-mingled collection system experiences higher recovery rates than the equivalent 2 stream collection system, primarily because of increased convenience for the user. For the purposes of this project, it is conservatively projected that recovery rates for the 2 stream systems are 90% of those for the single stream co-mingled system. In addition, in the case of 2 stream systems E and F, where collectors have opportunities to sort visible contaminants from a box, recovery rates of some of these unwanted materials (e.g. liquid beverage cartons, non-recyclable paper, etc.) have been assumed lower than for those materials in the fully co-mingled single stream systems, since there is no opportunity in a bag or a wheeled bin collection to sort out these materials.

These material compositions are used as in-feed to each of the respective MRF designs described in more detail in following sections. Even though most of the non-recyclables are assumed to be removed during collection, small quantities are still assumed to be included in the incoming recyclables stream delivered to the MRF. These materials will form part of the MRF residue stream requiring ultimate disposal.

### 4.3 Targeted Materials

Materials that are assumed as targeted materials, that is, materials that local authorities designate as officially part of their collection scheme and that householders are requested to recycle, are highlighted in blue in the “Materials” column of Table A1. These include:

- Fibre:
  - News and PAMs
  - Directories and catalogues
  - Paper and card packaging
Cardboard
Other recyclable paper, including office paper

Containers:
- Ferrous food and beverage
- Ferrous aerosol cans
- Aluminium food and beverage
- Aluminium aerosol cans
- Clear, green and brown glass bottles and jars
- All plastic bottles.

Several other items were considered but not included, such as liquid beverage cartons (laminated and plastic/foil cartons for orange juice, milk, etc.), textiles and film plastic. Instead, provision has been allowed in the MRF designs for the addition of one additional fibre sort and one additional container sort. It was considered that textiles are more appropriately recycled through charity organizations (Salvation Army, etc.) and that because of the problems associated with sorting film plastic throughout the MRF, it should not be included as a designated recyclable material. If textiles are to be included, they are best collected in a plastic carrier bag and removed at a presort station. Although food wrap, carrier bags, etc. are not designated materials, film sacks such as those used to contain recyclables during kerbside collection, become designated recyclables if the user selects to evaluate this option.

In addition to “targeted” recyclables, most collection programmes experience some level of contamination, that is, additional materials are collected that are not “targeted” recyclables. As noted previously, in the case of 2 stream systems E and F, where collectors have opportunities to sort visible contaminants from a box, recovery rates of some of these non-recyclable materials (e.g. liquid beverage cartons, non-recyclable paper, etc.) have been assumed lower than for those materials in the single stream systems. Typically, there is no opportunity in a bag or a wheeled bin collection system to reject ‘non targeted’ materials at the kerbside.

The user is not able to adjust the assumed list of incoming materials or composition in the costing models, since the equipment design is based on these. Minor variations (e.g. eliminating aerosols from the mix) will not have any significant impact on the design or the resulting costs, but other quantity variations may be sufficient magnitude to require changes to the assumed equipment throughput capacity, thereby changing the size and cost.
4.4 Co-mingled Single Stream Collection Systems and the Issue of Including Glass with Paper

The co-mingled single stream debate has continued in the UK for more than 5 years in the same manner as it has in other countries (such as Canada and the United States) that have seen co-mingled single stream collection and processing systems grow in popularity. The debate on this issue was given extra impetus by the development of the European Standard for Recovered Paper and Board in 2001, implemented in the UK as BS EN 643.

Prior to this time the former UK standard (the UK waste paper grading schedule) listed 11 groups of recovered paper, with each group being sub-divided in up to 15 grades. Each grade had a full description of what is, and is not, acceptable, a maximum permissible level of objectionable materials and full descriptions of both objectionable and prohibited materials.

In generating the new standard, consensus between European countries was difficult for a number of reasons; some countries, driven by national legislation, wanted to define grades according to their source or collection systems. The UK did not manage to include an intended differentiation between hard mixed and soft mixed grades and most significantly there were difficulties in agreeing levels of objectionable materials. The result was a schedule, agreed by all parties, but in the main it only dictates the type(s) of paper required, but with nil contamination. In virtually all cases, nil contamination is not achievable and hence suppliers of recovered paper can only approach, rather than actually achieve, the specifications set.

This new grading schedule did not lead to any overnight changes in the composition of materials collected in the UK, but did achieve its objectives of improving clarity where grades are traded across national borders. However, as suppliers can only approach the specification set then it is noted in the standard that both: “The description of the standard grades is brief, and for this reason it is recognized that specific deals between buyer and supplier for standard grades with special specifications will be necessary to meet individual requirements...” and, “The criteria for defining the percentage of unusable materials for these grades will be subject to individual mills’ specifications”.

The only clearly defined quality requirements in EN 643 are as follows:

a) recovered paper and board originating from multi-material collection systems, containing only material of a valuable, recyclable nature must be specifically marked;
b) recovered paper from refuse sorting stations is not suitable for use in the paper industry;

c) recovered paper and board will, in principle, be supplied with moisture of not more than the naturally occurring level (10 %).

In summary, EN 643 has been in existence since November 2001 and has aided clarity in cross-border trading of recovered paper in Europe. It is though, fundamentally, a grading schedule and not a quality standard, as it only dictates to which name and code recovered papers should be graded, and does not define the quality of these grades.

With BS EN643 being an absolute standard, the UK paper industry published “A Guide to the Quality Requirements of Recovered Paper”\(^6\), based on its own experience and observations. The guide outlines the industry’s views on the ability of different paper collection systems to meet its quality requirements. Although not to be mistaken as the standard itself, the guide has prompted some concerns among local authorities regarding the ability of current and planned recycling systems to produce recovered paper and board products of the specified quality. (It should be noted that a wider European debate on paper quality and recovery is also ongoing. The Confederation of European Paper Industries, CEPI, has published a strategy discussing the issues and presenting the views of the European paper industry\(^7\). Two other North American studies also present views on this topic\(^8\)\(^9\)).

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\(^8\) “Paper Recycling - Quality is Key to Long-Term Success”; The American Forest and Paper Association; March, 2004

To inform the debate on paper quality in the UK, WRAP commissioned an objective assessment of the quality of paper recovered by UK local authorities in relation to the specifications set out in BS EN 643. An important aim was to establish how the quality of paper consigned to paper reprocessors by local authorities varies between different collection systems. This study showed that for 560 paper and board samples collected from 80 different local authorities across the UK, “for all paper grades, non-fibre contamination was found to be minimal” and that “the widespread perception of poor quality material arising from kerbside collection systems is incorrect”.

A few trends are evident related to single stream co-mingled recycling:

- More local authorities in the UK are implementing single stream co-mingled collection and processing schemes, with and without including glass as a designated co-mingled material. It is a trend that seems likely to continue.
- Most of these produce a news and PAMs grade of fibre and it appears that most rely on export markets for this material particularly where glass is a targeted material.
- When assessing the cost of single stream co-mingled collections compared to other collection systems, in particular, kerbside sort schemes the costs of collection and sorting must be considered.
- Single stream co-mingled recycling can result in higher recovery of targeted recyclables but higher contamination than comparable 2-stream collections.
- Technologies continue to improve to separate and process single stream co-mingled recyclables. As a result, newer MRFs are able to produce grades of paper that meet and, in fact, exceed those of older MRFs.
- As local authority recycling programmes expand, more and more recyclables will be collected from multi-occupancy households, flats and estates – many of these schemes will collect co-mingled materials resulting in higher contamination of the MRF in-feed.

Whether to include glass as part of a co-mingled single stream recyclables mixture that includes paper is a sensitive issue. Glass is a particular concern to paper mills. Most mills will reject loads of recovered paper for small quantities of this material. It is technically difficult to screen the glass fragments from the paper as it breaks down into an abrasive powder which causes damage to the papermaking process.

As a consequence, local authorities should be aware that there are potential market issues both with implementing single stream co-mingled systems and with including glass as a targeted material in the co-mingled recyclables. Some UK mills have publicly stated that they will not source

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recovered paper from MRFs and would never accept paper that has been collected with glass. The further consequence of this is that, especially for paper collected with glass, there will be a reliance on the export market, and in the longer term this too could become limited.

Paper is the material most likely to be contaminated if collected co-mingled either with glass or other dry recyclates and since paper is one of the weightier materials, it is an important component of local authority recycling collections contributing both to statutory recycling targets and landfill diversion targets. A key task facing local authorities, therefore, is to ensure that the paper collection systems they introduce and manage can meet both quantity and quality requirements of the reprocessors.

WRAP has taken the view that the MRF models need to provide the user with the ability to identify associated equipment and operating costs of both of these options (with and without glass), so that an informed decision can be made.

It is not the purpose of this guide to comment further on details of this debate, but rather to highlight to the user that the debate continues and to point to pertinent reference material.

4.5 The Issue of Compaction

MRF equipment, for the most part, is designed to sort recyclables based on their inherent size, shape and weight. With increasing pressure to maximize collection efficiencies and thereby minimize collection cost increases, more and more collectors are compacting recyclables on collection or transfer vehicles for delivery to a MRF. Processing complications arise when recyclables have been over-compact ed during collection and transfer.

Experience has shown that recyclables can be compacted to a density of about 2.5 times their loose density before they become so dense that it becomes difficult to readily separate them. Excessive compaction leads to cross contamination in MRF products. For instance, if a ferrous can and aluminium can are squashed together so tightly that they stay together through the initial sorting process, they will likely be ejected together by the overband magnet. While this may not be a problem in terms of ferrous contamination, it does result in lost revenue (since aluminium has a significantly higher value than ferrous). Similarly, a plastic PET bottle crumpled together with a PVC bottle, depending on the sorting system, will either result in contamination of the PET stream, or the loss of both bottles to the residue stream.
Where co-mingled collection includes glass, the problems detailed in Section 4.4 are further exacerbated as glass bottles can be crushed thus ensuring that glass fragments will be present in paper.

MRF operators and collection officers need to be aware of the processing implications of over-compaction and need to work together to find a balance that suits both parties. Compaction monitoring can be done through visual examination of material as it is unloaded onto the tipping floor and/or through periodic monitoring of incoming vehicle loads at the weighbridge (with maximum payloads assigned to vehicles of a given size). Ultimately, the MRF operator should have the capability of refusing to receive delivery vehicles that repeatedly refuse to comply with required density limits.
5. Marketed materials

In most cases, a MRF is designed to separate a number of basic products for which market specifications are known and prices are reasonably stable. These form the core materials separated in the process. However, each MRF operator has a degree of operating flexibility in responding to changes in market conditions by varying the quality (and hence the revenue received) of the individual materials marketed. In addition, modern MRFs are typically designed to allow for anticipated changes, including new materials to be included in the incoming mix or new technologies to separate or process materials.

The MRFs in the costing models have been designed to produce three grades of paper and five types of containers as listed in Table 5.1. When bagged recyclables are delivered, the MRF will be capable of baling the plastic sacks (as other film is considered contamination). In addition, conveyor sorting and bunker space has been provided to allow one future sort (e.g. for beverage cartons, etc.).

**Table 5.1: Materials to be Marketed**

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
<th>Shipping Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>News and PAMs</td>
<td>All white paper, including newspapers, magazines, catalogues, junk mail, photocopy paper, etc. (&lt; 2% objectionable material)</td>
<td>Export quality bales or loose</td>
</tr>
<tr>
<td>Old Corrugated</td>
<td>Clean, dry, brown cardboard boxes (&lt; 2% objectionable material, up to 10% grey card)</td>
<td>Export quality bales</td>
</tr>
<tr>
<td>Containers (OCC or</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old KLS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed paper</td>
<td>Clean, dry, mixed paper from various sources, including cartons, board, newsprint, magazines and grey card (&lt; 2% objectionable material)</td>
<td>Export quality bales</td>
</tr>
<tr>
<td>PET bottles</td>
<td>Mixed or colour sorted (optional)</td>
<td>Baled</td>
</tr>
<tr>
<td>HDPE bottles</td>
<td>Mixed or colour sorted (optional)</td>
<td>Baled</td>
</tr>
<tr>
<td>Aluminium cans</td>
<td></td>
<td>Baled or loose/flattened, depending on market location</td>
</tr>
</tbody>
</table>

11 Approximately 1.1m x 1.1m x variable length so as to maximize overseas container loading.
<table>
<thead>
<tr>
<th>Ferrous cans</th>
<th>Baled or loose/flattened, depending on market location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass bottles &amp; Jars</td>
<td>Coloured (mixed broken) from single stream MRFs, clear and coloured from 2 stream MRFs</td>
</tr>
</tbody>
</table>

The MRFs have been designed so as to allow news and PAMs to either be baled or delivered loose to the marketplace. It has been assumed that the other grades of fibre will all be baled.

Also, storage silos (or smaller cages for the small MRFs) have been provided for temporary storage of all container materials prior to baling. In the case of PET and HDPE containers, the user has the option of deciding whether or not to colour sort these containers. If colour sorting is chosen, it has been assumed that the silos can be divided to store each material. The user can add the cost of additional cages as necessary to allow for colour separation.

It has also been assumed that in single stream co-mingled MRFs, no attempt will be made to provide for colour sorting of glass, since much of the glass is broken during the process and therefore is difficult to sort by hand. In fact, in most single stream MRFs, glass is intentionally broken early in the process and removed either with screens or trommels so as to reduce wear and tear on downstream equipment and to minimize the amount of glass mixing with other recyclables. In 2 stream MRFs, it has been assumed that two products will be produced: clear and mixed colour glass.
6. The single stream co-mingled MRF model

This section will describe the MRF model design and opportunities for user interface. For the purpose of discussion here, the description refers to the “85” sheet (referring to 85,000 tonnes/yr design capacity).

A. Assumptions

The user has the option of selecting one of the four incoming types of single stream co-mingled delivery systems by entering A, B, C, or D in cell B4. The user should take care to ensure that the input designation is in caps with no spaces. This defines the composition of materials to be delivered to the MRF and whether or not the materials are delivered bagged or loose on the tipping floor.

<table>
<thead>
<tr>
<th>DESIGNATE THE TYPE OF INCOMING STREAM FROM THE LIST BELOW</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single stream bagged with glass</td>
<td>A</td>
</tr>
<tr>
<td>Single stream bagged without glass</td>
<td>B</td>
</tr>
<tr>
<td>Single stream with glass</td>
<td>C</td>
</tr>
<tr>
<td>Single stream without glass</td>
<td>D</td>
</tr>
</tbody>
</table>

All of the other input data in this section are linked to the “Assumptions” spreadsheet.

B. Incoming Materials

This is a breakdown of incoming materials delivered to the MRF, based on the type of system selected above, the design throughput capacity of this MRF (85,000 tpa), and the operating conditions selected on the “Assumptions” spreadsheet as shown below:

<table>
<thead>
<tr>
<th>A. Operation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days/Week</td>
</tr>
<tr>
<td>Paid hrs/shift</td>
</tr>
<tr>
<td>Productive hrs/shift</td>
</tr>
<tr>
<td>Incoming storage capacity read (days)</td>
</tr>
</tbody>
</table>

The left-hand set of data in the spreadsheet represents tonnages based on a single shift operation while the right-hand set refers to maximum throughput on a 2 shift basis. “Effective tonnes/hr” is
calculated using actual operating hours. This is increased by the 20% factor in Cell I12 (which is listed in the “Assumptions” spreadsheet) to give “Design tonnes/hr”. This increase allows for fluctuations in material flow and composition change. The design tonnes/hr is used to determine material storage and equipment needs.

The user has the ability to select any throughput tonnage and to assess the corresponding impact on operating costs.

C. Equipment Costs

This section of the model shows design details for this particular MRF, recognizing the type of incoming system selected and the throughput tonnage. The designs have been based on the use of various disc screening systems to separate fibres and containers as well as to further process these materials. A conceptual process layout drawing was prepared for each MRF size so as to assist in selecting the type and size of each piece of equipment to be used.

It is recognized that there many different layouts as well as many other types of processing equipment (e.g. trommel screens) that can be used to accomplish the same processing functions. Although the layout details and how the process is done may change, the important issue is that the total capital cost is representative for the input mixture and quantity. Experience has shown that regardless of the approach taken, the designs offered by MRF equipment suppliers result in similar total capital costs.

In the accompanying MRF models, the user is not able to select MRF equipment - the process has been designed and costed for the size and type of system selected. Details are shown to indicate what has been included in the process design and the summary cost for each component of the processing system. A schematic process flow for the single stream MRFs is shown in Figure 6.1.

The model has been designed so that some individual pieces of equipment (e.g. bag breaker) are included and costed according to the system selected. For instance, two bag breakers are shown for this size of MRF when the bagged systems A or B are selected in Cell B4.
In a similar manner, glass sorting conveyors, etc. are included when glass is a designated part of the co-mingled recyclables (System A and C) but not included when Systems B and D are selected.
Figure 6.1: Processing Schematic – Single Stream Co-mingled MRF

In-feed conveyor

Inclined conveyor

Pre-sort Cabin

OCC Screen

Fines Screen

Screen (2)

“Unders”

Screen

Mixed paper

News & pams

“Separation”

Containers

Air classifier

OH Magnet

Flattener

Plastics sorting

Eddy Current

Natural PET

Col PET

Natural HDPE

Col HDPE

Alum cans

Fe

Residue

Mixed Glass

Residue

Film plastic (baler if bagged)

Non-recyclables (residue to compactor)
The user has the ability to update equipment capital costs by including an appropriate inflation index in Cell I66.

The equipment prices used in the models are indexed to November 2005 when they were obtained. The user can select what they feel is the most appropriate index (e.g. RPI or Baxter’s) to represent capital costs increases.

**Mobile Plant and Other Equipment**

The user can select the type (Cells H161-165), capital cost (Cells K161-165) and number of individual pieces of mobile plant, roll-off containers and weighbridge equipment (Cells A161-165) that will be required to operate the MRF.

Representative costs and the number of pieces of equipment required have been included here for illustration. These requirements have been scaled back for the smaller MRFs (50, 25 and 10) according to the design and the tonnages to be handled. The user can select to use this if no other

---

**Systems B&D (no glass)**

- **Glass Line:**
  - Air Classifier
  - Light transfer conv
  - Sorting conveyor
  - Glass transfer conveyor
  - Transfer conveyor (1)
  - Broken Glass Loadout
  - Glass cleanup equipment

**Systems A&C (with glass)**

- **Glass Line:**
  - Air Classifier
  - Light transfer conv
  - Sorting conveyor
  - Glass transfer conveyor
  - Transfer conveyor (1)
  - Broken Glass Loadout
  - Glass cleanup equipment

The user has the ability to update equipment capital costs by including an appropriate inflation index in Cell I66.
data are available (the costs automatically increase with inflation as per the inflation factor selected) or more appropriate data can be substituted as necessary.

**Other Related Costs**

The cost of other related items, such as steel for platforms, equipment supports, stairs, etc. electrical instrumentation and controls, storage bunkers, etc. are itemized here. In most cases, these are shown as a percentage of the equipment capital costs as itemized on the “Assumptions” spreadsheet. A provisional sum is shown for “Start-up and Testing”.

<table>
<thead>
<tr>
<th>Other Related Costs</th>
<th>15% of subtotal</th>
<th>£323,995</th>
<th>£41,307</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platforms, Chutes &amp; Hoppers</td>
<td>15%</td>
<td>£323,995</td>
<td>£41,307</td>
</tr>
<tr>
<td>Weighbridge &amp; house</td>
<td>1</td>
<td>£655,000</td>
<td>£81,619</td>
</tr>
<tr>
<td>Elec., Inst. &amp; Controls</td>
<td>15%</td>
<td>£246,200</td>
<td>£31,470</td>
</tr>
<tr>
<td>Glass bunkers</td>
<td>3</td>
<td>£3,000</td>
<td>£1,196</td>
</tr>
<tr>
<td>Equipment - Shipping</td>
<td>10%</td>
<td>£204,400</td>
<td>£27,181</td>
</tr>
<tr>
<td>Equipment - Installation</td>
<td>20%</td>
<td>£431,800</td>
<td>£56,533</td>
</tr>
<tr>
<td>Start-Up and Acceptance Test</td>
<td>6 Weeks</td>
<td>£80,000</td>
<td>£7,770</td>
</tr>
</tbody>
</table>

This cost is very specific to the requirements that a local authority requests in a tender and the degree of complexity of the MRF design. Typically, “Start-up and Testing” is comprised of three phases:

1. **Equipment Startup** - operation of the equipment without material for 6 hrs for 2 consecutive days to test equipment speeds, motor current and voltage, etc. and all control functions

2. **Initial Operation** - 3 consecutive days with material, to demonstrate that the equipment is capable of “processing” the specified materials at the specified feed rates without overloads, trip outs, spillage, etc., and

3. **Acceptance Test** - 5 consecutive days with material to check throughput, recovery rates, staffing levels and product specifications.

Estimates for the duration and costs of this item have been included for each MRF design. Users are free to substitute their own cost estimates related to their own requirements as necessary.
Equipment Cost Summary

Equipment and related costs are then summarized for each processing component:

<table>
<thead>
<tr>
<th>Equipment Cost Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Inv/Feed/Presst:</td>
</tr>
<tr>
<td>Separation:</td>
</tr>
<tr>
<td>Fiber Line:</td>
</tr>
<tr>
<td>Mixed Container Lines:</td>
</tr>
<tr>
<td>Rolling Stock:</td>
</tr>
<tr>
<td>Other Related Costs:</td>
</tr>
<tr>
<td>Contingency:</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

**TOTAL EQUIPMENT COST:** £1,407,294  £501,125

**D. Building costs**

Building requirements are comprised of four components:
1. receiving area (tipping floor)
2. processing area
3. material storage and shipping, and
4. administration area (offices, staff areas, toilets, etc.).

**Receiving Area**

Receiving area storage requirements are calculated using the selected incoming material *tonnages* (automatic when selecting the MRF type in cell B4), the *densities* of the individual materials, selected *average height* of the stored materials on the tipping floor and the minimum *number of days of storage* required in the receiving area. The user can input densities, average storage height and the number of days required storage in the "Assumptions" spreadsheet.

**Minimum Storage Capacity**

MRFs designed to process household dry recyclables typically receive these materials during the daytime hours corresponding to local authority collection schedules. Even when MRFs operate one shift per day, additional material is required on the tipping floor to allow early morning processing to continue until collection vehicles arrive. More and more storage capacity is required to
accommodate operating hours that are extended beyond those in a single shift. For a two shift operation (the design premise of the MRFs in the Costing Model), it has been assumed that 2 day’s storage capacity is required.

The user has the option of selecting both the operating conditions at the MRF and the receiving area design storage capacity. In addition, a peaking factor has been included in the calculation for receiving capacity to allow for peak seasonal flow of incoming material. The peaking factor in the model has initially been set at 0% in the “Assumption” spreadsheet (cell B14). Tipping floor storage capacity can be reduced if delivery of a steady supply of recyclables can be assured (transfer from other local authorities).

Material Densities

Estimates of loose densities for all materials included in the incoming dry recyclables mix are outlined in Column “D” of the “Assumptions” sheet. These values have been taken from a variety of information sources including in-situ measurements and published density data and the values used in the KAT model. The user has the ability to substitute values for any of these density estimates. Incoming tonnages are converted to volume estimates in the receiving area calculation using the selected densities.

Average Material Height (on the tipping floor)

Collection vehicles delivering recyclables to the MRF off-load onto the tipping floor. A loading shovel then either moves the material to a “quiet” storage area of the tipping floor, or directs the recyclables onto the initial feed conveyor for processing. To maximize storage capacity, recyclables can be stored against properly-designed push walls (often side wall of the building). Calculation of the required tipping floor area takes into account an average height of recyclables stored on the tipping floor (cell B16 – “Assumptions” sheet). Designation of this average height must take into consideration how much of the recyclables are to be stored on the open floor as opposed to against push walls. An average 2 metres has been selected as the default height in the model, recognizing that this will result in a conservative (i.e. larger) area calculation. By selecting a conservative approach, additional tipping floor space will be provided to allow for vehicle unloading and wheeled loader manoeuvring.
Bale Storage Area

Calculations in this section of the model identify:

- baling requirements (which materials require baling and the resulting baling throughput capacity)
- the average number of bales produced each day
- the average number of bale shipping vehicles required per day, and
- the floor space required to store bales for shipping.

The user is able to select which materials are to be baled by indicating “v” in Column B for the appropriate material as indicated below.

<table>
<thead>
<tr>
<th>Designate “v” if Baling Req’d</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bale Storage Area:</strong></td>
</tr>
<tr>
<td>Material</td>
</tr>
<tr>
<td>News &amp; Paper</td>
</tr>
<tr>
<td>Magazines</td>
</tr>
<tr>
<td>Directories</td>
</tr>
<tr>
<td>MVR</td>
</tr>
<tr>
<td>ODB</td>
</tr>
<tr>
<td>OCC</td>
</tr>
<tr>
<td>Liquid Cartons</td>
</tr>
<tr>
<td>Other Paper</td>
</tr>
</tbody>
</table>

This information is used to determine the required baling throughput (tonnes/hr) for fibre and containers and hence the baler(s) to be used in the MRF. The selected baler specification(s) is then used to determine average bale size and weight.

| Bale length (m) = | 1.550 |
| Bale width (m)  = | 1.125 |

Although the calculation in the model assumes a common bale size for each type of material, some balers permit variations in bale length. If this is the case, and the user wishes for the model to be more exact, adjustments will be required in the calculation in Column “G” for individual materials.

The type of vehicle used to transport bales to market and the number of bales per vehicle is identified in Columns “J” and “K”, respectively. The number of bales required (based on the number of loads required for storage selected in Cell B16 – “Assumptions” sheet) and the resulting floor area required (based on how high bales can be stored, as selected in Cell B15 – “Assumptions” sheet) are then identified. The user can modify these details as desired.
Approximate Processing Area

The area required for processing is very specific to the equipment selected and the layout of the process. To assist in determining the processing area required for each MRF, a variety of operating MRFs were reviewed to identify their processing areas. These areas are listed in the table at Cell P275 and were plotted in the accompanying graph. The trendline on this graph was then used to determine the appropriate processing area required for the MRF sizes in this study. These areas are automatically entered in Cell D274. The user is free to designate an alternative area in this cell, or to use the default area shown.

Staff and Administration Area

An allowance has been made in each MRF design for a staff administration area. Typically, this would include offices, a reception area, a meeting room, toilets, change rooms and a staff lunchroom. In some of the larger MRFs, additional space is also provided for an education and training room. The default space allowance in the cost model should be reviewed by the user and adjusted as necessary based on the particular requirements of the user.

E. Labour costs

The next component of the model determines labour required in the process for sorting recyclables. The user identifies where positive sorting of a material is required by entering a “v” beside the material in Column C as illustrated below:

<table>
<thead>
<tr>
<th>Material</th>
<th>Tonnage/day</th>
<th>Sort Required</th>
<th>Sorting Rate (kg/hr)</th>
<th>Theoretical Sorters/day</th>
<th>Actual Sorters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bag Breaking &amp; film removal</td>
<td>170.0</td>
<td>v</td>
<td>4000</td>
<td>5.1</td>
<td>7</td>
</tr>
<tr>
<td>OCC</td>
<td>0.7</td>
<td>v</td>
<td>360</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>Residue</td>
<td>1.1</td>
<td>v</td>
<td>270</td>
<td>0.6</td>
<td>1</td>
</tr>
<tr>
<td><strong>Sub-total pre-sort</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>6.9</strong></td>
<td><strong>8</strong></td>
</tr>
</tbody>
</table>

12 “positive” sorting refers to a material being removed from a sorting conveyor (usually manually), whereas a negative sorted material refers to material left to fall off the end of a sorting conveyor.
Sorting Rates

Based on the quantity of material to be sorted and the sorting rate identified in the “Assumptions” spreadsheet, the theoretical number of sorters is determined (in Column E). The manual sorting rates have been compiled from personal observations in a variety of MRFs and from published industry sources. These rates are meant to be representative of average sorting rates, recognizing that sorting rates at a given MRF are very dependent on a number of variables, including the speed of the sorting conveyor, the depth of the material on the conveyor, the design of the sorting station (position of chutes, height of the conveyor, etc.) and the sorting ability of the sorters themselves. The user has the ability to substitute alternate sorting rates in the “Assumptions” spreadsheet.

Manual Selection of Sorter Requirements

The calculation of sorter requirements in Column E identifies portions of sorters required for each material (e.g. 6.1, 0.3, etc.). The user must select the number of full time equivalent (FTE) sorters required (in columns “F” and “L”), considering the fractional sorters calculated and the material being sorted. For instance, in the example shown above in the pre-sort cabin, 7 sorters have been conservatively selected for film removal, where 6.1 were shown as required. For OCC and residue (0.3 and 0.6 sorters, respectively), 1 FTE sorter is selected, assuming that sorter will be responsible for removal of both of those materials. In a similar manner, the user is required to review each of the theoretical sorter requirements and to manually select the number of sorters to be included. The model uses the manual FTE designations in columns “F” and “L” for all subsequent cost calculations.

Automated Calculations

A number of automated calculations are imbedded in the model where appropriate. For instance, the quantity of OCC requiring sorting in both the pre-sort and the fibre sort cabins varies, depending on whether an OCC screen is used in the selected processing equipment as illustrated in the schematic below:
Similarly, when the user selects a MRF with incoming bagged recyclables – if a bag breaker is included in the design, the manual sorting rate for plastic film in the pre-sort cabinet is automated to 4000 kg/sorter/hr, but is 2500 kg/sorter/hr if no bag breaker is used (the lower rate takes into account that the sorter is required to break bags as well as remove the film). Also, when bagged recyclables are selected, the pre-sort conveyors and cabinet are automatically made larger to accommodate the additional sorters required to remove film plastic.

Similar automated calculations are included for glass. When glass is selected in the incoming recyclables, provisions are automatically made for additional processing equipment as required for such as an air classifier, fines screen, sorting conveyors, etc. Also, as indicated below, for the 2 stream MRFs, Cell C308 automatically indicates with a “v” that manual sorting is required when glass is included.

Notes are included in the individual cells where these automatic calculations are included (e.g. B289 and B290) to highlight the assumptions to the user.
Single Shift and Double Shift

The left side of the table shows sorter requirements for a single shift operation, while the right side shows sorter requirements for a two shift operation. It should be pointed out that because of economies of scale, sorter requirements do not exactly double for the two shift system.

Labour Summary

Below the sorter table, a summary of all labour requirements is presented. The number of sorters and the number of operators for mobile plant (loaders, forklifts, etc.) previously selected are automatically carried down to this summary. The user can now select the number of other staff required to operate the MRF as highlighted in the yellow shaded cells illustrated below.

<table>
<thead>
<tr>
<th>Summary</th>
<th>Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Manager</td>
<td>1</td>
</tr>
<tr>
<td>Foreman</td>
<td>1</td>
</tr>
<tr>
<td>Elder Operators</td>
<td>1</td>
</tr>
<tr>
<td>Vehicle Operators</td>
<td>4</td>
</tr>
<tr>
<td>Pressed</td>
<td>1</td>
</tr>
<tr>
<td>Fibre sorters</td>
<td>13</td>
</tr>
<tr>
<td>Container Sorters</td>
<td>12</td>
</tr>
<tr>
<td>Labourer</td>
<td>2</td>
</tr>
<tr>
<td>Equipment Maintenance</td>
<td>1</td>
</tr>
<tr>
<td>Weigh Scale Op</td>
<td>1</td>
</tr>
<tr>
<td>Admin &amp; Clerical</td>
<td>1</td>
</tr>
<tr>
<td>Benefits</td>
<td></td>
</tr>
</tbody>
</table>

These cells include managers, labourers, administration staff, etc. Benefits (annual leave, insurance, etc.) are included for all staff, at the rate selected in the “Assumptions” spreadsheet.

F. Variable operating costs

A number of additional costs are associated with operating a MRF. Most of these vary according to the MRF throughput but some are fixed. These are discussed below.
Baling Wire

Baling wire cost is calculated based on those materials selected for baling (described on page 21) and an average cost of £2.50/tonne baled, as indicated in the “Assumptions” spreadsheet.

Very often, materials such as plastic will require more bale wire per bale than a material like card (OCC). The cost of baling wire is a function of the number of bales produced, the size of the bale, the number of ties used per bale, and the type of wire (thickness or “gauge”) used. The cost of baling wire used as a default in the model is meant to represent an average cost per bale, taking into account all of these factors. The user can substitute a more appropriate cost if one is available.

Residue Disposal

The cost of disposing of residue generated from the MRF is calculated using the tipping fee selected in the “Assumptions” spreadsheet and the annual tonnes requiring disposal. The disposal cost should include the tipping fee at the disposal site as well as the cost of transport to that site. The tonnage of residue requiring disposal is calculated and discussed in Section H “Estimated Revenues and Residue”.

Fuel and Oil

This item accounts for operation of the various forklifts, loading shovels, etc. selected. The costs shown are provisional allowances and can be modified as necessary to correspond to the equipment selected.
Utilities

Electrical consumption is the largest utility cost incurred in MRF operations. The use of water and natural gas is minimal. The majority of electrical consumption is used to power the processing equipment and can be estimated based on the horsepower of the selected equipment and the load utilization factor. An allowance for annual kWh usage for each size of MRF has been provided in cell B354. This is multiplied by the cost of electricity (£0.075/kWh) as identified in the “Assumptions” spreadsheet.

Insurance and Taxes

A provisional sum has been included in cell D355 for the cost of site insurance and taxes.

Spare Parts

An inventory of spare parts most frequently required to maintain or repair processing equipment is normally stored in the MRF. Experience has shown that these parts represent about 2% of the capital cost of the processing equipment. This percentage is identified in cell B80 of the “Assumptions” sheets.

Security

The user has an opportunity to include the cost of any site security in the annual operating cost by entering this cost estimate in cell D357. If the MRF is to be sited on a property where security is already provided, or if security is deemed unnecessary, this item can be disregarded.

Office

An allowance is provided in cell D358 for miscellaneous supplies such as stationary, safety equipment, etc.
Equipment Maintenance

The annual cost of maintenance, expressed as a percentage of the capital cost of the processing equipment, is itemized in Cell B81 of the “Assumptions” spreadsheet. This estimate (4%) is increased by 2% if glass is included, to account for additional maintenance and earlier replacement of glass-handling conveyor belts.

Business Tax

A space is included to add the cost of business tax, if this is appropriate to the MRF under consideration. This cost has not been included in the models shown.

G. Summary – gross costs

Each of the major component costs are summarized here, to as to show the total capital and annual costs (capital and operating) as well as the gross costs per tonne.

H. Estimated revenues and residue

This section compiles estimates of revenues gained from the recyclables to be marketed and identifies the tonnage of material to be sent for disposal.

Residue

Recovery rates for the targeted recyclables identified in the “Assumptions” spreadsheet are used to calculate the quantity of each recyclable to be marketed. The remaining tonnage (comprised of recyclables not recovered and non-recyclables that are in with the recyclables delivered to the MRF) is identified as residue. Residue is highlighted for both fibre and the containers and then averaged for all of the incoming material. With the default values used in these models, residue is 14-18% for the single stream MRFs and 7-8% for the 2 stream MRFs.
Revenues

Individual prices entered in the “Assumptions” spreadsheet for materials marketed are listed in Column F. These are prices paid at the market or reprocessor. Users need to identify the cost of shipping each recyclables material to the market selected and enter this value (expressed as £/tonne) for each material in Column G. Sales prices for materials will vary according to how the material is prepared. For instance, prices will differ if fibre is delivered to the market loose or baled, or if aluminium is flattened or baled.

Users need to check market specifications and prices with markets under consideration to assess the economics of marketing the recyclables in alternate forms. If baled news and PAMs has been selected (as described in Section D “Bale Storage Area”), the corresponding market price and shipping cost for baled news and PAMs needs to be entered in Columns “F” and “G”, respectively. If it is decided not to bale news and PAMs and to send this material loose to market, the appropriate market price needs to be entered in Columns “F” and “G”. The model as designed does not take into account a portion of news and PAMs being baled and a portion sent loose to market. The user will need to perform a manual calculation to identify the associated revenue for this option.

In some instances, depending on the arrangement that a MRF operator may negotiate with the market, the price paid for a material may be at the MRF (i.e. no shipping cost). In these cases, the user should either enter zero (“0”) for the shipping cost or leave the cells blank.

Net revenues take into account projected revenue from the sale of recyclables. These are also expressed per tonne of material delivered and per tonne of material marketed.

I. Summary of Costs

At the bottom of each MRF model, costs and key operating details are summarized for use in the “Summary Cost” spreadsheet in both the SSMRFs.xls and 2Stream MRFs.xls workbooks. This spreadsheet presents a comparison of this information for each MRF size.

In addition, the spreadsheet entitled “Graph” in each workbook plots both the gross and net costs for each of the four MRF models, for MRFs operating at full capacity (2 shifts) and at 50% capacity (1 shift).
When comparing costs for each of the four MRF sizes on either the “Summary Cost” or “Graph” spreadsheets, the user must be careful to ensure that the same type of MRF conditions are selected for each of the four MRFs. For instance, if comparing single stream co-mingled MRFs, all MRFs must be operating on the same incoming composition (either “A”, “B”, “C”, or “D”). Also, users must make sure to manually confirm the number of FTE sorters each time a change is made to the MRF design or operation.
7. 2-Stream MRF model

Components of the 2-stream MRF costing model were developed in the same manner as the single stream MRF model. A schematic of the process flow for the 2-stream system is shown in Figure 7.1.

**Figure 7.1: Processing Schematic for 2-Stream MRF**
Each of the two streams (containers and fibres) has their own separate tipping floors and in-feed conveyor lines. Since screens are used in the larger MRF models, pre-sort facilities are incorporated. In the smaller MRFs, pre-sorting is done as the first step in sorting fibre.

Two balers are provided in the larger MRFs, with separate conveyor feeds to each baler. In the smaller MRFs, a single baler feed conveyor system is used to feed a single baler. As for the single stream designs, a baler bypass is provided to allow for shipping news and PAMs loose to market.

As previously discussed, when glass is included with the incoming recyclables, provisions for sorting clear glass have been included in the MRF design. Revenue for glass assumes that all other glass is marketed as mixed broken glass.
8. Sample model applications

The primary intent of the MRF models is to provide local authorities with a costing tool that can be used in conjunction with the KAT collection model to evaluate various options for collecting and processing recyclables. By using the model for a MRF of a particular design capacity, the user is able to identify:

- the costs of a 2-stream and single stream co-mingled processing system
- the cost of adding glass to the incoming recyclables streams
- the additional costs associated with processing bagged recyclables at a single stream co-mingled MRF.

Each of these can be investigated under a wide range of operating parameters and several material marketing options.

8.1 The Cost of Processing Bagged Recyclables

The following example is provided to show how a user might use the MRF model to identify the additional cost of processing bagged recyclables. This example will look at a 25,000 tpa single stream co-mingled MRF without glass for the bagged and loose options (“B” and “D” respectively in Cell B4 of the 25,000 MRF model).

The following table summarizes net costs for each of the two systems:

<table>
<thead>
<tr>
<th>Incoming Stream</th>
<th>Single Shift (£/tonne)</th>
<th>Two Shifts (£/tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagged (B)</td>
<td>£59</td>
<td>£31</td>
</tr>
<tr>
<td>Loose (D)</td>
<td>£52</td>
<td>£26</td>
</tr>
<tr>
<td>Difference</td>
<td>£7</td>
<td>£5</td>
</tr>
</tbody>
</table>

The bagged MRF requires a bag breaker, additional pre-sorting for the plastic film, a longer pre-sort conveyor and sorting cabin and a dedicated film baler. On average, the additional cost of processing plastic bags in a MRF of this size from a bagged recycling collection programme is between £5-7/tonne of incoming recyclables, depending on the quantity processed and the operating conditions.
8.2 The Cost of Processing Glass

The model can also be used to identify the processing cost of including glass in the incoming mix of recyclables to be processed. For an 85,000 tpa 2-Stream MRF, the following costs result for a glass in ("E") and glass out ("F") scenario:

Table 8.2: Net Processing Cost - 85,000 tpa 2-Stream MRF

<table>
<thead>
<tr>
<th>Incoming Stream</th>
<th>Single Shift (£/tonne)</th>
<th>Two Shifts (£/tonne)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass in (E)</td>
<td>£8</td>
<td>-£4</td>
</tr>
<tr>
<td>Glass out (F)</td>
<td>£1</td>
<td>-£10</td>
</tr>
<tr>
<td>Difference</td>
<td>£7</td>
<td>£6</td>
</tr>
</tbody>
</table>

* in this model, negative costs (e.g. -£3/tonne) indicate a net revenue

The net cost of processing glass ranges between £7 and £6/tonne of incoming recyclables processed. The model shows that for a single shift operation, the net cost of processing glass is about £7/tonne, while for a 2 shift operation, there is a net revenue difference of about £6/tonne.

The user should recognise that each of the MRF models use the incoming tonnages identified in the "Composition" worksheet. If glass is included in the mixture, as in systems “A”, “C” and “E”, then the percentage composition of each of the other component materials changes. For instance, when glass is included in system “A” the percentage of news and PAMs is 20.5%. When glass is not included (system “B”) the percentage of news and PAMs increases to 24.6% of the overall mixture. This has a bearing on the models since the number of sorters, material sales revenues, etc. fluctuate according to the quantity of each component material. In this example, if glass is in the mixture, the revenue for paper, plastics and other materials falls since the incoming tonnages of these materials are lower.

By using the model to identify the net cost of processing glass at the MRF, the user can weigh the additional processing cost against the additional cost of collecting glass in a segregated form.
8.3 Co-mingled Single Stream vs 2-Stream Processing

In addition to the two MRF Excel workbooks, there is a worksheet with the title “Summary Cost Graph.xls”. This contains summary graphs of the gross and net costs of the Single Stream and the 2-Stream MRFs. When using this worksheet, users must ensure that:

- all three workbooks are opened at the same time, and
- all MRFs in each of the cost models are set up to evaluate the same system e.g. single stream with glass (“C”) to compare with 2-stream with glass (“E”).

The net MRF Cost graph shows that the cost of processing for a single stream MRF (with glass) exceeds that of a 2-stream MRF from about £7/tonne (for a 85,000 tpa MRF) to £22/tonne (for a 10,000 tpa MRF), both operating at 100% capacity.

8.4 Optical Sorting

More and more of today’s modern MRFs are incorporating optical sorting technology to replace manual sorting, primarily for paper, plastics and glass. Although this technology for sorting recyclables is relatively new to the UK and North America, it has been used in Europe since the early 1990’s.

Typically, containers are flattened (to reduce rolling) and directed onto a high-speed acceleration conveyor that is required to spread material out and to reduce the burden depth on the belt. Ideally, as the material passes under the sensors, there should be separation between each object on the conveyor belt. This separation allows for accurate identification of the material type and also reduces the possibility of unwanted material being ejected together with the target materials.

Identification of a container type on the conveyor is typically determined using the near infrared (NIR) part of the electromagnetic spectrum. Each material absorbs and reflects different amounts of specific frequencies of the near infrared spectrum and by analyzing the reflected spectrum, the type of plastic can be determined.

A number of NIR sensors arranged across the width of the machine above the belt analyse the light reflected from the part of the belt immediately below it. Each object on the conveyor is identified based on its position and as the targeted materials reach the end of the conveyor, they are selectively removed from the material flow using directed and controlled compressed air impulses.
These sensors generally allow removal of 90-95% of the targeted materials from the mixture (known as the “hit rate”), but in doing so, also include a certain portion of other non-targeted materials. The quantity of the targeted materials in the ejected stream is described by its “purity”. Most sensors are capable of producing a purity rate of 85-90% meaning that 10-15% of the ejected material is non-targeted material. In most instances, this level of contamination in the ejected product means that some degree of manual quality control sorting is required before the material is shipped to market.

There are a number of well known manufacturers of this equipment with a track record in MRF sorting applications (MSS, Pellenc, TiTech, Binder). The optical sorters and related equipment are relatively expensive and their use is therefore often easier to justify in larger MRF applications. Optical sorting equipment has not been included in these MRF models because of the difficulty of incorporating the wide variety of applications into the model formulae. However, an example of how to evaluate the economics of such an application is presented below.

Optical sorting of Plastics

The following is an example using system “D” (Single Stream without glass) for the 85,000 tpa single stream co-mingled MRF. The following are the manual sorting requirements for plastics at full throughput capacity (2 shifts):

<table>
<thead>
<tr>
<th>Material</th>
<th>Theoretical Sorters/day</th>
<th>Actual Sorters/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>PET natural</td>
<td>2.6</td>
<td>3</td>
</tr>
<tr>
<td>PET coloured</td>
<td>2.0</td>
<td>2</td>
</tr>
<tr>
<td>HDPE natural</td>
<td>3.6</td>
<td>4</td>
</tr>
<tr>
<td>HDPE coloured</td>
<td>2.1</td>
<td>3</td>
</tr>
<tr>
<td>PVC</td>
<td>1.1</td>
<td>2</td>
</tr>
<tr>
<td>Other bottles</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

Since the greatest number of sorters are required for natural PET (3) and natural HDPE (4), it is assumed that a dual eject optical sorter will be evaluated to eject these resins. A schematic of this system follows and Table 8.3 summarises representative costs for the sorting equipment for this application.

---

13 A maximum of two ejected plastic streams is possible with a single optical sorter. More resin separations would require more optical sorters.
Table 8.3: Approximate Capital Cost of Optical Sorting Equipment

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual eject optical sorter</td>
<td>£150,000</td>
</tr>
<tr>
<td>Accelerator conveyor, flattener, conveyors</td>
<td>£100,000</td>
</tr>
<tr>
<td>Associated platforms, supports, conveyors</td>
<td>£50,000</td>
</tr>
<tr>
<td><strong>Sub total</strong></td>
<td><strong>£300,000</strong></td>
</tr>
<tr>
<td>Electrical and Mechanical, freight, installation</td>
<td>£150,000</td>
</tr>
<tr>
<td>Contingency (10%)</td>
<td>£45,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>£495,000</strong></td>
</tr>
<tr>
<td><strong>Say</strong></td>
<td><strong>£500,000</strong></td>
</tr>
</tbody>
</table>

Both of the ejected plastic streams will require a minimum of 1 sorter for quality control on each line. A comparison of the system cost of each alternative follows:

Table 8.4: Optical Sort vs Manual Sort Costs

<table>
<thead>
<tr>
<th>Manual Sort</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural PET (3 sorters @ £7 x 2000 hrs +27% OH) =</td>
<td>£53,340</td>
</tr>
<tr>
<td>Natural HDPE (4 sorters @ £7 x 2000 hrs +27% OH) =</td>
<td>£71,120</td>
</tr>
<tr>
<td><strong>Total Annual Cost</strong></td>
<td><strong>£124,460</strong></td>
</tr>
<tr>
<td>Optical Sort (£500,000 initial capital cost)</td>
<td></td>
</tr>
<tr>
<td>QC sorters (2 sorters @ £7 x 2000 hrs +27% OH) =</td>
<td>£35,560</td>
</tr>
<tr>
<td>Estimated annual maintenance =</td>
<td>£10,000</td>
</tr>
<tr>
<td><strong>Total Annual Cost</strong></td>
<td><strong>£45,560</strong></td>
</tr>
</tbody>
</table>
The annual cost of the manual sorting alternative is £124,460 per year. For the optical sort option, if the initial capital expenditure (£500,000) is realized in 2006, the additional annual operating cost thereafter is projected at £45,560\textsuperscript{14}. Figure 8.1 illustrates that the payback period (i.e. the number of years at which the cumulative costs of the systems are equal) for the optical sorter is less than 7 years.

**Figure 8.1: Optical Sort Pay-Back Period**

![Graph showing payback period for manual and optical sorting](image-url)

In 2012, the cumulative cost of optically sorting two plastic resins approaches the cumulative cost of the seven manual sorters. Aside from the cost, there may be other reasons to replace sorters with automated equipment. These include difficulties in recruiting competent staff, periodic absenteeism, the cost of training and supervision, etc.

\textsuperscript{14} This does not include incremental costs for compressed air and power
9. Summary

Although the intent of the MRF Costing Model is to provide the user with a tool to identify representative costs for a variety of MRF sizes and processing options, there are a number of general observations that can be drawn from using the model:

1. The cost curves for both the single stream co-mingled and the 2-stream MRFs rise dramatically at lower tonnages and flatten out at higher tonnages with little further reduction in processing cost per tonne once over around 90,000tpa capacity has been reached.

   ![Cost Curves](image)

   This demonstrates there are economies of scale to be realized by processing more recyclables at larger MRFs.

2. There is an economic advantage to processing as much tonnage as possible at a MRF. As shown in the sample chart above, the lowest cost curve for any particular MRF is that produced when the MRF is operating at full design capacity. Any reduction in throughput tonnage below that level increases the unit cost of processing. The chart above shows the impact of operating at 50% capacity (i.e. 1 shift as opposed to 2 shifts).

3. The Costing Model shows that processing costs at a single stream co-mingled MRF are higher than those at the same capacity 2-stream MRF. The additional gross cost ranges from £6/tonne (at 85,000 tpa) to £23/tonne (at 10,000 tpa).
4 The cost of processing bagged recyclables at a MRF is higher than processing loose recyclables and ranges from a low of £5/tonne (at 85,000 tpa, full capacity) to £13/tonne (at 10,000 tpa, 50% capacity).

5 With the assumptions used in the Costing Models, processing glass at full capacity, single stream co-mingled MRFs adds from £6 to £10/tonne to the processing cost and from £5/tonne to £10/tonne at full capacity, 2-stream MRFs.
Appendix A

Background composition data
## Defra Waste Audits

### Waste Composition Analysis - Guidance for Local Authorities, 2004

#### Dr Julian Parfitt, Principal Analyst, WRAP

**Sample size:** 9 authorities in Wales

**Type of waste:** Household waste

### Waste Audits

<table>
<thead>
<tr>
<th>Material</th>
<th>Average % of total</th>
<th>Amount</th>
<th>Average participation rate</th>
<th>% of total</th>
<th>% of total recovered</th>
<th>kg/hh/yr</th>
<th>Average kg/hh/yr</th>
<th>% of total</th>
<th>% of total recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper and card</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stock</td>
<td>6.6%</td>
<td>4.16</td>
<td>40.00%</td>
<td>33.8%</td>
<td>21.8%</td>
<td>71</td>
<td>58</td>
<td>64%</td>
<td>3.3%</td>
</tr>
<tr>
<td>Fabrics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Furniture &amp; curtains</td>
<td></td>
<td>1.3%</td>
<td>80.00%</td>
<td>6.6%</td>
<td>6.6%</td>
<td>11</td>
<td>10</td>
<td>14%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Non-food packaging</td>
<td></td>
<td>5.5%</td>
<td>80.00%</td>
<td>8.6%</td>
<td>7.2%</td>
<td>51</td>
<td>15</td>
<td>29%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Plastic bags</td>
<td>2.7%</td>
<td>2.7%</td>
<td>80.00%</td>
<td>2.7%</td>
<td>2.7%</td>
<td>31</td>
<td>15</td>
<td>58%</td>
<td>2.1%</td>
</tr>
<tr>
<td>Cardboard</td>
<td>1.9%</td>
<td>1.9%</td>
<td>80.00%</td>
<td>1.9%</td>
<td>1.9%</td>
<td>7</td>
<td>4</td>
<td>52%</td>
<td>1.1%</td>
</tr>
<tr>
<td>Confidential film packaging</td>
<td>0.2%</td>
<td>0.2%</td>
<td>80.00%</td>
<td>0.2%</td>
<td>0.2%</td>
<td>3</td>
<td>2</td>
<td>66%</td>
<td>0.4%</td>
</tr>
<tr>
<td>Cardboard</td>
<td>0.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other packaging</td>
<td>0.5%</td>
<td>0.5%</td>
<td>80.00%</td>
<td>0.5%</td>
<td>0.5%</td>
<td>3</td>
<td>2</td>
<td>66%</td>
<td>0.4%</td>
</tr>
<tr>
<td>Bottle top</td>
<td>0.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Household paper</strong></td>
<td></td>
<td>5.8%</td>
<td>80.00%</td>
<td>5.8%</td>
<td>4.0%</td>
<td>28</td>
<td>27</td>
<td>97%</td>
<td>2.1%</td>
</tr>
<tr>
<td><strong>Plastic residue</strong></td>
<td></td>
<td>5.8%</td>
<td>80.00%</td>
<td>5.8%</td>
<td>4.0%</td>
<td>28</td>
<td>27</td>
<td>97%</td>
<td>2.1%</td>
</tr>
<tr>
<td><strong>Aluminium-based paper</strong></td>
<td></td>
<td>4.8%</td>
<td>80.00%</td>
<td>4.8%</td>
<td>4.8%</td>
<td>14</td>
<td>13</td>
<td>95%</td>
<td>1.4%</td>
</tr>
<tr>
<td><strong>Other non-ferrous</strong></td>
<td></td>
<td>5.8%</td>
<td>80.00%</td>
<td>5.8%</td>
<td>4.0%</td>
<td>28</td>
<td>27</td>
<td>97%</td>
<td>2.1%</td>
</tr>
<tr>
<td><strong>Glass</strong></td>
<td>0.0%</td>
<td>0.0%</td>
<td>80.00%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>1</td>
<td>1</td>
<td>7.1%</td>
<td>0.2%</td>
</tr>
<tr>
<td><strong>Plastic</strong></td>
<td>6.0%</td>
<td>6.0%</td>
<td>80.00%</td>
<td>6.0%</td>
<td>6.0%</td>
<td>42</td>
<td>11</td>
<td>63%</td>
<td>4.6%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>88.3%</td>
<td>99.8%</td>
<td>17.9%</td>
<td>100.0%</td>
<td>872</td>
<td>156</td>
<td>887</td>
<td>90</td>
<td>744</td>
</tr>
</tbody>
</table>

### Key Figures

- **Average kg/hh/yr:** 87.2 kg/hh/yr
- **Average recovery %:** 88.7%
- **Total kg/hh/yr:** 872 kg/hh/yr
- **Total recovery kg/hh/yr:** 744 kg/hh/yr
- **Total recovery %:** 88.7%

### Notes

- **Paper and card** includes paper, card, magazines, and other paper products.
- **Plastic residue** includes plastic bags, plastic film, and other plastic products.
- **Aluminium-based paper** includes aluminium and other aluminium-based materials.
- **Other non-ferrous** includes non-ferrous metals, non-ferrous metal, and other non-ferrous materials.
- **Glass** includes all glass, glass bottles, and glass jars.
- **Plastic** includes all plastics, plastic bottles, and plastic film.
- **Total** includes all materials, total kg/hh/yr, and total recovery %.