THE EFFECT OF INCREASED KERBSIDE PROVISION AND MATERIALS RECOVERY FACILITY DEVELOPMENT ON RECYCLING RATES IN A RURAL COMMUNITY

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Doctor of Philosophy

By

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SUMMARY

Traditionally, the UK has relied heavily on landfill as a means of dealing with its MSW, However, the UK waste management industry is undergoing a significant period of change as a result of legislative drivers implemented on an European level. The key driver is the Landfill Directive, which has set targets for the reduction of the quantity of biodegradable waste sent to landfill. This Directive has been implemented in Wales by the Landfill Allowance Scheme (LAS), which essentially sets each local authority an annual tonnage of Biodegradable Municipal Waste (BMW) which it can landfill. Failure to comply with the annual target can result in significant financial penalties which are set at £200 per tonne landfilled over the target. This driver coupled with the ever increasing landfill tax, which is set to increase by £8 per annum, is making alternatives to landfill become more economically viable.

As well as these statutory drivers, there are also non-statutory drivers. In Wales, the Welsh Assembly Government (WAG) issued the non-statutory requirement for local authorities to achieve 40% recycling and composting by 2009/10, with a minimum of 15% recycling and 15% composting. It has also been announced that post 2010, the targets are likely to increase rapidly, culminating in a 70% recycling and composting target by 2024/25.

This thesis uses a case study authority to investigate whether a Materials Recovery Facility (MRF) coupled with changes to its kerbside provision could assist the region to meet its LAS and WAG targets. Key aspects of the thesis include:

- a compositional analysis of household waste within the case study authority, to ascertain the quantities of material available for diversion via a dry recyclate and organics collection scheme;
- a review of a variety of different MRFs within the UK and overseas to determine best practice operations;
- the development of a MRF conceptual design based on the information obtained from compositional analysis and the process reviews conducted on other MRFs;
- the efficiency testing of the MRF commissioned within the case study authority to determine its performance and areas which could be improved; and,
- the modelling of various scenarios to determine what changes could be made to waste management practices so as to maximise the quantity of material diverted from landfill, and assist the authority to meet its LAS and WAG targets.

The compositional analysis study identified that the average household waste generation within the Case Study Authority was 14.9 kg/hh/wk, which was lower than the Welsh average figure of 17 kg/hh/wk. Participating households typically segregated 4.7 kg/hh/wk and 3.0 kg/hh/wk of dry recyclate and organic material respectively. It was also interesting to note that the compositional analysis established that the average BMW content within the Case Study Authority was 72%, which was significantly higher than the 61% used to define MSW for the LAS purposes.

An efficiency study carried out on the first phase of the MRF implementation highlighted that when processing a residual waste (black bag) stream 11.2% was recovered in the form of dry recyclate, and 27.7% in the form of a mechanically segregated fine organic stream (less than 50mm fraction). When processing a dry recyclate stream, the efficiency study identified that 95% of the material was recovered for recycling; however, two-thirds of this was in the form of a low grade paper product, which was sensitive to market changes.

The thesis highlights that a MRF has a significant role to play in an integrated solution for municipal waste management; however, it is clear that ultimately some form of thermal process will be required for the residual waste stream in order for local authorities to comply with the LAS targets.

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ACRONYMS/ ABBREVIATIONS

ABPR	Animal By-Products Regulations
ACORN	A Classification of Rural Neighbourhoods
AH	Additional Households
AWC	Alternative Weekly Collection
BHS	Bulk Handling Systems
BMW	Biodegradable Municipal Waste
BOD	Biochemical Oxygen Demand
CA Site	Civic Amenity Site
CIWM	Chartered Institution of Wastes Management
DEFRA	Department of the Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and Regions
DOE	Department of the Environment
DTI	Department of Trade and Industry
EC	European Commission
EEA	European Environment Agency
EPA90	Environmental Protection Act 1990
EU	European Union
EU-15	15 member states of the EU prior to enlargement in 2004
GDP	Gross Domestic Product
HDPE	High Density Polyethylene
HWRC	Household Waste Recycling Centres
IPI	International Paper Industries
kg	kilograms
kg/hh/wk	kilograms per household per week
LAS	Landfill Allowance Scheme
LATS	Landfill Allowance Trading Scheme
LAWDC	Local Authority Waste Disposal Company
LDPE	Low Density Polyethylene
MBP	Mechanical Biological Pre-treatment
MBT	Mechanical Biological Treatment
MRF	Materials Recovery Facility
MSW	Municipal Solid Waste
MSWSF	Mixed Solid Waste Sorting Facilities
NEWS	Norfolk Environmental Waste Services
O_A	% of MRF Streams Segregated by Automated Means
OECD	Organisation for Economic Cooperation and Development
PCV	Pedestrian Controlled Vehicle
PET	Polyethylene Terephthalate
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl Chloride

R	Recovery of Targeted Material
RCT	Rhondda Cynon Taff
RCV	Refuse Collection Vehicle
RDF	Refuse Derived Fuel
S	Weekly Set Out
SI	Statutory Instrument
T	tonnes
TOC	Total Organic Carbon
Tp	Throughput per picker
tph	tonnes per hour
TRecS	Total Recycling Systems
UK	United Kingdom
USA	United States of America
WAG	Welsh Assmbly Government
WCA	Waste Collection Authority
WDA	Waste Disposal Authority
Δ	Change

CHAPTER 1: Introduction

1.1 WHAT IS WASTE?

Waste can be defined simply as anything that is no longer needed that is thrown away. There are a number of legal definitions for waste, these include:

- the European Union (EU) defines waste as "an object the holder discards, intends to discard or is required to discard" is waste under the Waste Framework Directive (European Directive 75/442/EC as amended);
- the United Kingdom (UK) Environmental Protection Act 1990 (chapter 43) indicated waste includes "any substance which constitutes a scrap material, an effluent or other unwanted surplus arising from the application of any process or any substance or article which requires to be disposed of which has been broken, worn out, contaminated or otherwise spoiled; this is supplemented with anything which is discarded otherwise dealt with as if it were waste shall be presumed to be waste unless the contrary is proved;" (OPSI, 1990) and,
- the UK Waste Management Licensing Regulations 1994 define waste as "any substance or object which the producer or the person in possession of it, discards or intends or is required to discard but with exception of anything excluded from the scope of the Waste Directive" (OPSI, 1994).

The types of waste produced can be further classified, for example, in terms of the sector from which the waste is produced, for example municipal waste, industrial waste, construction and demolition waste, agricultural waste and so forth.

1.2 WASTE AND RECYCLABLE ARISINGS

1.2.1 Waste and Recyclable Management and Arisings in the EU

It is estimated that approximately 1.4 billion tonnes of waste are generated each year in the 15 member states of the EU (EU-15), these are the 15 members states in the period prior to enlargement in 2004, i.e. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom (Eurostat, 2005). Figure 1.1 shows the proportion of different wastes generated per sector in 2002 in the EU-15. This Figure highlights that the construction and manufacturing industries account for 58%, while municipal waste only accounts for 15% of the total waste arisings in the EU-15.

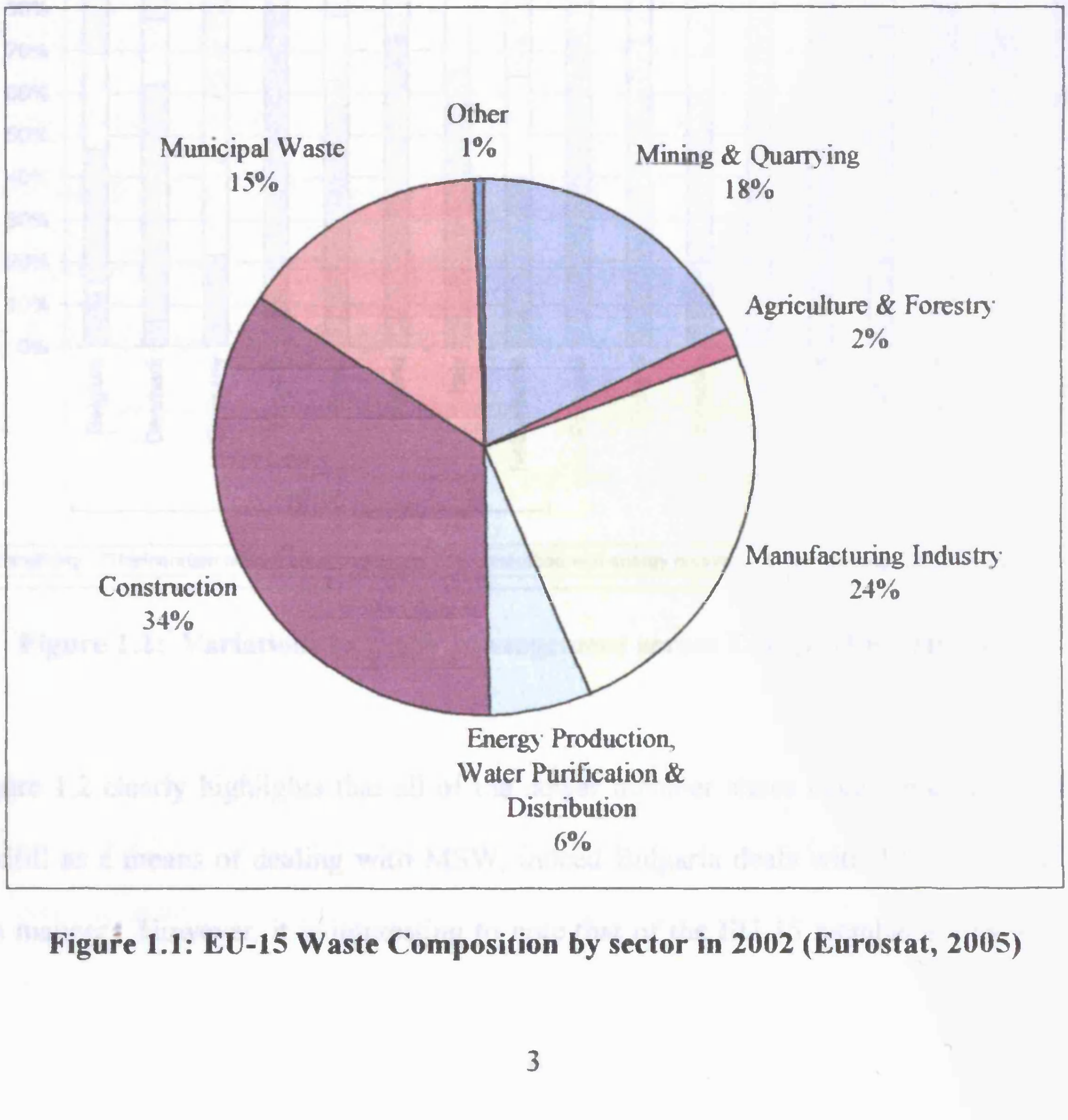


Figure 1.1: EU-15 Waste Composition by sector in 2002 (Eurostat, 2005)

It is estimated that each person in the EU generates approximately 534kg of Municipal Solid Waste (MSW) per annum (Eurostat 2005). Generation is higher in the EU-15 states however at 574 kg per person per annum, compared to the newer member states at 312 kg per person per annum (Eurostat 2005). The management of this waste varies greatly between member states, this is highlighted in Figure 1.2, which displays variations in MSW management across a selection of EU member states. It should be noted that the definition of MSW varies among member states, therefore only broad comparisons can be made between countries.

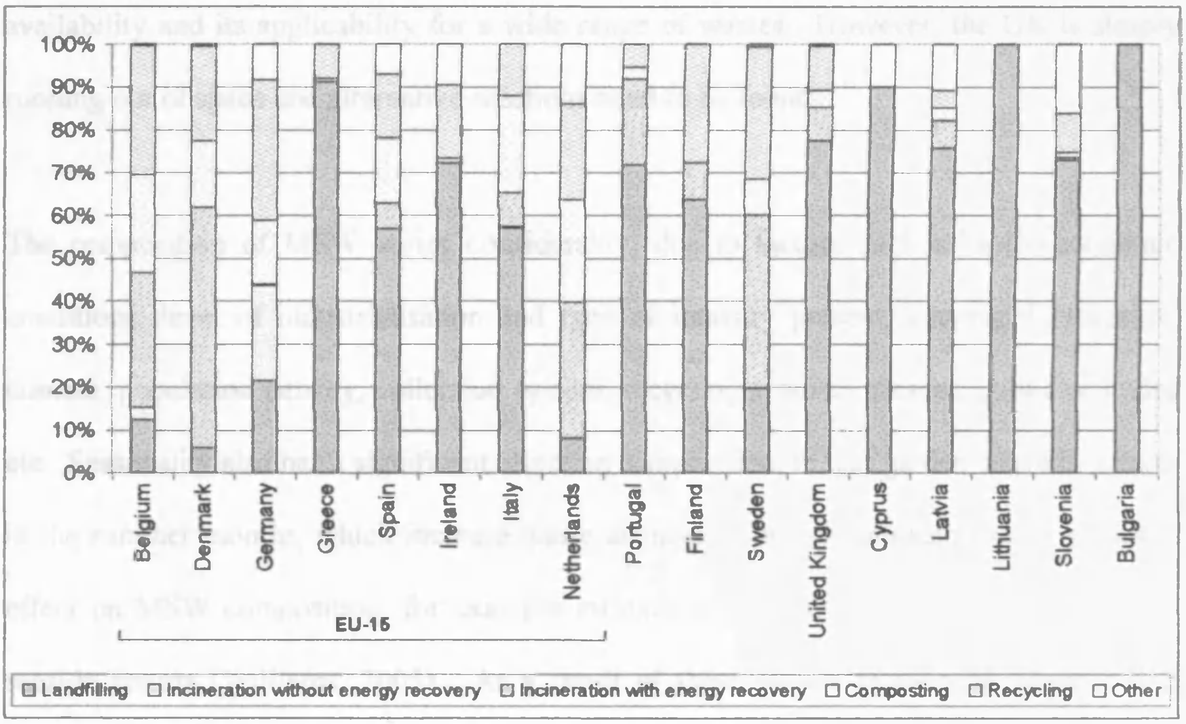


Figure 1.2: Variations in MSW Management across Europe (Eurostat, 2005)

Figure 1.2 clearly highlights that all of the newer member states have a high reliance on landfill as a means of dealing with MSW, indeed Bulgaria deals with 100% of MSW in this manner. However, it is interesting to note that of the EU-15 member states, Greece, Ireland, the United Kingdom, Italy, Portugal, Spain, and Finland dispose of more than 55% of their MSW to landfill, compared with Denmark, Belgium, the Netherlands, Sweden and Germany which dispose of less than 25% of MSW to landfill. In contrast to other member states, incineration is the main method of waste disposal in Denmark, with more than 50% of their MSW being treated in that manner. The Figure also highlights that Belgium composts or recycles the greatest proportion of its MSW stream, accounting for over 50%; closely followed by the Netherland and Germany which both recycle and compost over 45% of its MSW stream. It can also be seen that high recycling countries also have high incineration rates. The Figure also highlights the UK's reliance on landfill as over 75% of MSW is landfilled. This dependence in the UK has generally been due to low cost, availability and its applicability for a wide range of wastes. However, the UK is simply running out of space and alternative solutions need to be found.

The composition of MSW varies considerably, due to factors such as socio-economic conditions, level of industrialisation and type of industry present, geographic location, climate, population density, collection system, recycling systems present, public attitudes etc. Seasonality also has a significant effect on composition, in that garden waste is greater in the summer months, which increase waste arisings. Tourism can also have a seasonal effect on MSW composition, for example influxes of tourists in the summer months to seaside resorts (Williams, 2005). As a result of these effects along with lifestyle and cultural differences, MSW composition varies from country to country. Factors which affect waste composition are discussed further in section 2.2.

Figure 1.3 highlights the significant variation in MSW composition among a selection of EU member states. The organic fraction varies considerably across the member states, ranging from about 20% for the UK, Ireland and Finland, to 51% in Greece. Similarly the paper fraction ranges from 8% for Bulgaria to 43% in Finland. The Figure demonstrates that in the UK that over 50% of MSW consists of paper and organic material; the paper fraction represents the main component, representing approximately 32% of MSW, followed by the organic fraction which constitutes about 20% of MSW, with the plastic and other waste fractions contributing the bulk of material to the remaining MSW. In contrast, the MSW composition for the Netherlands highlights again the paper and organic material constitute the majority of the MSW stream, at approximately 68%; however, the organic fraction is double that of the UK at about 40%, and paper constitutes a lesser fraction, at about 28%.

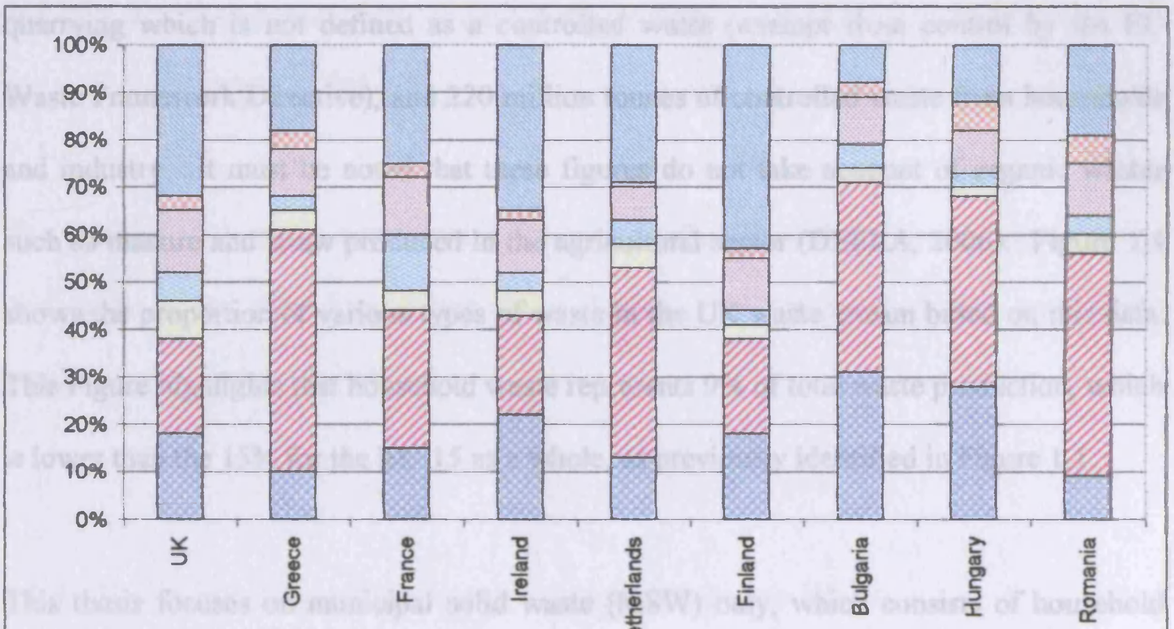


Figure 1.3: MSW Composition for a selection of European Countries (European Commission, 2003)

It is important to note that the definition of MSW varies between member states, which has an impact on compositional analysis undertaken, and therefore care must be taken when comparing member states. For example, in the UK waste from households accounts for 82% of MSW; however, in Ireland waste from households only accounts for 58%, and in Finland only accounts for 42% (Eurostat, 2005).

1.2.2 Waste and Recyclable Management and Arisings in the UK

It is estimated that in 2004 approximately 335 millions tonnes of waste was generated in the UK; these data includes 100 million tonnes of mineral waste from mining and quarrying which is not defined as a controlled waste (exempt from control by the EU Waste Framework Directive), and 220 million tonnes of controlled waste from households and industry. It must be noted that these figures do not take account of organic wastes such as manure and straw produced in the agricultural sector (DEFRA, 2006). Figure 1.4 shows the proportion of various types of waste in the UK waste stream based on this data. This Figure highlights that household waste represents 9% of total waste production, which is lower than the 15% for the EU-15 as a whole, as previously identified in Figure 1.1.

This thesis focuses on municipal solid waste (MSW) only, which consists of household waste and other wastes collected by a waste collection authority, for example commercial or industrial waste and waste from public parks. The UK produces approximately 35 million tonnes of MSW each year (DEFRA, 2007). Much of the MSW stream however may be reused, and therefore must be considered as a resource for industrial production or energy generation. Other types of waste are outside the scope of this thesis.

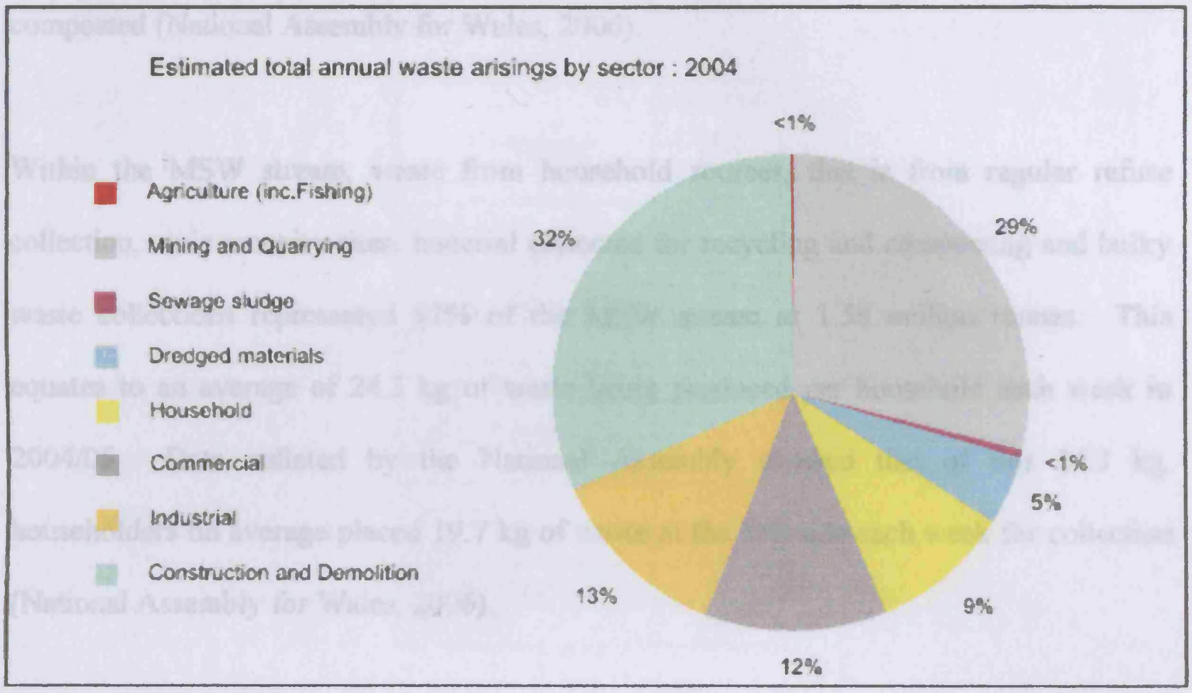


Figure 1.4: Estimated Total Annual Waste Arisings in the UK in 2004 by Sector (DEFRA, 2006)

The problem with waste management practices in the UK and in many other countries worldwide is that they depend heavily on landfill as a means of dealing with waste generated. (Denison *et al*. 1994).

1.2.3 Waste and Recyclable Management and Arisings in Wales

In 2004/05, 1.93 million tonnes of MSW was produced in Wales, this total showed an increase of 6% on the 2003/04 figure of 1.82 million tonnes. Landfill was the dominant waste disposal method in 2004/05, with 78% of MSW being sent to landfill. This was a decrease however on the proportion of MSW being sent to landfill, with 82% being sent to landfill in 2003/04. Of the remaining material (22%), 15% was recycled and 7% was composted (National Assembly for Wales, 2006).

Within the MSW stream, waste from household sources, that is from regular refuse collection, civic amenity sites, material collected for recycling and composting and bulky waste collections represented 82% of the MSW stream at 1.58 million tonnes. This equates to an average of 24.3 kg of waste being produced per household each week in 2004/05. Data collated by the National Assembly showed that of this 24.3 kg, householders on average placed 19.7 kg of waste at the kerbside each week for collection (National Assembly for Wales, 2006).

Between 2001 and 2003, a municipal waste analysis was carried out in Wales by AEA Technology on behalf of the National Assembly for Wales (National Assembly for Wales, 2003). The study found that the composition of MSW in Wales was as shown in Table 1.1. The bulk of MSW in Wales consists of garden and kitchen waste which constitutes 36% of the total, followed by 25% in the form of paper and cardboard. Hence, 61% of the MSW stream is biodegradable.

Table 1.1: The Welsh Average MSW Composition (National Assembly for Wales, 2003)

Category	Wales (%)
Paper	25
Cardboard	
Garden Waste	36
Kitchen Waste	
Glass	7
Textiles	2
Ferrous Metal	5
Non-Ferrous Metal	
Plastics	11
Fines	3
Miscellaneous	11
TOTAL	**100**

1.3 HISTORICAL BACKGROUND OF WASTE MANAGEMENT LEGISLATION

In historical times, food scraps and other wastes were simply thrown out into the streets, where they accumulated. At around 320 B.C. in Athens, the first known piece of legislation forbidding this practice was established and a system of waste removal was introduced. In ancient Rome, property owners were responsible for cleaning the streets outside the property, however, the disposal methods consisted of an open dump just outside the city walls (Williams, 2005).

In the UK, the industrial revolution between 1750 and 1850 resulted in an increase in the amount of industrial waste produced, and also an increase in the generation of domestic waste due to the migration of many people from rural areas to the cities. The industrial revolution led to an increasing awareness of the relationship between the environment and public health. As a result, a series of Nuisance Removal and Disease Prevention Acts were introduced during the nineteenth century, which gave local authorities the power to set up teams of inspectors to deal with offensive trades and control pollution within city limits. These Acts were reinforced by the Public Health Act of 1875 which placed a duty on local authorities to arrange for the collection and disposal of waste. The first refuse incinerator was built in 1875 as a means of waste disposal, and by 1912 there were over 300 incinerators in the UK. Incineration was second to the main method of waste disposal which was open dumping (both legally and illegally). Fire and vermin however were a risk; hence, waste was buried to minimise these risks; there was little consideration given to the effects of landfill gas emissions and leachate (Williams 2005).

The Public Health Act of 1936 introduced a provision whereby District Councils had to collect waste if they so wished, and if they opted to not do so, members of the public were entitled to claim 5 shillings per day for failure to collect. It was not until the late 1960s and 1970s however that waste management improved significantly in the UK, this was a result of a number of toxic chemicals being dumped, such as the case of drums of cyanide being dumped on a site used as a playground near Nuneaton in 1972. These cases led to pressure being placed on the Government to introduce stricter controls on waste disposal, which were the Deposit of Poisonous Waste Act 1972 and the Control of Pollution Act 1974 (Williams 2005). The main criticism of this latter act was that it merely created a framework to deal with the issue of waste disposal, it did not tackle the issue of increasing waste generation.

The Control of Pollution Act 1974 was superseded by the Environmental Protection Act 1990 (hereafter referred to as EPA90) which set out the UK waste strategy and introduced integrated pollution control. Integrated Pollution Control was based on the notion that the environmental impacts of a process on air, water and land are viewed as a whole. Prior to this they were subject to separate controls. EPA90 is a framework Act, which essentially means that the requirements of the Act will be implemented by a number of regulations. EPA90 introduced the notion of 'duty of care', which is essentially a measure to ensure the safe storage, handling and transport of waste by authorised people and to authorised sites for treatment/ disposal (Open University 1993).

The 1995 Environment Act established the Environment Agency and also introduced the principle of 'producer responsibility', its aim being to encourage the producer of a product to become more responsible for dealing with the waste produced due to the production of that product, and therefore increase the re-use or recycling of waste materials (Williams 2005).

The European Union also acts as a driver for UK legislation by the introduction of Directives, which set out standards and procedures which must then be implemented in the member states including the UK via each member's legislative system.

The main EU measure was the 1975 Waste Framework Directive (75/442/EEC) as amended by the Framework Directive on Waste (91/156/EEC) and the Decision on Waste (96/330/EC). This Directive requires waste to be dealt by measures that do not endanger the environment or human health; that is, it set the foundation for sustainable waste management. The Waste Directive states that waste must be managed "without causing a nuisance through noise or odours". As a means of minimising these environmental impacts, the Council Directive 1999/31/EC on the landfill of waste (commonly referred to as the Landfill Directive) was introduced by the European Commission (EC) in 1999, which was transposed to UK law through the Landfill (England and Wales) Regulations 2002. The aim of this legislation is to prevent, or reduce as far as possible, the adverse environmental effects of landfill (Holgate, 2002).

The requirements of the Landfill Directive include the following:

- sites are classified into three categories: hazardous, non-hazardous or inert, depending on the type of waste they receive;
- biodegradable waste is progressively diverted away from landfills in line with the targets stipulated in the Directive;
- certain hazardous and other wastes, including liquids are prohibited from landfills; and
- pre-treatment of waste prior to landfilling is required after 16th July 2004 (Holgate, 2002).

The amount of biodegradable waste landfilled must be reduced in line with the following targets in order for the UK to comply with the Landfill Directive:

- to 75% of the biodegradable waste produced in 1995, by 2010;
- to 50% of the biodegradable waste produced in 1995, by 2013; and
- to 35% of the biodegradable waste produced in 1995, by 2020 (Holgate 2002 and Audit Commission in Wales, 2005).

The Landfill Directive has been implemented differently in each part of the UK. In Wales, this was implemented by means of the Landfill Allowance Scheme (Wales) Regulations 2004 (Statutory Instrument No. 1490). Under this scheme, each local authority is allocated an annual allowance for the amount of biodegradable municipal waste (BMW) it can send to landfill within that period. This allowance declines year on year in order to comply with the Landfill Directive targets. A significant financial penalty exists for local authorities which exceed their annual allowance, this is set at £200 per tonne of BMW landfilled in excess of their annual target. In contrast, the English scheme as laid out the by the Landfill Allowance Trading Scheme (LATS) Regulations 2004 (Statutory Instrument No. 3212) again sets an annual allowance for each Local Authority; however, English Local Authorities can trade their allowances in order to buy or sell as their needs require. Also, the financial penalties involved are more lenient than the Welsh regulations, at £150 per tonne of BMW landfill in excess of the annual allowance. Table 1.2 shows the Welsh BMW landfill allowance figures until 2009/10, which highlights the significant changes that will be needed to meet these stringent targets.

Table 1.2: Annual BMW Landfill Allowance for Wales until 2009/10 (Welsh Assembly Government, 2004)

Year	BMW Landfill Allowance (Tonnes)
2005/06	1,022,000
2006/07	944,000
2007/08	866,000
2008/09	788,000
2009/10	710,000

A number of EU Directives are in place which target key wastes and industries, for example the packaging and packaging waste directive, the end of life vehicles directive, and the waste electrical and electronic equipment. A number of key Directives are also proposed which affect the waste management industry, on issues such as biowaste and waste from extraction industries. The proposed Biowaste Directive may enforce the separate collection of biowaste in order to maximise the use of composting and anaerobic digestion (DEFRA, 2004).

The Welsh Assembly Government published its own waste strategy 'Wise about Waste' in 2002, with its general aim being to reduce the amount of waste disposed of in landfill sites and to increase recycling and source segregated composting. This general aim was broken down into set targets; these are:

- by 2003/04 achieve at least 15% recycling/ composting of MSW with a minimum of 5% composting and 5% recycling;
- by 2006/07 achieve at least 25% recycling/ composting of MSW with a minimum of 10% composting and 10% recycling; and
- by 2009/10 achieve at least 40% recycling/ composting of MSW with a minimum of 15% composting and 15% recycling (Friends of the Earth 2002; National Assembly for Wales 2002).

It has also been announced by WAG, that targets are likely to increase post 2010 as follows:

- 52% recycling and composting by 2012/13;
- 58% recycling and composting by 2015/16;
- 64% recycling and composting by 2019/20; and,
- 70% recycling and composting by 2024/25 (Welsh Assembly Government, 2007).

No information is yet available as to whether these targets will be statutory or non-statutory.

As a result of these regulations and targets, and in particular the landfill regulations, the waste management industry in the UK will have to undergo a radical change in order to meet the targets required by law. The aim of these regulations is essentially to create a more sustainable approach to waste management, and a greater utilisation of the waste hierarchy.

A waste hierarchy can be traced back to the 1970s, when the environmental movement developed the hierarchy, and argued that waste was made up of different materials, and as a result the different fractions should be treated differently, i.e. some should not be produced in the first place, some should be re-used, some recycled and composted, some should be burnt, and some should be buried (Schall, 1992). It was not until the 1991 'Waste Management Paper on Recycling' (Department of the Environment, 1991) that the waste hierarchy was officially recognised by the Government. This version of the waste hierarchy is shown in Figure 1.5. The waste hierarchy was then updated by 'Making Waste Work' (DETR, 1995), to the version that is still used today. This is illustrated in Figure 1.5.

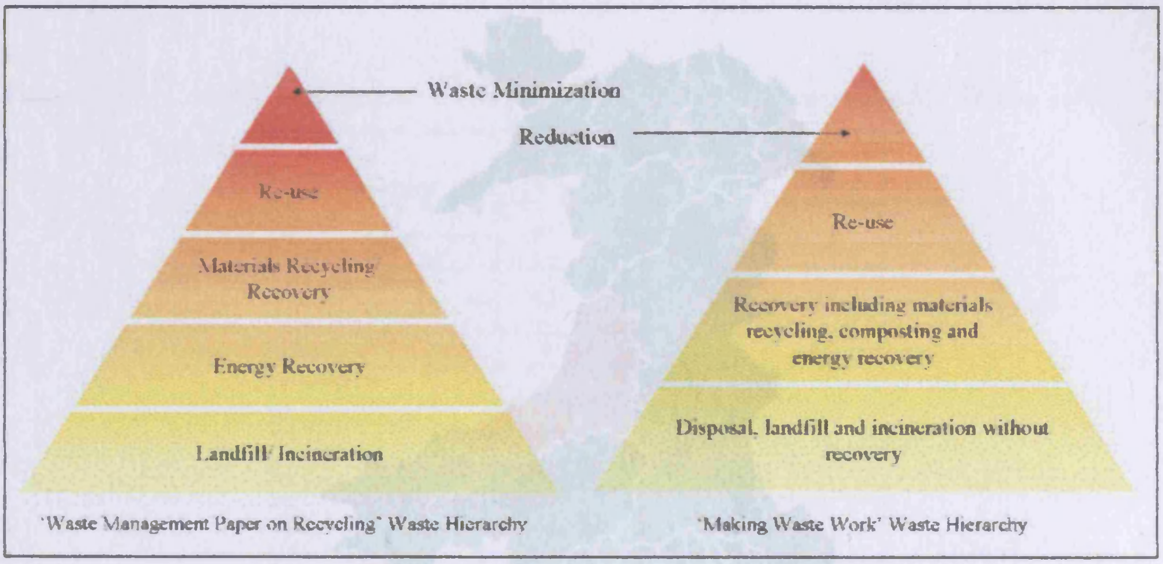


Figure 1.5 Waste Hierarchy (Department of the Environment, 1991 and DETR, 1995)

1.4 CASE STUDY AREA - CEREDIGION

Ceredigion is a rural authority on the west coast of Wales as highlighted in Figure 1.6, and covers an area of 179,426 hectares. The county has a population of approximately 75,000, which equates to an average population density of 0.42 persons per hectare (National Statistics, 2001).

The recycling rate for Ceredigion in 2003/04 was 26.6%, this increased to 32.8% in 2004/05 (National Assembly for Wales, 2006). The recycling scheme run by the local authority covers about 20,000 properties (residential and business) in the south of the County; the scheme uses a clear survival bag to collect dry recyclable such as paper, card, plastics and metals, and residents are also given the option to purchase green survival bags for garden waste.

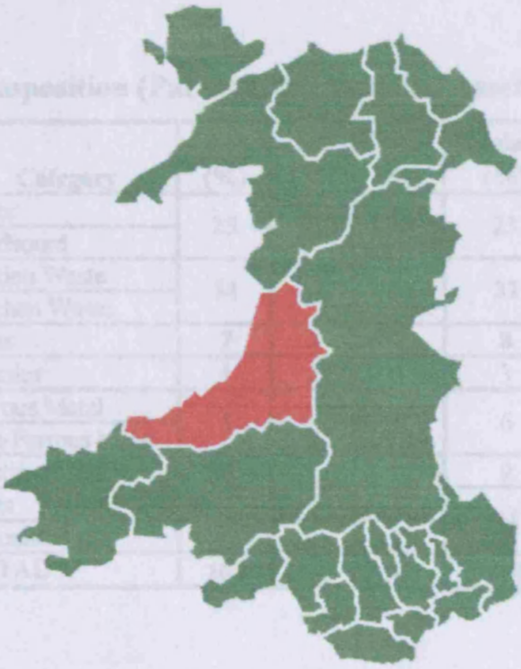


Figure 1.6: Map of Wales showing Local Authority Boundaries highlighting Ceredigion (Wikimedia, 2008)

MSW contains a large proportion of recyclable and compostable material, as is indicated by the results of MSW composition studies highlighted in Table 1.3. The Table highlights that although the composition of MSW varies considerably, a large proportion of recyclable is contained within the stream, these include paper, cardboard, plastic, metals, and glass; along with a large proportion of kitchen and garden waste. Currently the Authority is piloting a survival bag scheme in order to segregate this material for recycling. Within the pilot area, the survival bags are collected in the same refuse vehicle as the residual waste stream, prior to being delivered to a materials recovery facility (MRF) which is being trialled to process the survival bag material as well as the residual waste stream, and therefore segregate materials for recycling from the MSW stream. Currently there is very little scientific data available in the public domain related to the performance of MRFs due to issues relating to commercial confidentiality.

Table 1.3: MSW Composition (Parfitt 2002; National Assembly for Wales 2003)

<table>
<tr><th>Category</th><th>EU (%)</th><th>UK (%)</th><th>Wales (%)</th><th>England (%)</th></tr>
<tr><td>Paper</td><td rowspan="2">23</td><td rowspan="2">32</td><td rowspan="2">25</td><td rowspan="2">23</td></tr>
<tr><td>Cardboard</td></tr>
<tr><td>Garden Waste</td><td rowspan="2">34</td><td rowspan="2">21</td><td rowspan="2">36</td><td rowspan="2">37</td></tr>
<tr><td>Kitchen Waste</td></tr>
<tr><td>Glass</td><td>7</td><td>9</td><td>7</td><td>8</td></tr>
<tr><td>Textiles</td><td>4</td><td>2</td><td>2</td><td>3</td></tr>
<tr><td>Ferrous Metal</td><td rowspan="2">5</td><td>6</td><td rowspan="2">5</td><td rowspan="2">6</td></tr>
<tr><td>Non-Ferrous Metal</td><td>2</td></tr>
<tr><td>Plastics</td><td>12</td><td>11</td><td>11</td><td>9</td></tr>
<tr><td>Fines</td><td rowspan="2">15</td><td>7</td><td>3</td><td rowspan="2">14</td></tr>
<tr><td>Miscellaneous</td><td>10</td><td>11</td></tr>
<tr><td>TOTAL</td><td>100</td><td>100</td><td>100</td><td>100</td></tr>
</table>

1.5 AIMS AND OBJECTIVES

This thesis will examine Materials Recovery Facilities (MRFs) and increased kerbside provision as a means of diverting recyclable materials contained in household waste away from landfill. Considerable variation was observed in MRFs in terms of the separation processes utilised, type of material processed and so forth, and the thesis will examine this variation and their flexibility in terms of fitting into a local authorities waste strategy.

The thesis will present data obtained for composition of household waste within the case study authority, and using this information a design for a MRF will be developed, which will be commissioned within the case study authority, and its performance analysed. This will then allow modelling to be carried out on the case study authority's municipal solid waste (MSW) stream data, in order to assess the impact of the MRF and increased kerbside provision on the study authority's performance in terms of meeting statutory and non-statutory targets.

1.6 STRUCTURE OF THE THESIS

Chapter 2 of the thesis examines the factors which affect household waste arisings, and the various options available for dealing with it. Waste management in the case study area is discussed, giving a historical perspective on the provision of recycling services within the local authority.

Chapter 3 presents the results of the waste characterization survey conducted within the study area, and assesses variations on both a seasonal basis and socio-economic basis across the local authority.

Chapter 4 introduces MRFs, outlining the variety of separation processes which are commonly used, and the difference between dirty and clean MRF operations. This chapter also details the results from process reviews undertaken at a number of MRFs both in the UK and overseas.

Chapter 5 details the development of the MRF, and also the results of a MRF efficiency trial conducted to assess performance and areas to target for improvement.

Chapter 6 examines the impact of MRF development and increased kerbside provision on the recycling and composting rates achieved by the case study authority. The impact on biodegradable municipal waste (BMW) diversion is also assessed in this chapter.

Chapter 7 concludes the thesis, and proposes areas for future research.

CHAPTER 2:
Review of Waste & Recycling in the Case Study Area

2.1 INTRODUCTION

Municipal Solid Waste (MSW) should be treated as a resource as it contains many materials which can be reused or recycled such as glass, metals, and paper along with biodegradable material (DETR, 2000). This is highlighted in Table 2.1 which shows the results of a variety of waste characterisation studies that have been completed. This Table has been constructed based on data obtained from four studies conducted in four regions of the UK, these are Rhondda Cynon Taf (RCT) County Borough Council, Carmarthenshire County Council, Cheshire and the Wirral. It is clear that there are significant variations in the MSW composition of the four regions. For example, the paper and cardboard content ranges from 20% for the Wirral to 37% for Cheshire, this variation can be explained by the variations in socio-economic status of the areas, in that more affluent areas tend to read more broadsheet newspapers, and therefore generate a greater proportion of paper waste. Garden and kitchen waste varies considerably, ranging from 25% for Cheshire to 39% for the Wirral. Significant variation is also seen in the textiles fraction, with both Welsh regions (RCT and Carmarthenshire) having a lower proportion (4% and 2% respectively) than the English regions (Cheshire and the Wirral) (6% and 7% respectively). There is also a variation in the plastics component of the MSW stream across the four regions, ranging from 8% in the Wirral to 14% in Cheshire.

The BMW content of the MSW streams for the four regions also varies considerably. The data show that the two Welsh regions of RCT and Carmarthenshire had BMW contents of 55% and 65% respectively, compared to the 61% defined for Wales in the Landfill Allowance Scheme (Wales) Regulations. Therefore, the data in Table 2.1 suggests that Carmarthenshire has a greater pool of material to target in terms of BMW diversion, while

RCT has less than the average Welsh figure. In comparison, the two English regions of Cheshire and the Wirral have BMW contents of 62% and 59%; compared to the 68% BMW defined for England by the LATS Regulations. Hence, both regions have a lower pool of BMW to target for diversion, which suggests that these regions may struggle to comply with the LATS without having to trade allowances.

Table 2.1: Examples of MSW Composition (Cardiff University 2000; Owen *et al.* 2005; and Cheshire Local Government Association 2001)

<table>
<tr><th>Category</th><th>RCT (%)</th><th>Carmarthenshire (%)</th><th>Cheshire (%)</th><th>Wirral (%)</th></tr>
<tr><td>Paper</td><td rowspan="2">25</td><td rowspan="2">32</td><td>25</td><td rowspan="2">20</td></tr>
<tr><td>Cardboard</td><td>12</td></tr>
<tr><td>Garden Waste</td><td>11</td><td rowspan="2">33</td><td>14</td><td>17</td></tr>
<tr><td>Kitchen Waste</td><td>19</td><td>11</td><td>22</td></tr>
<tr><td>Glass</td><td>7</td><td>7</td><td>6</td><td>8</td></tr>
<tr><td>Textiles</td><td>4</td><td>2</td><td>6</td><td>7</td></tr>
<tr><td>Ferrous Metal</td><td>4</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td>Non-Ferrous Metal</td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>Plastics</td><td>10</td><td>9</td><td>14</td><td>8</td></tr>
<tr><td>Fines</td><td>6</td><td rowspan="2">13</td><td rowspan="2">8</td><td>7</td></tr>
<tr><td>Miscellaneous</td><td>13</td><td>7</td></tr>
<tr><td>TOTAL</td><td>100</td><td>100</td><td>100</td><td>100</td></tr>
</table>

The composition of MSW varies as a result of a number of factors including socio-economic status, geography, demographics, collection system and so forth, and this variation in composition can be observed on a number of scales, i.e. national, regional and local which further complicates waste management strategies.

2.2 FACTORS WHICH AFFECT WASTE AND RECYCLABLE ARISINGS

One of the key factors which impacts waste composition and arisings is socio-economic status, i.e the affluence of an area. This is highlighted in Table 2.2, which shows the results of a study carried out by the Department of the Environment (Department of the Environment, 1991 in Williams, 2005). The Table shows that generally the more affluent the area the greater the amount of waste generated, for example the average MSW arisings for terraced housing is 12.6 kilograms per household per week, while waste for higher status municipal housing increases to 14.6 kilograms per household per week. Indeed it was found that average MSW arisings were greatest in agricultural areas at 22.1 kilograms per household per week. The information contained within this table essentially enables MSW arisings to be predicted for a particular area based on the 'A Classification of Residential Neighbourhoods' (ACORN) information for that area. The ACORN system is a demographic tool which categorises each UK postcode based on census data (ACORN, 2003).

Table 2.2: MSW Generation for Different Household Types (Department of the Environment, 1991 in Williams, 2005)

ACORN Group	MSW Arisings (kg/hh/wk)*		Projected Average MSW Arisings 2005 (kg/hh/wk)* (2% Annual Growth)
	Range	Average	
Agricultural area	17.9 - 32.4	22.1	29.7
High income, modern family housing	9.6 - 21.5	14.3	19.2
Older housing, intermediate income	9.0 - 14.8	11.8	15.9
Older terraced housing	8.8 - 20.4	12.6	17.0
Municipal housing, higher status	10.7 - 23.3	14.6	19.6
Municipal housing, intermediate status	7.2 - 16.7	12.2	16.4
Municipal housing, lower status	7.2 - 17.6	13.6	18.3
Mixed metropolitan areas	5.0 - 12.3	9.8	13.2
High status, non-family areas	7.7 - 27.1	13.1	17.6
Affluent suburban housing	5.4 - 20.7	14.2	19.1
High status retirement areas	5.4 - 16.6	11.1	14.9

* kg per household per week

However, it must be noted that the information contained in Table 2.2 does not take into account variations in the method of waste collection, for example the use of wheelie bins, or the traditional dust bin, which can have an impact on waste generation. Also, this information does not provide any information on compositional changes to the waste stream in relation to socio-economic status.

The data from the Department of the Environment study contained in Table 2.2 was published in 1991, and is therefore somewhat dated. Hence, the average data were projected with an annual growth rate of 2% to gain an indication of the data for 2005 in order to compare with the average Welsh MSW arisings figure for 2004/05 of 24.3 kg/hh/wk (National Assembly for Wales, 2006). From the Table it can be seen that the projected average MSW arisings for 2005 ranged from 13.2 kg/hh/wk for a mixed metropolitan area to 29.7 kg/hh/wk for an agricultural area. It can also be noted that it is only the average figure of 29.7 kg/hh/wk which exceeds the 24.3 kg/hh/wk figure reported for Wales in 2004/05, with all other projected average figures being below 19.6 kg/hh/wk.

Seasonality is another key factor which impacts on waste composition and recycling. For example garden waste is greatest during the growing season, and therefore has a significant impact on both arisings and composition (Franklin, 1994). Table 2.3 highlights the impact of garden waste on MSW composition. The Table shows the results of a study that found that the putrescible fraction of MSW increased from 30 to 52% between the Winter and Summer study.

Table 2.3: General composition of MSW in winter and summer (Godley et al. 2002)

General Components	% Winter	% Summer
Paper	30	22
Putrescibles (Kitchen and Garden)	30	52
Textiles	5	2
Glass	16	12
Metal	11	6
Plastic	6	3

2.3 OPTIONS IN MSW MANAGEMENT

There is a variety of options for the management and disposal of MSW, these include:

- landfill;
- thermal processes such as incineration, pyrolysis and gasification;
- composting;
- anaerobic digestion;
- mechanical biological treatment; and,
- centralised and kerbside sorting of recyclable.

There is no one solution that fits all in waste management, it is a question of assessing what is required to meet relevant legislation and national targets, and assessing local conditions and needs. In most cases an integrated waste management programme, that is many ways of waste treatment such as incineration, composting and recycling are used to fulfil the needs required (Kreith 1994).

2.3.1 Landfill

Landfill is the oldest and most widely used method for waste disposal, whereby waste is placed in a void in the ground which is lined to minimise pollution. The landfilling of organic wastes is an environmental problem in terms of the leachate it produces during decomposition which requires treatment, also decomposition in an anaerobic environment generates methane, which is a potent 'greenhouse' gas; indeed it is about 21 times more potent than carbon dioxide (Biomass Energy Centre, 2008). Landfills generate approximately 40 million tonnes of methane worldwide. In the UK and Europe, landfills are the first (48%) and second (31%) largest sources of anthropogenic methane respectively (Hilger and Humer, 2003).

Another problem with the landfilling of waste is that the material may remain biologically and chemically active for as much as 10,000 years, and the containment around landfills will not last this length of time. Hence, the purpose of containment methods is to create time to treat and manage the leachate from the landfill (Joseph, 1996). Landfills are becoming scarce in the UK, simply because there is very little void space remaining in which to engineer new landfill sites. As a result of this and increasing landfill tax imposed by the UK government, landfill disposal costs are increasing rapidly, which as a result are making other waste treatment and disposal options more attractive.

2.3.2 Thermal Processes

Thermal processes for waste treatment include the more common process of incineration and newer processes such as pyrolysis and gasification.

Incineration is a chemical process in which the combustible fractions of the waste are combined with oxygen, forming mostly carbon dioxide and water, i.e. oxidation. This results in the release of thermal energy. Incineration can reduce the total volume of MSW by as much as 95%. Two types of output material remain at the end of an incineration process, these are 'bottom ash' and 'fly ash'. Much of the material will be present in the form of 'bottom ash', this is a non-hazardous material and can be disposed of to landfill, or can be reused, for example in road construction. However, 'fly ash' which contains heavy metals, polycyclic aromatic hydrocarbons, etc. is a hazardous material and must be disposed of to hazardous waste landfill. The heat produced as a result of incineration can also be recovered for use in power generation (Knox, 2005).

Incinerators are commonly used in many countries, for example the Netherlands and Japan. In the UK, however there is strong public opposition to incineration, as a result of the poorly operated incineration plants that have been in operation in the UK in the past. The Waste Incineration Directive (No. 2000/76/EC) has imposed strict rules for the incineration of waste material, which has resulted in a significant improvement in the quality of emissions from incinerators.

The other two forms of thermal treatment are pyrolysis and gasification. Pyrolysis is a thermal process which in contrast to incineration occurs in the absence of oxygen, which typically occurs in the range of 400 to 800°C, and produces by-products which can be used as fuels. The process conditions can be modified to produce either a solid char, gas or liquid/oil product. In contrast, gasification is the thermal processing of the wastes with oxygen in the form of air, steam or pure oxygen to produce a gas, ash and tar products.

The operating temperatures are much higher than those for pyrolysis, being 800-1100°C for air gasification and 1000-1400°C for oxygen gasification. The gas product is typically used by direct combustion in a boiler or furnace, and the heat energy is used for process heat or to produce steam for electricity generation (Knox 2005).

2.3.3 Composting

Composting is a biological process where the organic material is allowed to decompose under controlled conditions. The decomposition and transformation of the material is carried out by bacteria, fungi and other micro-organisms. Composting can reduce the volume of the raw organic material by up to 50%, and the material produced can also be used as a soil conditioner or mulch. This material can be a high-quality product if the input material is source segregated; however, the composting of mixed, solid waste may cause problems in terms of contaminants and loss of valuable resources. Non-compostable materials in MSW such as glass, heavy metals and plastic contaminate the final compost product and therefore impacts on quality, and limits its application (Denison *et al.* 1994; and Diaz *et al.* 1994).

2.3.4 Anaerobic Digestion

Anaerobic digestion has been widely used to treat sewage sludge and agricultural waste for many years, but has only recently been applied to municipal wastes. Essentially the waste is degraded in an anaerobic environment to produce a stabilised waste which is disinfected and deodorised. The process generates methane and carbon dioxide, and the methane can be used to produce energy (Williams 2005; and Golueke 1977).

2.3.5 Mechanical Biological Treatment (MBT)

Mechanical biological treatment (MBT) (also known as mechanical biological pre-treatment (MBP), is a two step approach to waste management in that initially mechanical separation is used to separate recyclable materials such as glass, plastic and metal, the remaining material is then treated biologically by means of composting, anaerobic digestion etc. Hence, there is no single form of MBT, there are a variety of methods for carrying out this technique, i.e. it is a mixture of processing operations (Kebekus et al. 2000; and Damiecki 2002).

MBT may be used as a means of treating waste prior to landfill, but it may also be used for the production of refuse derived fuels (RDF). Disposing of the treated material in landfill, has a number of advantages, these include:

- reduction in the amount of waste sent to landfill;
- the waste sent to landfill is stabilized i.e. reduction in biodegradability;
- significant reduction in methane generation once material is landfilled;
- significant reduction in Biochemical Oxygen Demand (BOD) and Total Organic Carbon (TOC) in the leachate; and,
- saving in landfill volume due to mass reduction in both the mechanical and biological stages (Bockreis *et al.* 2003; Damiecki 2002, Adani *et al.* 2000, Kebekus *et al.* 2000, and Binner 2002).

2.3.6 Centralised and Kerbside Sorting of Recyclable

When collecting material for recycling, there are two main options for sorting, that is, the material can either be sorted at a centralised facility, i.e. a materials recovery facility (MRF) or materials reclamation facility, or it can be sorted at the kerbside into compartmentalised vehicles. Centralised sorting has a higher capital investment cost than kerbside sorting as more equipment is needed for the sorting activity, and it is often said that the quality of the segregated material is less than that for kerbside sorting; however, the on-going costs are generally lower.

A MRF consists of a number of unit operations (both mechanical and manual), receives, separates and prepares recyclable materials for marketing to end-user manufacturers. The unit operations employed in processing recyclable materials include baling, magnetic separation, screening, size reduction, air classification, eddy current separation, and can flattening and densifications (Spencer 1994). There are two distinct types of MRF, those that process source segregated mixed recyclable, commonly referred as 'clean MRFs', and those that process household waste, commonly referred to as 'dirty MRFs'.

Kerbside sorting of recyclable is where material is sorted by operatives into various stillages of a collection vehicle at the kerbside as shown in see Figure 2.1. The segregated material is then returned to a bulking facility, where some basic processing such as separation of steel and aluminium cans, and the baling of the recovered material for more cost effective transportation to the reprocessor is carried out.

Figure 2.1: Example of a Compartmentalised Vehicle used for Kerbside Sorting of Recyclable (Newport Wastesavers, 2005)

2.4 THE CASE STUDY AUTHORITY – THEIR APPROACH

2.4.1 Introduction

The Local Authority fulfils the roles of both the Waste Collection and Waste Disposal Authority, and as part of this role collects household waste on a weekly basis from all households within its boundary. In terms of the current waste management contracts in place, the Authority is split into two: north and south as shown in Figure 2.2. Waste collected in the North is delivered to a transfer station on the outskirts of Aberystwyth; here, the waste is bulked up and taken for disposal at Bryn Posteg landfill site near Llanidloes, Powys. Waste collected in the South is delivered to LAS Recycling Ltd., in Lampeter where some of the household waste is subject to further processing. The residue from this process and the untreated household waste is sent to landfill, again at Bryn Posteg (Ceredigion County Council, 2002).

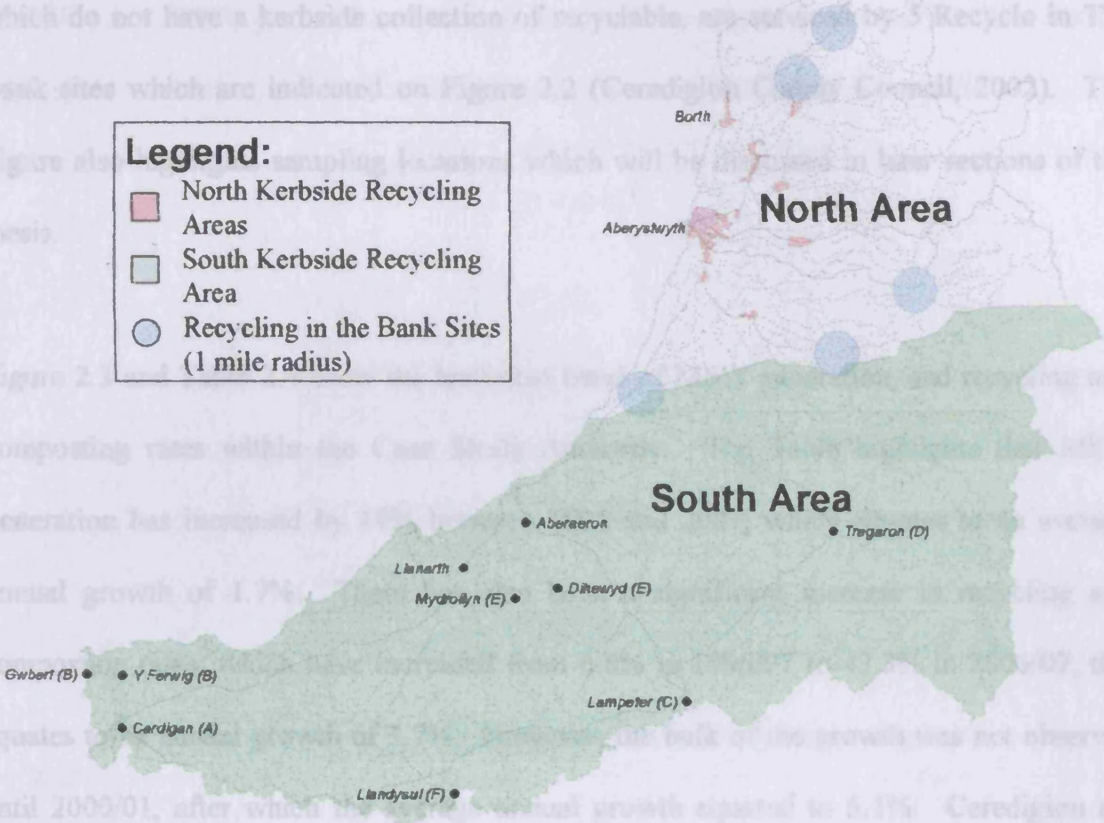


Figure 2.2: Map of Ceredigion indicating CA site and Recycle in the Bank locations (Hodgett, 2008).

There are five civic amenity (CA) sites located within the County; which are indicated in Figure 2.2, these are at:

- Borth CA site;
- Glanyrafon CA site, Aberystwyth,
- Rhydeinon CA site, Llanarth;
- Lampeter CA Site; and,
- Cilmaenllwyd CA site, Cardigan (Ceredigion County Council, 2002).

These are supplemented by a network of recycling centres located around the county, which are found in car parks, supermarkets, schools etc., with facilities ranging from a single glass, paper or can bank to a range of multiple banks. Areas in the North of County which do not have a kerbside collection of recyclable, are serviced by 5 Recycle in The Bank sites which are indicated on Figure 2.2 (Ceredigion County Council, 2002). The Figure also highlights sampling locations which will be discussed in later sections of the thesis.

Figure 2.3 and Table 2.4 show the historical trend of MSW generation, and recycling and composting rates within the Case Study Authority. The Table highlights that MSW generation has increased by 19% between 1996 and 2007, which equates to an average annual growth of 1.7%. There has also been a significant increase in recycling and composting rates; which have increased from 6.6% in 1996/97 to 43.3% in 2006/07; this equates to an annual growth of 3.7%. However, the bulk of the growth was not observed until 2000/01, after which the average annual growth equated to 5.1%. Ceredigion are currently the best performing authority in terms of recycling in Wales, however, since 2002/03 the annual waste generation has remained fairly constant apart from in 2004/05. It was suggested that this increase arose as a result of the collection of green waste at the kerbside a practice which was stopped in 2005/06 (Keenan, 2007).

Figures 2.4 and 2.5 illustrate the source of MSW generated in the years 2003/04 and 2006/07 respectively. It highlights that the proportion and quantity of waste at CA sites changed very little between both years; however, the proportion and quantity of waste from refuse collection vehicles (RCV's) declined from 2003/04 to 2006/07, and an increase was seen in the proportions of other household waste, and non-household waste from 2003/04 to 2006/07.

Table 2.4: MSW generation and recycling and composting rates in the Case Study Authority (Ceredigion County Council 2002 and Keenan 2007)

Year	MSW Generated (T)	Recycling & Composting Rate (%)
1996/97	33,275	6.6
2000/01	37,873	12.8
2002/03	40,389	20.4
2003/04	40,794	28.6
2004/05	43,549	35.9
2005/06	40,801	35.6
2006/07	40,140	43.3

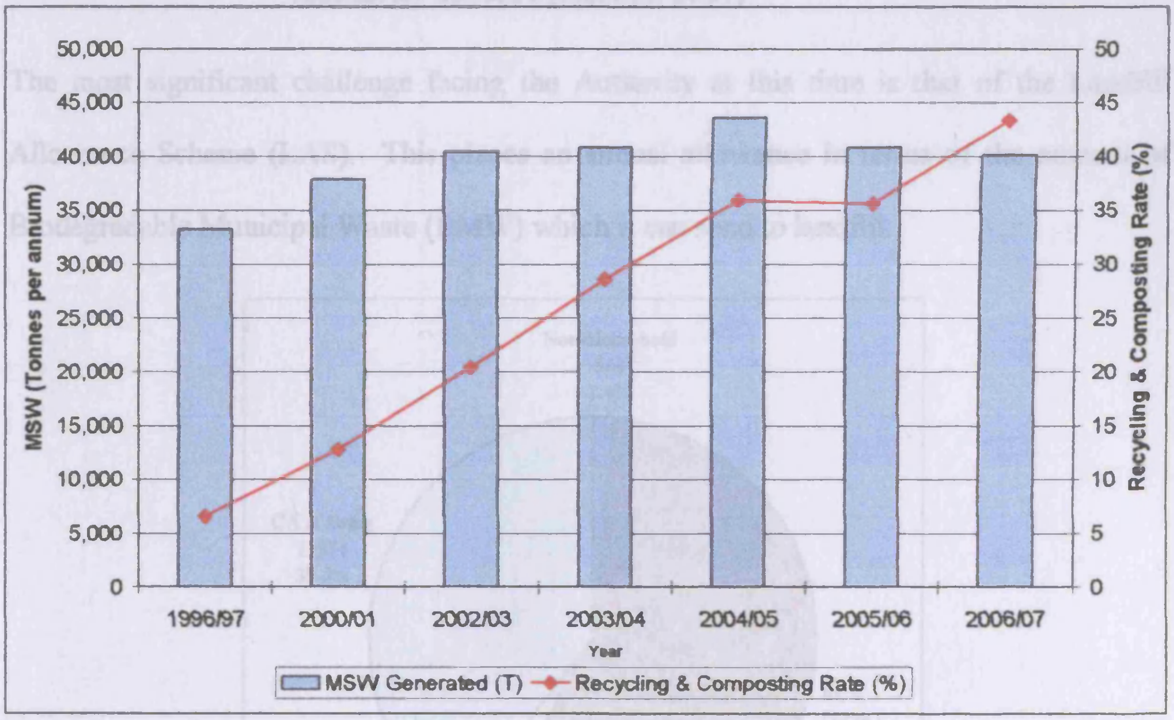
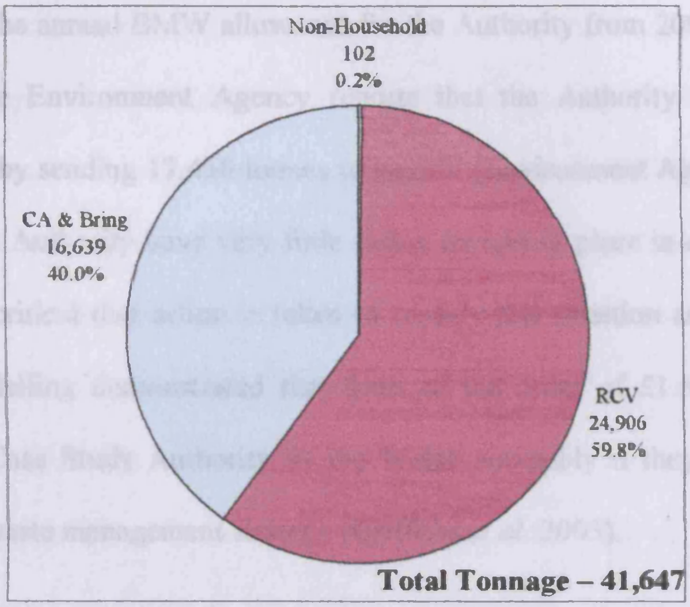


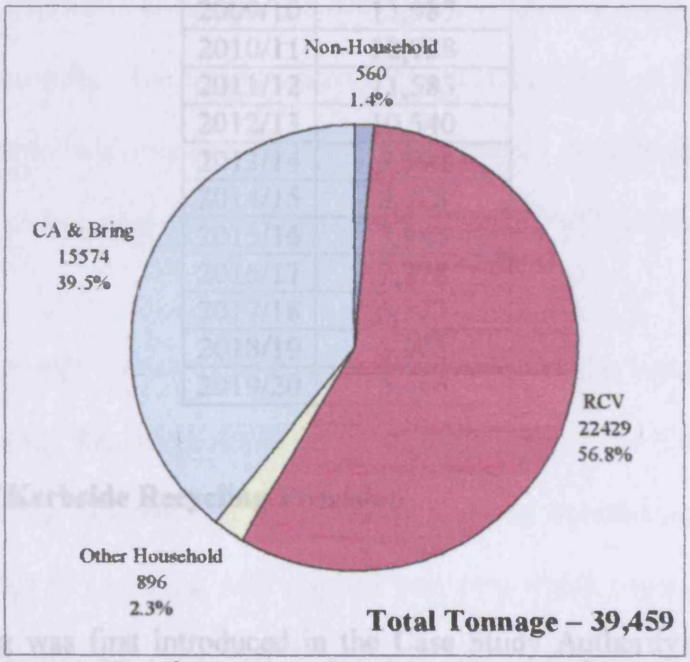
Figure 2.3: MSW generation and recycling and composting rates in the Case Study Authority (Ceredigion County Council 2002 and Keenan 2007)



(Data in tonnes unless otherwise stated)

Figure 2.4: MSW Collection Tonnage and Composition in the Case Study Authority 2003/04 (Keenan 2007)

The most significant challenge facing the Authority at this time is that of the Landfill Allowance Scheme (LAS). This places an annual allowance in terms of the amount of Biodegradable Municipal Waste (BMW) which it can send to landfill.



(Data in tonnes unless otherwise stated)

Figure 2.5: MSW Collection Tonnage and Composition in the Case Study Authority 2006/07 (Keenan 2007)

Table 2.5 shows the annual BMW allowance for the Authority from 2005 to 2020. In the year 2005/06, the Environment Agency reports that the Authority met their landfill allowance target, by sending 17,450 tonnes to landfill (Environment Agency, 2006). This illustrates that the Authority have very little safety margin in place in order to meet their targets, and it is critical that action is taken to remedy this situation as soon as possible. Indeed LAS modelling demonstrated that fines of the order of £1.6 million could be imposed on the Case Study Authority by the Welsh Assembly if they do not make any changes to their waste management strategy (Griffiths *et al.* 2005).

Table 2.5: BMW Landfill Allowance for Case Study Authority (Griffiths *et al.* 2005)

Year	BMW Landfill Allowance (tonnes)
2005/6	18,620
2006/7	17,461
2007/8	16,303
2008/9	15,145
2009/10	13,987
2010/11	12,728
2011/12	11,583
2012/13	10,540
2013/14	9,592
2014/15	8,728
2015/16	7,943
2016/17	7,228
2017/18	6,577
2018/19	5,985
2019/20	5,446

2.4.2 History of Kerbside Recycling Provision

Kerbside recycling was first introduced in the Case Study Authority in 2003; this first foray into offering kerbside recycling was a small pilot scheme which operated in the county town of Cardigan and the surrounding areas. This scheme involved the provision of two survival bags to householders: a clear bag for mixed dry recyclable, that is paper, card, plastic, tins and cans, and a green bag for kitchen waste (excluding meat) and garden waste. These two bags were issued free of charge to the 3000 households covered by the pilot scheme area. These bags were collected on a weekly basis, in the same vehicle as that used for their normal refuse collection; that is, the coloured survival bags are collected mixed with the black bag (residual waste) stream. The survival bags survive the compaction exerted on them by the RCVs, as the bags are made of a thicker gauge of plastic and also have air holes at the bottom of the bags, so that when the bags are compacted, air can escape and hence the bags do not burst. The RCVs then delivered the collected material (i.e. residual waste, clear and green bags) to a pilot dirty MRF at LAS Recycling Ltd in Lampeter. This was a very basic process where initially the coloured bags were removed from the picking belt, and the remaining residual waste was then sorted to recover recyclable, paper, cardboard and plastics were manually removed from the waste stream, and an overband magnet and eddy current separator were used to remove the steel and aluminium cans. The clear bags were then batched through the same process to recover the recyclable from this segregated stream. Organic material from the green bags was composted in an in-vessel composting process (Keenan 2007 and Saunders 2007).

During 2004, a kerbside sorting pilot scheme commenced in the town of Lampeter, and was run by Ceredigion Recycling Authority in conjunction with the Case Study Authority as a result of funding obtained via a Strategic Recycling Scheme grant. This scheme provided households in Lampeter with a green box, into which paper, cardboard, plastic bottles, glass bottles, tins and cans could be placed. These were then collected on a weekly basis by one of two pedestrian controlled vehicles (PCV) as shown in Figure 2.6, which operated around Lampeter. These vehicles carried a number of bags on the rear which were used by the operatives to segregate the materials sorted from the boxes left at the kerbside. Once these bags were full, the operatives returned to a central bulking area in Lampeter where the bags were emptied, and then retuned to the collection round (Keenan 2007).

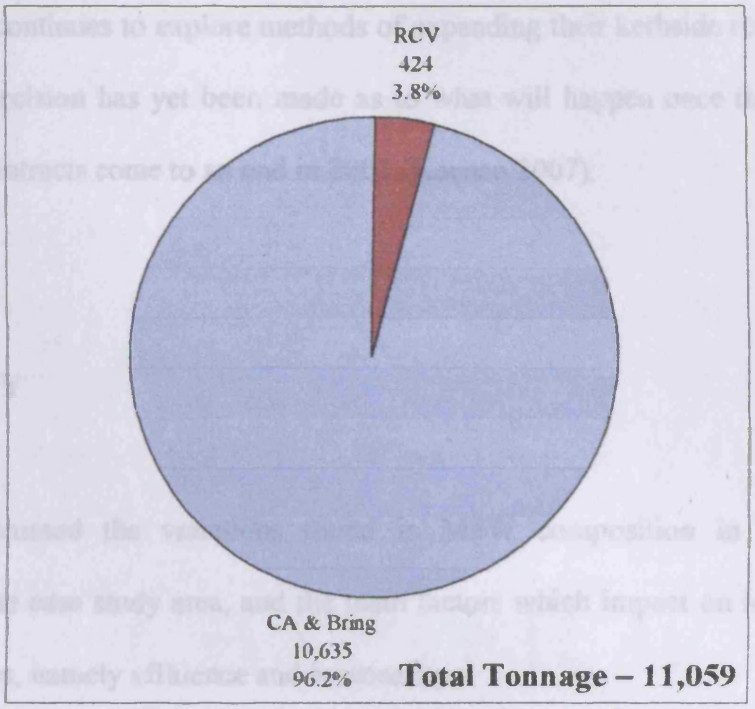
Figure 2.6: Pedestrian Controlled Vehicle (TRecS 2007)

During 2005, the Case Study Authority made a decision that the PCV trial operated in Lampeter would be unviable to continue once the grant money had run out, due to the collection costs and the small quantities of material recovered. As a result the Authority removed their support of the PCV trial, and started what was called the "recycle in the bag" scheme in Lampeter. This made use of the clear bags utilised in the survival bag pilot scheme in Cardigan. In this trial, glass was added to the materials which could be placed in the bags as this could be placed in the green boxes utilised by the PCV scheme. These clear bags were collected by a dedicated caged vehicle on a weekly basis and delivered to the MRF at LAS Recycling in Lampeter (Keenan 2007).

In the spring of 2006, the Authority rolled out the survival bag scheme in operation in Cardigan and the surrounding area to the south of the county (excluding Lampeter which continued with the "recycle in the bag scheme"), that is the area of the county where waste was delivered to the LAS Recycling transfer station in Lampeter. However, the local authority decided to change the features of the green bag; whereas in the pilot scheme this was for kitchen and garden waste and provided free of charge, it was decided that it was only to be used for garden waste and a charge of 20p per bag was to be levied when the bags were purchased to subsidise the collection costs. This decision was made as a result of the significant increase in waste arisings observed in the pilot scheme area. The council felt that home composting would be a better method of dealing with this material (Keenan 2007).

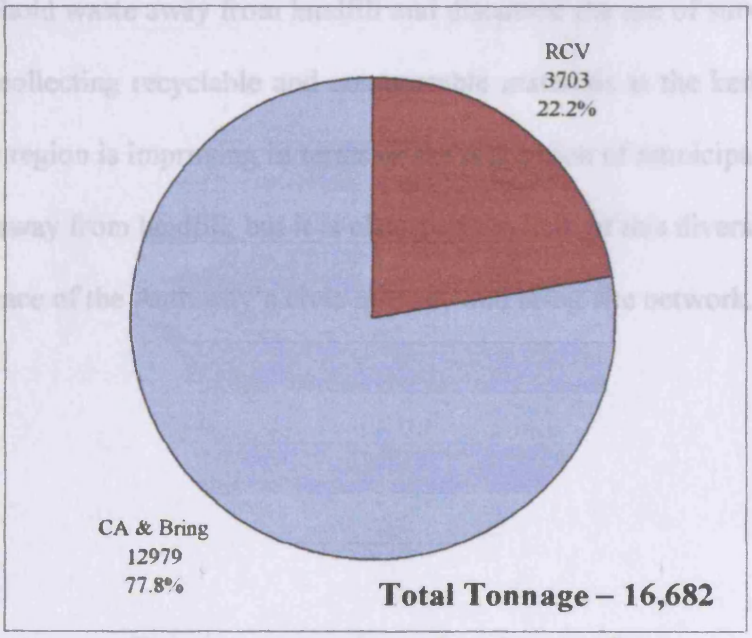
In the Summer of 2006, a "recycle in the bag scheme" commenced in Aberystwyth and the surrounding area. This again utilised the clear bags used in the south of the county, into which paper, card, plastics, tins and cans could be placed. This material was collected on a weekly basis by a dedicated vehicle and after collection was bulked up at Glanyrafon transfer station on the outskirts of Aberystwyth. Bulk loads of this material were then delivered to the LAS Recycling MRF for processing (Keenan 2007).

Figures 2.7 and 2.8 illustrate the source of the material segregated for recycling in the years 2003/04 and 2006/07 respectively. It highlights that the quantity of material recycled increased from 11059 tonnes in 2003/04 to 16682 tonnes in 2006/07. This increase was observed in both material taken to CA sites and also collected at the kerbside via RCVs. The proportion of material collected for recycling at CA sites decreased significantly from 96.2% to 77.8% in 2003/04 and 2006/07 respectively. Both the proportion and quantity of material recovered for recycling by Refuse Collection Vehicles (RCV) at the kerbside increased from 2003/04 to 2006/07, this was as a result of the expansion of the kerbside recycling scheme within the Authority.



(Data in tonnes unless otherwise stated)

Figure 2.7: Recyclable Source Tonnage and Composition in the Case Study Authority 2003/04 (Keenan 2007)



(Data in tonnes unless otherwise stated)

Figure 2.8: Recyclable Source Tonnage and Composition in the Case Study Authority 2006/07 (Keenan 2007)

The Authority continues to explore methods of expanding their kerbside recycling scheme. However, no decision has yet been made as to what will happen once the current waste management contracts come to an end in 2008 (Keenan 2007).

2.5 SUMMARY

Chapter 2 discussed the variations found in MSW composition in various studies conducted in the case study area, and the main factors which impact on MSW generation and composition, namely affluence and seasonality.

This chapter detailed the infrastructure available within the case study authority for diverting household waste away from landfill and discussed the use of survival bags as the main mode of collecting recyclable and compostable materials at the kerbside within the Authority. The region is improving in terms of the proportion of municipal waste which is being diverted away from landfill, but it is clear that the bulk of this diversion is as a result of the performance of the Authority's civic amenity and bring site network.

CHAPTER 3: Characterisation of Household Waste

3.1 INTRODUCTION

This chapter will consider the total household waste composition in the case study area, as well as the composition of dry recyclable, organics collection and residual waste. Weekly set out in the kerbside recycling scheme will also be discussed. The main thrust of the discussion will look at the variation in composition at various sampling locations within the study area and also the seasonal variation in waste composition. This chapter will further consider the potentially recoverable fraction of household waste and the capture of this material in the established kerbside recycling scheme.

The quantity of waste generated per household varies significantly. Numerous studies have been conducted on the factors impacting on waste generation and composition. These factors include socio-economic factors, population growth, location, seasonality for example. Research has shown that the generation of MSW is linked to the economic development of a location, i.e., as the Gross Domestic Product (GDP) increases, so too does MSW generation (Stanners and Bordeau 1995). Changes in housing trends also affects MSW generation, for example a growth in single occupancy households tends to increase waste generation (OECD, 2004).

Changes are also observed in waste composition, which varies on an international, national and even local scale. Waste composition is dependent on a number of factors including, level of industrialisation and type of industry, location, climate, collection system, population density, legislative controls, seasonality and public attitudes. For example affluent areas tend to generate high levels of glass and paper in their household waste stream, a sign that a large amount of jars and bottles are used (cooking sauces, wine) and also that broad sheet newspapers may be read. Less affluent areas tend to have lower levels of paper and glass, but high levels of combustibles, mainly from disposal nappies. Garden waste also increases during the summer months, which varies waste composition on a seasonal basis. The influx of tourists to areas can also affect waste composition (DoE, 1994 and Williams, 2005).

Waste characterisation studies highlight the changes in waste generation habits over the years. One of the most notable changes has been the decrease in the ash content of household waste, which has been as a result of the move away from coal fires in the 1950s and 1960s;. Plastics are another notable change, as their introduction has added new elements to the household waste stream (Open University 1993, in Williams, 2005). These differences highlight changing consumer practices, and predictions for future changes to consumer practices and consequently waste composition are highly important to both the government to meet targets and also the waste management industry.

Household waste generally consists of the following materials:

- paper and cardboard, that is newspapers, magazines, containers, and other packaging;
- glass containers, e.g. jars, and bottles;
- ferrous metals, e.g. steel food and beverage cans;
- non-ferrous metals, that is beverage cans, aluminium foil;
- plastic containers and film;
- food waste, that is food preparation wastes such as vegetable peelings, leftover food etc.;
- garden waste, that is grass, leaves, tree and plant clippings etc.;

- textiles; and,
- other miscellaneous wastes.

It is vital that waste characterisation studies are conducted in order to determine the suitability and effectiveness of various waste management options. This work is needed to ensure that quality data are obtained for the case study authority, which can be used in the MRF design process, and also can be used for modelling purposes to determine the effectiveness of alternative kerbside schemes for example. The composition data can also be used to analyse the effectiveness of current kerbside schemes, for example the proportion of targeted materials recovered, and the significance of contamination problems (Owen *et al.*, 2006a).

3.2 METHODOLOGY

3.2.1 Background

Waste characterisation is essentially the breakdown of the waste into various categories, and these can be expressed as a percentage of the whole material. A number of waste characterisation studies have been completed, however, there is no nationally accepted method; hence, it can be difficult to compare results from different studies (Parfitt 2002; National Assembly for Wales 2003; Cheshire Local Government Association 2001). Waste characterisation data however vary significantly from area to area, and it is critical that Local Authorities within the UK collate this data so that they can be used in the design of waste management schemes, and also for the purposes of monitoring such schemes.

There are three main steps to characterise waste:

- select sample locations;
- obtain samples; and,
- categorise into type and mass.

Any samples collected must be representative of the whole area. The samples should be random, but with care not to collect from only areas of similar socio-economic status as that may not be representative of an area as a whole (only collecting from a council estate would bias the data). If samples are taken from a collection vehicle, the sample must again be taken randomly from that vehicle, this could be achieved for example by using a cone and quartering method for obtaining the sample (Woodcock and Mason, 1995).

It is vitally important when collecting any sample to obtain a large enough sample so that it is representative of the material as a whole, without the sample being too large to handle practicably. This is in order to ensure that any data obtained from the sample is accurate and is representative of the material as a whole. In terms of statistics, accuracy is dependent on the size and number of samples taken. Household waste is essentially a combination of a variety of materials, therefore determining the required sample size is difficult.

A number of studies have looked at the sample size required when analysing household waste. A study by Van den Broek and Kirov suggests that to obtain a representative sample, 1.3% of household waste in an area should be sampled (Van den Broek and Kirov, 1971). For the whole of the case study area, approximately 90 tonnes of household waste is collected by Refuse Collection Vehicles (RCV's) each day. Hence, in accordance with Van den Broek and Kirov's study 1.17 tonnes of RCV material would be a representative sample for the case study authority as a whole. For the households which were part of the pilot kerbside recycling schemes within the case study authority, approximately 16 tonnes of household waste was collected per day; hence, a 208kg sample would be representative for the pilot kerbside recycling schemes areas. Another study conducted by MEL suggests that 500kg of household waste containing fragments up to 300mm in diameter would be sufficient to provide a representative sample (MEL, 1996). A study carried out in the USA in the 1970s found that the standard deviation in results from samples were as valid from samples of 100kg to those of 800kg, that is the accuracy of the data from the 100kg sample were similar to the data obtained from 800kg samples (MEL, 1996). Also, a study by Moore *et al*, suggests that a sampling size of 100kg has an accuracy with a 90% confidence limit (Moore *et al.*, 1995). As a result, a characterisation methodology was developed based on sample sizes of approximately 500kg which would give results with a maximum standard error of 10% (Emery *et al.*, 2000a; Emery *et al.*, 2000b; and Emery *et al.*, 2002).

Any sorting activity can be carried out by two means: by hand or by machine. Hand sorting is a labour intensive operation, but is a highly effective option. Essentially the sample of waste is sorted manually into various categories until there is no residue. The sample can either be obtained from a collection vehicle or collected directly from homes. The latter is the preferred option as it reduces the compaction and contamination of different wastes, which makes the sorting process easier and more accurate. The health aspects of this option are an important consideration, by its nature household waste is a biologically active material. Hence, there are risks from bioaerosols and other biological matter. There are also health risks from broken glass, used needles and so forth. It is crucial that these risks are minimised by carrying out a risk assessment, and implementing control measures to minimise the risks identified, for example sorting the material in a well ventilated area, the use of appropriate safety equipment and ensuring that sorting personnel have adequate immunisations.

Machine separation is a more complex method and would be on the basis of a MRF. A conveyor belt would be used to carry the waste to various separating systems, which could include magnets, vibrating screens, etc. Though effective there are some inherent problems in these processes and would not get near to the accuracy of hand separation. Magnets can often miss objects if a larger fragment of a different material covers them. Similarly large ferrous fragments can pick up smaller fragments of other materials when being attracted to the magnets this in turn again causes contamination. This problem would not occur with hand separation.

The sorting categories used for various studies are very similar; however, there are many variations in the sub-categories. The best option is to sort the sample into as many sub-categories as possible within the time constraints of the project as it is then possible to combine some of these together to enable more accurate comparisons to be made with other studies.

3.2.2 Waste Characterisation Protocol

3.2.2.1 Study Area Selection

The aim of the study was to determine the composition of household waste in the case study area, to assess the effects of seasonality, and also to assess variation across a number of sampling locations. The study also looked at the performance of the existing kerbside recycling scheme. Hence, the potential sampling locations were limited to those areas which already had a kerbside recycling scheme in place. Within the study, the performance in rural and urban areas within the local authority were to be investigated; however, this was confined to the survival bag scheme, as the alternative recycling scheme was only found in an urban area. Sampling locations were governed to some extent by the collection days and routes. For each day a list of potential areas was drawn up, to aid the selection of three sampling locations to represent the following areas: urban survival bag scheme, rural survival bag scheme, and box scheme areas.

The Townsend Index is a score for socio-economic status and further information on the Townsend Index score can be found in Appendix A. The score for the Townsend Index was calculated from four of the 2001 census variables, these are unemployment, overcrowding, lack of owner occupied accommodation and lack of car ownership. The more negative the Townsend Index score, the more affluent the area, and the more positive the score the more deprived the area (Woollam *et al.*, 2003b). Using the 2001 census data, the Townsend Index scores were determined to aid the selection of sampling locations within the case study area.

At the time of the first characterisation in February 2005, only a small proportion of households were covered by a kerbside recycling scheme as discussed in Chapter 2. Hence, the choice of sampling locations was very limited, and as a result three sampling locations were selected:

- A (Cardigan Mwldan) – urban survival bag scheme area;
- B (Gwbert and Y Ferwig) – rural survival bag scheme area; and,
- C (Lampeter) – kerbside box scheme area.

Figure 2.2 highlights the locations of these sampling locations within the case study authority. Therefore, when assessing the seasonal variation in September 2005, the same three sampling locations were used for comparison. However, as a result of a change by the local authority in the Lampeter area, namely a move away from the kerbside box scheme to a clear bag scheme, and the fact that all recyclable is collected in Lampeter on the same day of the week, the sample study within Lampeter had to be changed so that clear bags and residual waste could be collected on the same day; however, a location within a similar demographic area to the previous study was selected.

3.2.2.2 Set Out Rate Survey

Prior to the start of the study, a set out rate survey was carried out to determine set out rates and the ratio of black bags to recycling bags/ boxes.

1. A survey was conducted in the study areas on the day of collection, the information collected was as follows:
    a. date and time
    b. street name
    c. number of households in street

d. number of houses participating in the recycling scheme, i.e. at least one bag/ box set out

e. number of black bags

f. number of recycling containers

2. Step 1 was repeated for each street/ cul de sac/ estate etc.
3. Data obtained from the set out rate survey was input into a spreadsheet to enable comparisons to be made between areas in terms of performance.

3.2.2.3 Sample Collection

The methodology for sample collection was adapted from the method used to carry out a waste characterisation on household waste (black bag material only) at Rhondda Cynon Taf (RCT) County Borough Council (Emery et al., 2000b). The procedure used is shown in steps A to E:

A. Samples were collected from homes by the sample team to minimise compaction and contamination of the material, which will make the waste classification process easier and will also improve the accuracy of the exercise.

B. The locations to be covered on the various days are shown in Table 3.1.

Table 3.1: Sample Locations and Collection Dates

Sampling Location	Winter 2005	Summer 2005	Townsend Index Score
A	Mon 04/03/05	Fri 16/9/05	+0.83
B	Mon 28/02/05	Mon 19/09/05	-2.11
C	Tue 01/03/05 (½) Thurs 03/04/05 (½)	Mon 12/09/05	+2.80

C. Samples were collected from different waste collection routes and types of location, for example towns, villages, hamlets, to determine if there were any differences in their performance.

D. Sample size for the waste classification exercise was typically 1000kg (approximately 30 households who were participating in the recycling scheme, except in the black bag area where waste from 30 households was collected). The only exception was in the case of the two survival bag schemes as there may not be many green/ brown organic bags due to the time of year. Therefore, as many green/ brown bags as possible were collected from the households.

E. After collection, samples were returned to site and sorted as shown in section 3.2.2.4

3.2.2.4 Waste Characterisation

The methodology for the characterisation was adapted from the method used to carry out a waste characterisation on household waste (black bag material only) at RCT County Borough Council (Emery et al., 2000b). The method is as follows:

I. The samples were returned to site and taken over the weighbridge and the total mass determined minus the mass of the vehicle.

II. The bag types were sorted into the following categories, that is black, clear (dry recyclable) and green (organic) bags. Each bag type was then weighed on the weighbridge to determine the mass of each of the three fractions.

III. The black bags were hand sorted first. The bags were simply emptied onto the sorting table (Dimensions 2m x 4m).

IV. The material was Hand sorted into the relevant bins/ boxes/ bags for each of the following categories:

- Paper and Cardboard:
  - Bin 1: Newspapers
  - Bin 2: Magazines
  - Bin 3: Other Paper
  - Bin 4: Liquid Cartons
  - Bin 5: Card Packaging
  - Bin 6: Composite Packaging
- Glass:
  - Bin 7: Brown glass bottles
  - Bin 8: Green glass bottles
  - Bin 9: Clear glass bottles
  - Bin 10: Broken brown glass
  - Bin 11: Broken green Glass
  - Bin 12: Broken clear glass
- Ferrous Metals:
  - Bin 13: Beverage cans
  - Bin 14: Food cans
  - Bin 15: Batteries
  - Bin 16: Other cans
  - Bin 17: Other ferrous
- Non-ferrous metals:
  - Bin 18: Beverage cans
  - Bin 19: Foil

    - Bin 20: Other
  - Plastic
    - Bin 21: PET (Polyethylene Terephtalate)
    - Bin 22: HDPE (High Density Polyethylene)
    - Bin 23: PVC (Polyvinyl Chloride
    - Bin 24: LDPE (Low Density Polyethylene)
    - Bin 25: PP (Polypropylene)
    - Bin 26: PS (Polystyrene)
    - Bin 27: Other
  - Putrescible:
    - Bin 27: Garden waste
    - Bin 28: Kitchen waste – animal products
    - Bin 29: Kitchen waste – non-animal products
    - Bin 30: Other putrescible
  - Textiles:
    - Bin 31: Textiles
  - Others:
    - Bin 32: Fines
    - Bin 33: Inert
    - Bin 34: Miscellaneous

V. The contents of each component bin was weighed (remembering to take account of the mass of the bin) to obtain the mass of each fraction present. A 75kg balance with an accuracy of 50g was used.

VI. Once weighed, the sorted material was removed from the bins and placed in a relevant section for recycling. If the segregated material was destined for disposal to landfill, this was placed in a different location.

VII. Once the above operations were completed, the sorting table was cleared for the next task.

VIII. The dry recyclable bags were the next type to be hand sorted. The bags were emptied onto the sorting table.

IX. Steps IV to VIII were repeated for the dry recyclable bags.

X. The organic bags were then placed on the sorting table. Each bag was opened, and any contamination (i.e. non-organic material) was removed and placed into the relevant bin.

XI. Repeat steps V to VIII as for black and dry recyclable bags.

XII. The next stage was to enter the results into a spreadsheet to determine the waste composition as a percentage of the total, and to give indications of waste generated per household. Recovery rates as a percentage of the total potential recyclable available were also determined.

XIII. A comparison was made of the weighbridge results with the summation of the 34 sorted categories.

3.3 RESULTS

Tables 3.2 to 3.7 highlights the raw data collated for sampling locations A, B and C. These tables identify the set out data collated for the sampling location during the Winter and Summer studies. The data collated included the number of households within the sampling area (H_T), the number of bags set out by householders and the number of households setting out in the kerbside recycling scheme (H_S). These data enabled the calculation of weekly set out (S), as follows:

$$S(\%) = \frac{H_S}{H_P} x100$$

Since set out was assessed during the Winter and Summer period, an assessment of improvements to the effectiveness of the kerbside recycling scheme can be made.

Tables 3.8 to 3.13 show the raw data obtained from the waste classification exercise at sampling locations A, B and C for both the Winter and Summer periods. A further breakdown of the waste classification data at Location C is shown in Appendix B. The data includes the number of households from which waste was collected, and a breakdown of the sample into the 34 sorting categories. This provides a compositional analysis of the residual (black bag) waste stream, the dry recyclable (clear bag) stream, and the organics (green bag) stream by percentage and also by mass. The figures for these three streams are directly combined to provide the total household waste composition data for the sampling location.

An assessment of contamination was also highlighted for the clear and green bag streams. This is quantified by taking account of the material streams not requested in the clear and green bag streams, and therefore can be quantified in terms of both mass and percentage. An assessment of seasonality can also be undertaken since data was collected in both the Winter and Summer periods.

Further analysis on these data and the data for the other sampling locations is discussed in the remaining sections of this chapter.

Table 3.2: Set Out Rate Data for Location A - Winter

Date:	03/02/2005
Time:	7.30-9.30am
E.D.	Cardigan Mwldan

Street	Ger y Meini (6-12)	Heol Helyg	Greenland Meadows	Heol Onnen	Grove Park	Maesglas (1-20)	Y Rhos	Maesglas (150-159 & 175-179	TOTAL
No. Households	6	31	25	10	24	20	38	15	169
No. Black Bags	6	23	23	4	12	20	32	20	140
No. Clear Bags	6	12	5	2	12	8	19	5	69
No. Green Bags	0	11	4	3	9	3	7	6	43
No. Households Participating	3	11	8	3	18	7	16	7	73
No. Households with no rubbish/ recycling set out	2	9	11	4	8	5	10	5	54
Recycling Scheme Set Out Rate (%)	50.0	35.5	32.0	30.0	75.0	35.0	42.1	46.7	43.2
Average no. black bags per household	1.0	0.7	0.9	0.4	0.5	1.0	0.8	1.3	0.8
Average no. clear bags per household	1.0	0.4	0.2	0.2	0.5	0.4	0.5	0.3	0.4
Average no. green bags per household	0.0	0.4	0.2	0.3	0.4	0.2	0.2	0.4	0.3

Table 3.3: Set Out Rate Data for Location A- Summer

Date:	07/10/2005
Time:	7.30-9.30am
E.D.	Cardigan Mwldan

Street	Ger y Meini (6-12)	Heol Helyg	Greenland Meadows	Heol Onnen	Grove Park	Maesglas (1-20)	Y Rhos	Maesglas (150-159 & 175-179	TOTAL
No. Households	6	31	25	10	24	20	38	15	169
No. Black Bags	7	37	38	10	37	23	44	15	211
No. Clear Bags	7	12	10	7	17	4	24	2	83
No. Green Bags	6	11	10	7	16	4	14	11	79
No. Households Participating	4	15	15	7	17	3	22	5	88
No. Households with no rubbish/ recycling set out	1	4	3	0	2	3	4	2	19
Recycling Scheme Set Out Rate (%)	66.7	48.4	60.0	70.0	70.8	15.0	57.9	33.3	52.1
Average no. black bags per household	1.2	1.2	1.5	1.0	1.5	1.2	1.2	1.0	1.2
Average no. clear bags per household	1.2	0.4	0.4	0.7	0.7	0.2	0.6	0.1	0.5
Average no. green bags per household	1.0	0.4	0.4	0.7	0.7	0.2	0.4	0.7	0.5

Table 3.4: Set Out Rate Data for Location B - Winter

Date:	07/02/2005
Time:	8.15-9.30am
E.D.	Penparc

Street	Y Ferwig					Gwbert			TOTAL
	Maes Pedrog	Clos y Gwyddil	rd by chapel	main road	road by Petrol station	rd by telephone box	dead end	main road	
No. Households	10	4	8	21	3	11	8	7	**72**
No. Black Bags	19	9	10	26	1	18	15	9	**107**
No. Clear Bags	4	1	8	13	1	1	5	7	**40**
No. Green Bags	2	0	2	17	1	5	0	7	**34**
No. Households Participating	3	1	7	11	1	2	4	5	**34**
No. Households with no rubbish/ recycling set out	4	0	0	8	2	4	2	0	**20**
Recycling Scheme Set Out Rate (%)	**30.0**	**25.0**	**87.5**	**52.4**	**33.3**	**18.2**	**50.0**	**71.4**	**47.2**
Average no. black bags per household	1.9	2.3	1.3	1.2	0.3	1.6	1.9	1.3	**1.5**
Average no. clear bags per household	0.4	0.3	1.0	0.6	0.3	0.1	0.6	1.0	**0.6**
Average no. green bags per household	0.2	0.0	0.3	0.8	0.3	0.5	0.0	1.0	**0.5**

Table 3.5: Set Out Rate Data for Location B - Summer

Date:	03/10/2005
Time:	8.15-9.30am
E.D.	Penparc

Street	Y Ferwig					Gwbert			TOTAL
	Maes Pedrog	Clos y Gwyddil	rd by chapel	main road	road by Petrol station	rd by telephone box	dead end	main road	
No. Households	10	4	8	21	3	11	8	7	**72**
No. Black Bags	13	11	20	25	6	19	16	3	**113**
No. Clear Bags	9	0	6	10	0	7	4	4	**40**
No. Green Bags	3	0	8	12	0	0	0	7	**30**
No. Households Participating	5	2	4	9	0	6	3	5	**34**
Recycling Scheme Set Out Rate (%)	**50.0**	**50.0**	**50.0**	**42.9**	**0.0**	**54.5**	**37.5**	**71.4**	**47.2**
Average no. black bags per household	1.3	2.8	2.5	1.2	2.0	1.7	2.0	0.4	**1.6**
Average no. clear bags per household	0.9	0.0	0.8	0.5	0.0	0.6	0.5	0.6	**0.6**
Average no. green bags per household	0.3	0.0	1.0	0.6	0.0	0.0	0.0	1.0	**0.4**

Table 3.6: Set Out Rate Data for Location C- Winter

Date:	08/02/2005	10/02/2005
Time:	11am	9.30am
E.D.	Lampeter	

Street	08/02/2005		10/02/2005			TOTAL
	Ffynnonbedr	Maesyllan	Mill Street	Maesyfelin	Parcyfelin	
No. Households	31	10	16	29	28	114
No. Black Bags	50	12	24	41	45	172
No. Green Boxes	16	9	1	8	12	46
No. Households Participating	16	9	1	8	12	46
No. Households with no rubbish/ recycling set out	4	0	4	5	4	17
Recycling Scheme Set Out Rate (%)	51.6	90.0	6.3	27.6	42.9	40.4
Average no. black bags per household	1.6	1.2	1.5	1.4	1.6	1.5
Average no. green boxes per household	0.5	0.9	0.1	0.3	0.4	0.4

Table 3.7: Set Out Rate Data for Location C - Summer

Date:	26/09/2005
Time:	8.15am
E.D.	Lampeter

Street	Penbryn	Bryn yr Eglwys (21-26)	Bryn yr Eglwys (1-20)	Maes y Deri	Gwel y Creuddyn	TOTAL
No. Households	46	5	20	53	23	147
No. Black Bags	67	2	36	90	28	223
No. Clear Bags	9	0	4	12	10	35
No. Green Boxes	25	2	19	0	0	46
No. Garden Waste Bags	0	3	1	0	0	4
No. Households Participating in clear bag scheme	9	0	2	10	7	28
No. Households Participating in green box scheme	14	2	18	0	0	34
No. Households Participating in garden waste scheme	0	1	1	0	0	2
No. Households with no rubbish/ recycling set out	16	3	2	17	4	42
Clear Bag Recycling Scheme Set Out Rate (%)	19.6	0.0	10.0	18.9	30.4	19.0
Green Box Recycling Scheme Set Out Rate (%)	30.4	40.0	90.0	0.0	0.0	23.1
Garden Waste Scheme Set Out Rate (%)	0.0	20.0	5.0	0.0	0.0	1.4
Total Recycling Schemes Set Out Rate (%)	50.0	40.0	100.0	18.9	30.4	42.2
Average no. black bags per household	1.5	0.4	1.8	1.7	1.2	1.5
Average no. clear bags per household	0.2	0.0	0.2	0.2	0.4	0.2
Average no. green boxes per household	0.5	0.4	1.0	0.0	0.0	0.3

Table 3.8: Waste Classification Data for Location A- Winter

Place:	Cardigan
E.D:	Cardigan Mwldan
Date:	04/03/2005
Households:	40

Category	Sub-category	BLACK BAGS			CLEAR BAGS			GREEN BAGS			TOTAL WASTE		
		Black Bags (kg)	% Composition	% Category Composition	Clear Bags (Kg)	% Composition	% Category Composition	Brown Bags (Kg)	% Composition	% Category Composition	Total Weight (kg)	% Composition	% Category Composition
Paper	Newspaper	3.74	1.25		48.54	32.39		0.00	0.00		52.28	9.85	
	Magazines	3.54	1.18		17.34	11.57		0.00	0.00		20.88	3.93	
	Other Paper	11.94	3.98		7.43	4.96		0.00	0.00		19.37	3.65	
	Liquid Cartons	0.89	0.30		1.24	0.83		0.00	0.00		2.13	0.40	
	Card Packaging	11.89	3.96		22.17	14.79		0.00	0.00		34.06	6.42	
	Composite Packaging	0.74	0.25	10.91	0.74	0.49	65.0	0.00	0.00	0.00	1.48	0.28	24.53
Glass	Brown Glass Bottles	2.64	0.88		0.00	0.00		0.00	0.00		2.64	0.50	
	Green Glass Bottles	6.33	2.11		0.00	0.00		0.00	0.00		6.33	1.19	
	Clear Glass Bottles	14.94	4.98		0.00	0.00		0.00	0.00		14.94	2.81	
	Broken Brown Glass	0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00	
	Broken Green Glass	0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00	
	Broken Clear Glass	0.00	0.00	7.97	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00	4.50
Ferrous Metals	Beverage Cans	0.29	0.10		0.49	0.33		0.00	0.00		0.78	0.15	
	Food Cans	4.39	1.46		7.09	4.73		0.00	0.00		11.48	2.16	
	Batteries	0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00	
	Other Cans	0.34	0.11		0.14	0.09		0.00	0.00		0.48	0.09	
	Other Ferrous	0.69	0.23	1.90	0.00	0.00	5.2	0.00	0.00	0.00	0.69	0.13	2.53
Non-ferrous metals	Beverage Cans	0.04	0.01		0.04	0.03		0.00	0.00		0.08	0.02	
	Foil	0.79	0.26		0.19	0.13		0.00	0.00		0.98	0.18	
	Other	0.00	0.00	0.28	0.00	0.00	0.2	0.00	0.00	0.00	0.00	0.00	0.20
Plastic	PET	1.99	0.66		4.89	3.26		0.00	0.00		6.88	1.30	
	HDPE	0.74	0.25		4.99	3.33		0.00	0.00		5.73	1.08	
	PVC	1.59	0.53		0.34	0.23		0.00	0.00		1.93	0.36	
	LDPE	8.94	2.98		6.84	4.56		0.00	0.00		15.78	2.97	
	PP	5.04	1.68		2.49	1.66		0.00	0.00		7.53	1.42	
	PS	1.34	0.45		0.64	0.43		0.00	0.00		1.98	0.37	
	Other	4.74	1.58	8.13	5.79	3.86	17.3	0.00	0.00	0.00	10.53	1.98	9.49
Putrescible	Garden Waste	1.39	0.46		0.00	0.00							
	Kitchen Waste - Animal	7.70	2.57		0.04	0.03							
	Kitchen Waste - Non-animal	126.69	42.24		1.34	0.89							
	Other Putresible	16.94	5.65	50.91	0.00	0.00	0.9	77.50	95.68	95.68	231.60	43.63	43.63
Textiles	Textiles	1.99	0.66	0.66	12.85	8.58	8.6	0.00	0.00	0.00	14.84	2.80	2.80
Other	Fines	25.74	8.58		0.04	0.03		0.00	0.00		25.78	4.86	
	Inert	0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00	
	Miscellaneous	16.54	5.51		4.19	2.80		3.50	4.32		24.23	4.56	
	Nappies	15.40	5.13	19.23	0.00	0.00	2.8	0.00	0.00	4.32	15.40	2.90	12.32
Combined Weight		**299.96**	100.00	100.00	**149.85**	**100.00**	**100.0**	**81.00**	**100.00**	**100.00**	**530.81**	**100.00**	**100.00**
CONTAMINATION					**21.08**		**14.07**	**3.50**		**4.32**			
Average Wt per household (kg/wk)		**7.50**			**4.10**			**2.03**			**13.27**		

Table 3.9: Waste Classification Data for Sampling Location A- Summer

Place:	**Cardigan**
E.D:	**Cardigan Mwldan**
Date:	**16/09/2005**
Household:	**30**

Category	Sub-category	BLACK BAGS			CLEAR BAGS			GREEN BAGS			TOTAL WASTE		
		Black Bags (kg)	% Composition	% Category Composition	Clear Bags (Kg)	% Composition	% Category Composition	Green Bags (Kg)	% Composition	% Category Composition	Total Weight (kg)	% Composition	% Category Composition
Paper	Newspaper	0.60	0.35		35.59	27.94		0.00	0.00		36.19	7.63	
	Magazines	0.00	0.00		22.79	17.89		0.00	0.00		22.79	4.80	
	Other Paper	9.29	5.46		28.04	22.01		0.00	0.00		37.33	7.87	
	Liquid Cartons	1.29	0.76		0.59	0.46		0.00	0.00		1.88	0.40	
	Card Packaging	2.39	1.40		14.74	11.57		0.00	0.00		17.13	3.61	
	Composite Packaging	0.39	0.23	8.20	1.04	0.82	80.7	0.00	0.00	0.00	1.43	0.30	24.61
Glass	Brown Glass Bottles	0.84	0.49		0.00	0.00		0.00	0.00		0.84	0.18	
	Green Glass Bottles	5.04	2.96		0.69	0.54		0.00	0.00		5.73	1.21	
	Clear Glass Bottles	9.59	5.64		0.60	0.47		0.00	0.00		10.19	2.15	
	Broken Brown Glass				0.00	0.00		0.00	0.00		0.00	0.00	
	Broken Green Glass				0.00	0.00		0.00	0.00		0.00	0.00	
	Broken Clear Glass	0.00	0.00	9.09	0.00	0.00	1.0	0.00	0.00	0.00	0.00	0.00	3.53
Ferrous Metals	Beverage Cans	0.24	0.14		0.04	0.03		0.00	0.00		0.28	0.06	
	Food Cans	1.64	0.96		4.44	3.49		0.00	0.00		6.08	1.28	
	Batteries	0.44	0.26		0.00	0.00		0.00	0.00		0.44	0.09	
	Other Cans	0.20	0.12		0.00	0.00		0.00	0.00		0.20	0.04	
	Other Ferrous	0.00	0.00	1.48	0.00	0.00	3.5	0.00	0.00	0.00	0.00	0.00	1.48
Non-ferrous metals	Beverage Cans	0.04	0.02		0.29	0.23		0.00	0.00		0.33	0.07	
	Foil	0.84	0.49		0.09	0.07		0.00	0.00		0.93	0.20	
	Other	0.69	0.41	0.92	0.29	0.23	0.5	0.00	0.00	0.00	0.98	0.21	0.47
Plastic	PET	0.44	0.26		3.34	2.62		0.00	0.00		3.78	0.80	
	HDPE	1.44	0.85		3.49	2.74		0.00	0.00		4.93	1.04	
	PVC	0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00	
	LDPE	6.99	4.11		4.59	3.60		0.00	0.00		11.58	2.44	
	PP	0.79	0.46		0.99	0.78		0.00	0.00		1.78	0.38	
	PS	0.14	0.08		0.24	0.19		0.00	0.00		0.38	0.08	
	Other	4.29	2.52	8.28	4.94	3.88	13.8	0.00	0.00	0.00	9.23	1.95	6.68
Putrescible	Garden Waste	2.39	1.40		0.00	0.00							
	Kitchen Waste - Animal	6.99	4.11		0.14	0.11							
	Kitchen Waste - Non-animal	78.59	46.18		0.24	0.19							
	Other Putresible	5.44	3.20	54.89	0.00	0.00	0.3	174.76	98.81	98.81	268.55	56.60	56.60
Textiles	Textiles	6.64	3.90	3.90	0.19	0.15	0.1	0.00	0.00	0.00	6.83	1.44	1.44
Other	Fines	3.23	1.90		0.00	0.00		0.00	0.00		3.23	0.68	
	Inert	0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00	
	Miscellaneous	8.89	5.22		0.00	0.00		2.11	1.19		11.00	2.32	
	Nappies	10.40	6.11	13.23	0.00	0.00	0.0	0.00	0.00	1.19	10.40	2.19	5.19
Combined Weight		**170.18**	100.00	100.00	**127.39**	**100.00**	**100.0**	**176.87**	**100.00**	**100.00**	**474.44**	**100.00**	**100.00**
CONTAMINATION					**8.96**		**7.03**	**2.11**		**1.19**			
Average Wt per household (kg/wk)		**5.67**			**4.25**			**5.90**			**15.81**		

Table 3.10: Waste Classification Data for Sampling Location B - Winter

Place:	Gwbert & Ferwig
E.D:	Penparc
Date:	28/02/2005
Households:	30

Category	Sub-category	BLACK BAGS			CLEAR BAGS			GREEN BAGS			TOTAL WASTE		
		Black Bags (kg)	% Composition	% Category Composition	Pink Bags (Kg)	% Composition	% Category Composition	Brown Bags (Kg)	% Composition	% Category Composition	Total Weight (kg)	% Composition	% Category Composition
Paper	Newspaper	2.79	1.57		26.19	16.38		0.00	0.00		28.98	6.51	
	Magazines	2.39	1.35		32.34	20.22		0.00	0.00		34.73	7.81	
	Other Paper	6.64	3.74		24.13	15.09		0.00	0.00		30.77	6.92	
	Liquid Cartons	0.69	0.39		0.19	0.12		0.00	0.00		0.88	0.20	
	Card Packaging	2.44	1.37		13.78	8.62		0.00	0.00		16.22	3.65	
	Composite Packaging	1.24	0.70	9.12	0.64	0.40	60.8	0.00	0.00	0.00	1.88	0.42	25.50
Glass	Brown Glass Bottles	1.69	0.95		1.14	0.71		0.00	0.00		2.83	0.64	
	Green Glass Bottles	4.84	2.73		0.34	0.21		0.00	0.00		5.18	1.16	
	Clear Glass Bottles	6.44	3.63		2.74	1.71		0.00	0.00		9.18	2.06	
	Broken Brown Glass	0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00	
	Broken Green Glass	0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00	
	Broken Clear Glass	0.00	0.00	7.31	0.00	0.00	2.6	0.00	0.00	0.00	0.00	0.00	3.86
Ferrous Metals	Beverage Cans	0.14	0.08		0.74	0.46		0.00	0.00		0.88	0.20	
	Food Cans	2.64	1.49		3.59	2.24		0.00	0.00		6.23	1.40	
	Batteries	0.19	0.11		0.00	0.00		0.00	0.00		0.19	0.04	
	Other Cans	0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00	
	Other Ferrous	0.19	0.11	1.78	0.10	0.06	2.8	0.00	0.00	0.00	0.29	0.07	1.71
Non-ferrous metals	Beverage Cans	0.49	0.28		0.39	0.24		0.00	0.00		0.88	0.20	
	Foil	0.99	0.56		0.10	0.06		0.00	0.00		1.09	0.24	
	Other	0.00	0.00	0.83	0.00	0.00	0.3	0.00	0.00	0.00	0.00	0.00	0.44
Plastic	PET	0.54	0.30		2.39	1.49		0.00	0.00		2.93	0.66	
	HDPE	1.64	0.92		3.89	2.43		0.00	0.00		5.53	1.24	
	PVC	0.19	0.11		0.00	0.00		0.00	0.00		0.19	0.04	
	LDPE	4.79	2.70		4.19	2.62		0.00	0.00		8.98	2.02	
	PP	2.04	1.15		1.69	1.06		0.00	0.00		3.73	0.84	
	PS	0.74	0.42		0.09	0.06		0.00	0.00		0.83	0.19	
	Other	4.84	2.73	8.33	2.69	1.68	9.3	0.00	0.00	0.00	7.53	1.69	6.68
Putrescible	Garden Waste	2.64	1.49		0.00	0.00							
	Kitchen Waste - Animal	7.24	4.08		0.19	0.12							
	Kitchen Waste - Non-animal	71.99	40.57		4.19	2.62							
	Other Putresible	7.84	4.42	50.55	0.00	0.00	2.7	92.95	86.42	86.42	187.04	42.04	42.04
Textiles	Textiles	1.94	1.09	1.09	0.05	0.03	0.0	0.00	0.00	0.00	1.99	0.45	0.45
Other	Fines	25.29	14.25		0.00	0.00		0.00	0.00		25.29	5.68	
	Inert	0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00	
	Miscellaneous	11.94	6.73		34.14	21.35		14.60	13.58		60.68	13.64	
	Nappies			20.98			21.3	0.00	0.00	13.58	0.00	0.00	19.32
Combined Weight		**177.46**	100.00	100.00	**159.92**	**100.00**	**100.0**	**107.55**	**100.00**	**100.00**	**444.93**	**100.00**	**100.00**
CONTAMINATION					**43.81**		**27.39**	**14.60**		**13.58**			
Average Wt per household (kg/wk)		**5.92**			**5.33**			**3.59**			**14.83**		

Table 3.11: Waste Classification Data for Sampling Location B - Summer

Place:	Gwbert & Y Ferwig
E.D:	Penparc
Date:	19/09/2005
Households:	30

Category	Sub-category	BLACK BAGS			CLEAR BAGS			GREEN BAGS			TOTAL WASTE		
		Black Bags (kg)	% Composition	% Category Composition	Clear Bags (Kg)	% Composition	% Category Composition	Green Bags (Kg)	% Composition	% Category Composition	Total Weight (kg)	% Composition	% Category Composition
Paper	Newspaper	4.94	2.64		67.79	34.65		0.00	0.00		72.73	12.73	
	Magazines	2.19	1.17		34.74	17.75		0.00	0.00		36.93	6.47	
	Other Paper	7.79	4.16		24.74	12.64		0.00	0.00		32.53	5.70	
	Liquid Cartons	1.09	0.58		0.79	0.40		0.00	0.00		1.88	0.33	
	Card Packaging	5.14	2.75		14.64	7.48		0.00	0.00		19.78	3.46	
	Composite Packaging	0.74	0.40	11.70	0.79	0.40	73.3	0.00	0.00	0.00	1.53	0.27	28.96
Glass	Brown Glass Bottles	4.59	2.45		0.00	0.00		0.00	0.00		4.59	0.80	
	Green Glass Bottles	5.19	2.77		0.00	0.00		0.00	0.00		5.19	0.91	
	Clear Glass Bottles	5.34	2.85		0.29	0.15		0.00	0.00		5.63	0.99	
	Broken Brown Glass	0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00	
	Broken Green Glass	0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00	
	Broken Clear Glass	0.00	0.00	8.08	0.14	0.07	0.2	0.00	0.00	0.00	0.14	0.02	2.72
Ferrous Metals	Beverage Cans	0.00	0.00		0.05	0.03		0.00	0.00		0.05	0.01	
	Food Cans	8.99	4.81		3.59	1.83		0.00	0.00		12.58	2.20	
	Batteries	0.10	0.05		0.00	0.00		0.00	0.00		0.10	0.02	
	Other Cans	0.49	0.26		0.00	0.00		0.00	0.00		0.49	0.09	
	Other Ferrous	3.50	1.87	6.99	0.00	0.00	1.9	0.00	0.00	0.00	3.50	0.61	2.93
Non-ferrous metals	Beverage Cans	0.05	0.03		1.39	0.71		0.00	0.00		1.44	0.25	
	Foil	0.49	0.26		0.19	0.10		0.00	0.00		0.68	0.12	
	Other	0.10	0.05	0.34	0.05	0.03	0.8	0.00	0.00	0.00	0.15	0.03	0.40
Plastic	PET	0.54	0.29		5.09	2.60		0.00	0.00		5.63	0.99	
	HDPE	2.69	1.44		4.44	2.27		0.00	0.00		7.13	1.25	
	PVC	0.05	0.03		0.19	0.10		0.00	0.00		0.24	0.04	
	LDPE	4.99	2.67		6.69	3.42		0.00	0.00		11.68	2.05	
	PP	1.04	0.56		0.94	0.48		0.00	0.00		1.98	0.35	
	PS	0.39	0.21		0.29	0.15		0.00	0.00		0.68	0.12	
	Other	4.89	2.61	7.80	4.54	2.32	11.3	0.00	0.00	0.00	9.43	1.65	6.44
Putrescible	Garden Waste	17.44	9.32		0.00	0.00							
	Kitchen Waste - Animal	3.89	2.08		0.00	0.00							
	Kitchen Waste - Non-animal	49.69	26.57		4.04	2.06							
	Other Putresible	0.99	0.53	38.50	0.00	0.00	2.1	185.65	98.54	98.54	261.70	45.82	45.82
Textiles	Textiles	10.54	5.63	5.63	0.49	0.25	0.3	0.00	0.00	0.00	11.03	1.93	1.93
Other	Fines	25.49	13.63		0.04	0.02		0.00	0.00		25.53	4.47	
	Inert	0.00	0.00		0.64	0.33		0.00	0.00		0.64	0.11	
	Miscellaneous	6.74	3.60		19.09	9.76		2.75	1.46		28.58	5.00	
	Nappies	6.95	3.72	20.95	0.00	0.00	10.1	0.00	0.00	1.46	6.95	1.22	10.80
Combined Wt (Kg)		187.06	100.00	100.00	195.67	100.00	100.0	188.40	100.00	100.00	571.12	100.00	100.00
CONTAMINATION					31.19		16.01	2.75		1.46			
Average Wt per household (kg/wk)		6.24			6.52			6.28			19.04		

Table 3.12: Waste Classification Data for Sampling Location C – Winter

Place:	**Lampeter Combined**
E.D:	**Lampeter**
Date:	**03/03/2005**
Households:	**43**

Category	Sub-category	Black Bags (kg)			Green Boxes (kg)			TOTAL WASTE		
		Black Bags (kg)	% Composition	% Category Composition	Green Boxes (Kg)	% Composition	% Category Composition	Total Weight (kg)	% Composition	% Category Composition
Paper	Newspaper	3.83	1.10		52.73	28.03		56.56	10.55	
	Magazines	6.38	1.83		29.53	15.70		35.91	6.70	
	Other Paper	24.93	7.17		15.48	8.23		40.41	7.54	
	Liquid Cartons	1.63	0.47		0.14	0.07		1.77	0.33	
	Card Packaging	7.08	2.04		15.67	8.33		22.75	4.25	
	Composite Packaging	1.73	0.50	13.11	0.13	0.07	60.43	1.86	0.35	29.72
Glass	Brown Glass Bottles	0.04	0.01		11.28	6.00		11.32	2.11	
	Green Glass Bottles	0.20	0.06		12.78	6.79		12.98	2.42	
	Clear Glass Bottles	5.93	1.71		17.83	9.48		23.76	4.43	
	Blue Glass Bottles	0.00	0.00		1.54	0.82		1.54	0.29	
	Broken Brown Glass	0.00	0.00		0.00	0.00		0.00	0.00	
	Broken Green Glass	0.00	0.00		0.00	0.00		0.00	0.00	
	Broken Clear Glass	0.09	0.03	1.80	0.00	0.00	23.09	0.09	0.02	9.27
Ferrous Metals	Beverage Cans	0.29	0.08		0.48	0.26		0.77	0.14	
	Food Cans	6.88	1.98		4.73	2.51		11.61	2.17	
	Batteries	0.74	0.21		0.02	0.01		0.76	0.14	
	Other Cans	0.19	0.05		0.13	0.07		0.32	0.06	
	Other Ferrous	0.34	0.10	2.43	0.99	0.53	3.38	1.33	0.25	2.76
Non-ferrous metals	Beverage Cans	0.05	0.01		2.73	1.45		2.78	0.52	
	Foil	1.23	0.35		0.00	0.00		1.23	0.23	
	Other	0.00	0.00	0.37	0.00	0.00	1.45	0.00	0.00	0.75
Plastic	PET	1.13	0.32		5.98	3.18		7.11	1.33	
	HDPE	1.08	0.31		6.98	3.71		8.06	1.50	
	PVC	-0.01	0.00		0.19	0.10		0.18	0.03	
	LDPE	10.58	3.04		3.63	1.93		14.21	2.65	
	PP	5.28	1.52		1.68	0.89		6.96	1.30	
	PS	1.48	0.43		0.31	0.16		1.79	0.33	
	Other	8.43	2.42	8.04	2.28	1.21	11.19	10.71	2.00	9.15
Putrescible	Garden Waste	3.03	0.87		0.00	0.00		3.03	0.57	
	Kitchen Waste - Animal	13.84	3.98		0.00	0.00		13.84	2.58	
	Kitchen Waste - Non-animal	174.39	50.15		0.10	0.05		174.49	32.56	
	Other Putresible	5.58	1.60	56.60	0.25	0.13	0.19	5.83	1.09	36.80
Textiles	Textiles	9.98	2.87	2.87	0.24	0.13	0.13	10.22	1.91	1.91
Other	Fines	24.83	7.14		0.00	0.00		24.83	4.63	
	Inert	0.00	0.00		0.00	0.00		0.00	0.00	
	Miscellaneous	18.83	5.41		0.29	0.15		19.12	3.57	
	Nappies	7.75	2.23	14.78	0.00	0.00	0.15	7.75	1.45	9.65
Combined Weight		**347.76**	100.00	100.00	**188.12**	**100.00**	**100.00**	**535.88**	**100.00**	**100.00**
CONTAMINATION					**1.48**		**0.79**			
Average Wt per household (kg/wk)		**8.09**			**4.37**			**12.46**		

Table 3.13: Waste Classification Data for Sampling Location C – Summer

Place:	Lampeter
E.D:	Lampeter
Date:	12/09/2005
Households:	22

Category	Sub-category	BLACK BAGS			CLEAR BAGS			TOTAL WASTE		
		Black Bags (kg)	% Composition	% Category Composition	Clear Bags (Kg)	% Composition	% Category Composition	Total Weight (kg)	% Composition	% Category Composition
Paper	Newspaper	2.39	1.20		26.09	24.16		28.48	9.26	
	Magazines	2.04	1.02		22.39	20.74		24.43	7.94	
	Other Paper	10.74	5.38		9.19	8.51		19.93	6.48	
	Liquid Cartons	1.19	0.60		0.19	0.18		1.38	0.45	
	Card Packaging	3.14	1.57		12.24	11.34		15.38	5.00	
	Composite Packaging	0.69	0.35	10.11	1.59	1.47	66.40	2.28	0.74	29.86
Glass	Brown Glass Bottles	0.05	0.03		3.44	3.19		3.49	1.13	
	Green Glass Bottles	0.05	0.03		0.24	0.22		0.29	0.09	
	Clear Glass Bottles	4.64	2.32		3.44	3.19		8.08	2.63	
	Broken Brown Glass	0.00	0.00		0.00	0.00		0.00	0.00	
	Broken Green Glass	0.00	0.00		0.00	0.00		0.00	0.00	
	Broken Clear Glass	0.00	0.00	2.37	1.19	1.10	7.70	1.19	0.39	4.24
Ferrous Metals	Beverage Cans	0.24	0.12		0.44	0.41		0.68	0.22	
	Food Cans	2.49	1.25		1.19	1.10		3.68	1.20	
	Batteries	0.00	0.00		0.01	0.01		0.01	0.00	
	Other Cans	0.69	0.35		0.00	0.00		0.69	0.22	
	Other Ferrous	1.59	0.80	2.51	0.04	0.04	1.56	1.63	0.53	2.17
Non-ferrous metals	Beverage Cans	0.09	0.05		0.59	0.55		0.68	0.22	
	Foil	1.04	0.52		0.09	0.08		1.13	0.37	
	Other	0.54	0.27	0.84	0.10	0.09	0.72	0.64	0.21	0.80
Plastic	PET	0.99	0.50		3.54	3.28		4.53	1.47	
	HDPE	1.74	0.87		4.69	4.34		6.43	2.09	
	PVC	0.00	0.00		0.04	0.04		0.04	0.01	
	LDPE	8.99	4.50		1.99	1.84		10.98	3.57	
	PP	3.79	1.90		0.84	0.78		4.63	1.50	
	PS	1.09	0.55		0.34	0.31		1.43	0.46	
	Other	7.39	3.70	12.01	1.94	1.80	12.39	9.33	3.03	12.14
Putrescible	Garden Waste	9.74	4.88		0.00	0.00		9.74	3.17	
	Kitchen Waste - Animal	20.40	10.21		0.00	0.00		20.40	6.63	
	Kitchen Waste - Non-animal	90.39	45.25		0.24	0.22		90.63	29.45	
	Other Putresible	0.00	0.00	60.34	0.00	0.00	0.22	0.00	0.00	39.25
Textiles	Textiles	4.69	2.35	2.35	0.00	0.00	0.00	4.69	1.52	1.52
Other	Fines	4.99	2.50		0.00	0.00		4.99	1.62	
	Inert	0.20	0.10		0.00	0.00		0.20	0.06	
	Miscellaneous	5.49	2.75		11.89	11.01		17.38	5.65	
	Nappies	8.25	4.13	9.48	0.00	0.00	11.01	8.25	2.68	10.02
Combined Weight		199.75	100.00	100.00	107.97	100.00	100.00	307.72	100.00	100.00
CONTAMINATION							16.20			
Average Wt per household (kg/wk)		9.08			4.91			13.99		

3.4 DISCUSSION

3.4.1 Dry Recyclables

3.4.1.1 Overview

Sample locations A and B are covered by a two bag survival scheme, that is, a clear bag is used for dry recyclables and a green bag used for organic material. Table 3.14 shows that the amount of dry recyclables collected per household per week, the Winter classification was greater in location B at 5.3kg compared to 4.1kg for location A. The non-requested fraction (contamination) present in the bags at this time was greater in location B than in location A, being 27.4% and 14.1% respectively. By taking these contamination figures into account, the true recyclable weight for participating households in both areas were 3.8kg in location B and 3.5kg in location A. In the Summer classification, the amount of dry recyclable collected from participating households was again greater in location B at 6.5 kg/hh/wk, compared to 4.3 kg/hh/wk in location A. The non-requested fraction (contamination) was considerably lower than in the winter classification, being 16% and 7% at locations B and A respectively. By taking account of the non-requested fraction, the true recyclable mass collected at the kerbside for participating households in locations A and B were 4.0 kg/hh/wk and 5.5 kg/hh/wk respectively.

Location C has a kerbside segregated recycling scheme, and the mass of dry recyclables collected from participating households was 4.4 kg/hh/wk and 4.9 kg/hh/wk for the Winter and Summer classification respectively. The non-requested fraction for location C was significantly lower than in the other sampling locations during the winter classification at

0.8%. During this time the material was sorted at the kerbside and any non-requested material was left behind. However, prior to the summer classification, the scheme was changed and the material was collected commingled at the kerbside to be sorted at a MRF. This seems to have a dramatic impact on the non-requested fraction, which had increased to 16.2% in the Summer classification.

Table 3.14: Dry Recyclable Data for Sampling Locations

	Location A		Location B		Location C	
	Winter 2005	Summer 2005	Winter 2005	Summer 2005	Winter 2005	Summer 2005
Average collected dry recyclable mass (kg/hh/wk)	4.1	4.3	5.3	6.5	4.4	4.9
Non-Requested Fraction (%)	14.1	7.0	27.4	16.0	0.8	16.2
True collected dry recyclable mass (kg/hh/wk)	3.5	4.0	3.8	5.5	4.4	4.1
Set Out Rate (%)	43.2	52.1	47.2	47.2	40.4	19.0
Total available dry recylable mass (kg/hh/wk)	4.7	4.8	5.0	6.9	6.3	6.1
% Recyclate Recovered from Total Waste Stream	75.0	82.3	77.7	79.4	69.3	67.3

The Winter set out rates for locations B, A and C were 47.2%, 43.2% and 40.4% respectively. Location B was the most rural and had the highest set out rates, while the more urban areas of locations A and C had the lowest set out rates. During the summer, the set out rate for location C remained the lowest, and indeed there had been a sharp decline in weekly set out, which is as a result of the change to the kerbside recycling scheme. The weekly set out rate for location B remained unchanged; however, the set out rate for location A had increased and was the highest of all three sampling locations in the Summer study at 52.1%.

A measure was only made of weekly set out, no assessment was made of participation. However, it would be incorrect to assume that all houses that had presented clear bags at the kerbside at the time of the survey, would do so every week, likewise it would be inaccurate to assume that houses which had not presented clear bags at the kerbside did not participate at other times. That is, some residents may set out clear bags on a weekly basis, while others may set out clear bags whenever the bag becomes full and so forth. The case study authority conducted a survey into their kerbside recycling scheme over a period of three weeks, the results of the survey indicate that of those residents which participated in the scheme, 49% put out a clear bag each week, 27% put out a clear bag twice during the survey, and 23% only presented a clear bag once during the survey (Ceredigion County Council, 2007). Similar studies have been conducted in other parts of the UK, for example a participation survey conducted over an 8 week period in RCT found that of those participating in the recycling scheme, 57% set out recyclable on a weekly basis, 10% on a fortnightly basis, and 33% on a random basis, which was defined as those that participated less than 75% of the time (Woollam, 2006).

Table 3.14 also presents the total available dry recyclable at each sampling location, which is based on the total amount of requested material available within the entire household waste stream. This then enables the percentage of recyclable recovered from the waste stream in participating households in each sampling location to be calculated. As can be seen there was a substantial variation in the recovery of dry recyclable varying from 69.3% in location C to 77.7% in location B during the Winter study. During the Summer study, the results in the two survival bag sampling locations (A and B) had increased from the Winter study, but that for location C was slightly lower at 67.3%. The highest performing location during the Summer study was location A with a 82.3% recovery of material. This data illustrates that there is scope for improvement in all sampling areas in terms of householders segregating greater quantities of material for recycling.

Table 3.15 shows the composition data of the dry recyclable component in the three study areas. They highlight that paper and card constitute the largest fraction in all three study areas, representing in excess of 60% for all sampling locations in both the Winter and Summer. This highlights that this scheme can have a significant impact in diverting BMW away from landfill.

Another significant stream in all sampling locations was the plastics stream which ranged from 9% to 17% at locations B and A respectively for the Winter classification, and ranged from 11% to 14% at locations B and A respectively for the Summer classification.

Glass was only collected in the recycling scheme at location C and indeed was the second largest fraction being 24% in the Winter classification. However, by the Summer classification the proportion of glass in the dry recyclable stream had declined, although it continued to be accepted by the new kerbside recycling scheme in operation.

At location B, the 'other' category constituted 21% of the recyclable waste stream in the Winter classification which was essentially due to the bags being used for general MSW, which had a significant impact on the quality of the recyclable, due to this contamination. Although this had declined to 10% in the Summer classification, the bags continued to be misused for general household waste. These results highlight that rogue users of the scheme have a great impact on the overall performance of the recycling schemes, and targeted education and awareness is required to improve this.

Table 3.16 shows the weighted dry recyclable composition and arisings for participating households within the case study authority, and shows that the overall average dry recyclable arisings within the Authority was 4.65 kg/hh/wk. The results also highlight that there was little difference in dry recyclable arisings in participating households, being 4.41 kg/hh/wk in the winter and 4.89 kg/hh/wk for the summer classification. The most significant seasonal change observed was an increase in the amount paper and card within the recyclable stream, increasing from 62.2% to 73.8% for the Winter and Summer classifications respectively. The only other stream which varies significantly between both seasons is the glass stream. However, in contrast to the paper and card stream, the glass content declined from 9.5% to 2.3% for the Winter and Summer classifications respectively.

Table 3.17 highlights that the average set out rate in the recycling schemes run by the case study authority was 42%, which is inline with what is being achieved by other local authorities in Wales and in wider areas of the UK (Woollam 2006; Bristol City Council 2000; Wilson and Williams 2007; Lyas *et al.* 2005; WRAP 2006). The Table also shows the level of non-requested material in the dry recyclable stream. The results indicate that the levels of non-requested materials were very similar for both classifications, being on average 12.7%. The results show that there was a slight increase in the amount of recyclable recovered in the summer classification compared to the winter classification, being 73.5% and 77.2% for the Winter and Summer classifications respectively, with an average figure of 75.4%.

Table 3.15: Dry Recyclable Composition for Sampling Locations

Category	Location A				Location B				Location C			
	Winter 2005		Summer 2005		Winter 2005		Summer 2005		Winter 2005		Summer 2005	
	kg/hh/wk	%	kg/hh/wk	%	kg/hh/wk	%	kg/hh/wk	%	kg/hh/wk	%	kg/hh/wk	%
Paper & Card	2.7	65	3.4	81	3.2	61	4.8	73	2.7	61	3.3	66
Glass	0.0	0	0.0	1	0.2	3	0.0	0	1.1	24	0.4	8
Ferrous Metals	0.2	5	0.2	4	0.2	3	0.1	2	0.1	3	0.1	2
Non-Ferrous	0.0	0	0.0	0	0.0	0	0.1	1	0.0	1	0.0	1
Plastic	0.7	17	0.6	14	0.5	9	0.7	11	0.5	11	0.6	12
Putrescibles	0.0	1	0.0	0	0.2	3	0.1	2	0.0	0	0.0	0
Textiles	0.4	9	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Other	0.1	3	0.0	0	1.1	21	0.7	10	0.0	0	0.5	11
TOTAL	**4.1**		**4.3**		**5.3**		**6.5**		**4.4**		**4.9**	

Table 3.16: Composition of Dry Recyclable Stream for Case Study Authority

Category	Average February 2005		Average September 2005		Annual Average	
	Composition (kg/hh/wk)	Composition (%)	Composition (kg/hh/wk)	Composition (%)	Composition (kg/hh/wk)	Composition (%)
Paper and Cardboard	2.74	62.2	3.62	73.8	3.18	68.0
Glass	0.42	9.5	0.11	2.3	0.27	5.9
Ferrous Metals	0.17	3.8	0.11	2.3	0.14	3.1
Non Ferrous Metals	0.03	0.7	0.03	0.7	0.03	0.7
Plastic	0.57	12.9	0.60	12.3	0.59	12.6
Putrescibles	0.05	1.1	0.05	1.1	0.05	1.1
Textiles	0.14	3.1	0.01	0.2	0.08	1.7
Other	0.30	6.7	0.36	7.3	0.33	7.0
TOTAL	**4.41**	**100.0**	**4.89**	**100.0**	**4.65**	**100.0**

Table 3.17: Set out Rates, Non-Requested Material and Recovery of Dry Recyclable for Participating Households in the Case Study Authority

	Average Winter 2005	Average Summer 2005	Annual Average
Set Out Rate (%)	43%	41%	42%
Non-requested material (%)	12.6	12.8	12.7
Recovery (%)	73.5	77.2	75.35

3.4.1.2 Paper and Cardboard

The results in Table 3.18 highlight the average amounts of different paper and cardboard types found in the dry recyclable stream within the case study area. The results highlight that the four largest fractions are newspaper, magazines, cardboard and other paper which account for over 98% of the paper and cardboard stream in the dry recyclable bag in both the winter and summer classifications.

The Table highlights that in the winter classification, the newspaper and magazines categories account for the greatest recovery, being 92.6% and 86.4% respectively, which are closely followed by the cardboard category which has a recovery rate of 70.8%. The other significant recovery rate was observed for the other paper category at 52.5%. The remaining categories of liquid cartons and composite packaging, were not requested in the kerbside recycling scheme; however, recovery rates 25.0% and 20.0% were observed. This emphasises that awareness of the materials requested by the kerbside scheme could be improved. However, it is clear from the data collected for the Summer classification that awareness remained an issue, indeed the situation had worsened, as the recovery rates for these non-requested fractions were 33.3% and 66.7% for the liquid cartons and composite packaging streams. These non-requested materials observed include TetraPak, jiffy bags, and window envelopes.

Table 3.18: Paper and Cardboard Composition in Case Study Authority

Category	Winter 2005			Summer 2005		
	Recovered (kg/hh/wk)	Total Available (kg/hh/wk)	% Recovery	Recovered (kg/hh/wk)	Total Available (kg/hh/wk)	% Recovery
Newspaper	1.13	1.22	92.6	1.58	1.68	94.0
Magazines	0.70	0.81	86.4	0.97	1.03	94.2
Other Paper	0.42	0.80	52.5	0.76	1.10	69.1
Liquid Cartons	0.01	0.04	25.0	0.02	0.06	33.3
Cardboard	0.46	0.65	70.8	0.51	0.64	79.7
Composite Packaging	0.01	0.05	20.0	0.04	0.06	66.7

3.4.1.3 Plastics

The case study area does not request certain types of plastic in terms of their numbers as occurs in other areas, for example, many local authorities request PET (#1) and HDPE (#2). The guidance provided within the case study area states that plastic bottles (with tops removed), bags, yogurt pots, cling film and ice cream tubs are acceptable; however, they do stipulate that polystyrene was unacceptable.

The results in Table 3.19 highlight the average amounts of different plastic types found in the dry recyclable stream within the case study area. The results highlight that the PET, HDPE and LDPE are the largest recyclable plastic fraction in the recyclable stream, accounting for over 70% of the recovered plastics in both the winter and summer classifications. Waste composition analysis conducted in RCT (Emery *et al.*, 2002) found that the total amount of plastics present in the recyclable stream was 0.55 kg/hh/wk; thus the results for the case study authority are comparable with this being 0.55 kg/hh/wk and 0.64 kg/hh/wk for the winter and summer classifications respectively.

The data in the Table also highlighted that although PVC was specifically not requested by the kerbside recycling scheme, recovery rates for this stream were 25.0% and 33.3% for the winter and summer classifications respectively. Although, in terms of arisings, this only represents an average of 0.1kg/hh/wk of polystyrene in the dry recyclable stream, it does emphasise the fact that awareness of the materials requested within the scheme could be significantly improved.

Table 3.19: Plastic Composition in Case Study Authority

Category	Winter 2005			Summer 2005		
	Recovered (kg/hh/wk)	Total Available (kg/hh/wk)	% Recovery	Recovered (kg/hh/wk)	Total Available (kg/hh/wk)	% Recovery
PET	0.12	0.15	80.0	0.15	0.17	88.2
HDPE	0.14	0.17	82.4	0.15	0.23	65.2
PVC	0.00	0.02	0.0	2.80E-03	3.40E-03	82.4
LDPE	0.13	0.34	38.2	0.16	0.42	38.1
PP	0.05	0.16	31.3	0.03	0.10	30.0
PS	0.01	0.04	25.0	0.01	0.03	33.3
Other	0.10	0.25	40.0	0.14	0.34	41.2
Actual Arisings (kg/hh/wk)	**0.55**			**0.64**		
Potential Arisings (kg/hh/wk)	**1.13**			**1.29**		

3.4.2 Organics

Table 3.20 shows that with regards to the organic bag, there was a significant difference between sampling locations A and B, being 2.0 and 3.6 kg/hh/wk respectively for the Winter study, and 5.9 and 6.3 kg/hh/wk respectively for the Summer study. There was a significant difference in organic contamination levels between both areas in the Winter study, being 13.6% in location B and 4.3% in location A. This resulted in the true collected organics arisings being 3.1 kg/hh/wk and 1.9 kg/hh/wk for locations B and A respectively. A significant decrease was observed in the contamination levels in the Summer study, being 1.2% and 1.5% for locations A and B respectively, this represents a true organics arisings of 6.2 kg/hh/wk for location B and 5.8 kg/hh/wk for location A. Similar to the clear bag, most of the organic contamination was due to green bags being used for general MSW.

Table 3.20: Organics Data for Sampling Locations

	Location A		Location B	
	Winter 2005	Summer 2005	Winter 2005	Summer 2005
Average collected organics mass (kg/hh/wk)	2.0	5.9	3.6	6.3
Non-Requested Fraction (%)	4.3	1.2	13.6	1.5
True collected organics mass (kg/hh/wk)	1.9	5.8	3.1	6.2
Total available organics mass (kg/hh/wk)	4.0	9.1	10.7	8.7
% Organics Recovered from Total Waste Stream	47.9	64.1	29.1	71.3

Table 3.20 also presents the total organics fraction available at each sampling location, which is based on the total amount of requested material available within the entire household waste stream. This then enables the percentage of organics recovered from the waste stream in participating households in each sampling location to be calculated. The recovery of organics from the household waste stream as a whole in locations A and B during the Winter study showed significant variation, being 47.9% and 29.1% respectively; and during the Summer study a significant increase was seen in the proportion of organics recovered, being 64.1% and 71.3% for locations A and B respectively. These figures highlight that there is room for improvement in the scheme, which could be achieved by means of targeted education and publicity.

Table 3.21 shows the weighted average data for the case study area. The Table highlights that the average putrescible arisings from participating households was 4.4 kg/hh/wk, which varied from 2.7 to 6.1 kg/hh/wk between the Winter and Summer studies respectively. This was expected as putrescible arisings do increase in the summer due to greater amounts of garden waste. The Table also shows the level of non-requested material in the putrescible stream, and indicates that the levels of non-requested materials was on average 4.9%. The level of non-requested material fell from 8.3% for the winter classification to 1.4% for the summer classification, which does suggest that an improvement was made to the quality of the organic material collected. The non-requested material or contamination present was mainly due to the bags being used for general MSW.

Table 3.21: Arisings, Non-Requested Material and Recovery of Putrescibles in Participating Households in the Case Study Authority

	Winter 2005	Summer 2005	Average
Gross Putrescible Arisings (kg/hh/wk)	2.7	6.1	4.4
Non-requested material (%)	8.3	1.4	4.9
Net Putrescible Arisings (kg/hh/wk)	2.5	6.0	4.2
Potential Putrescible Arisings (kg/hh/wk)	5.6	8.8	7.2
Recovery (%)	44.7	68.0	56.4

Table 3.21 also shows the amount of organics recovered from participating households. The results highlight that on average 56.4% of the available organic material was collected in the green bag from participating households. These results indicate that there was significant room for improvement in the organics scheme, as recovery was much lower

than that observed for the dry recyclable. This further highlights that awareness needs to be raised by means of targeted publicity and education.

3.4.3 Residual Waste

Table 3.22 shows that the average black bag weight per household per week in the sampling locations varied from 5.9kg to 8.1kg during the Winter survey, and from 5.7kg to 9.1kg during the Summer survey. Location C produced the greatest amount of residual waste in both surveys; however, this was due to the fact that no organics collection scheme existed in this area. There was very little difference observed in average residual waste arisings between the winter and summer classifications being 7.1 kg/hh/wk and 6.8 kg/hh/wk respectively, with an overall average figure of 7.0 kg/hh/wk.

Table 3.23 shows the composition of residual waste in the three sampling locations. The Table illustrates that the putrescibles constitute the largest fraction, being 53%, 51% and 57% for locations A, B and C respectively in the Winter study. For the Summer study this varied from 55%, 39%, and 60% for locations A, B and C respectively. Location C had the greatest putrescible fraction of the three sampling locations in both studies, which again can be explained by the fact that no organics collection scheme exists at this location. The results emphasise that a significant amount of putrescible material remains in the residual waste at both locations A and B which could be placed in the organic collection.

Table 3.22: Residual Waste Arisings for Sampling Locations

Sampling Location	Residual Waste Arisings (kg/hh/wk)		
	Winter 2005	Summer 2005	Average
A	7.1	5.7	6.4
B	5.9	6.2	6.1
C	8.1	9.1	8.6
Weighted Average	7.1	6.8	7.0

Table 3.23: Residual Waste Composition for Sampling Locations

Category	Location A				Location B				Location C			
	Winter 2005		Summer 2005		Winter 2005		Summer 2005		Winter 2005		Summer 2005	
	kg/hh/wk	%	kg/hh/wk	%	kg/hh/wk	%	kg/hh/wk	%	kg/hh/wk	%	kg/hh/wk	%
Paper & Card	0.9	12	0.5	8	0.5	9	0.7	12	1.1	13	0.9	10
Glass	0.6	8	0.5	9	0.4	7	0.5	8	0.2	2	0.2	2
Ferrous Metals	0.1	2	0.1	2	0.1	2	0.4	7	0.2	2	0.2	3
Non-Ferrous	0.0	0	0.1	1	0.1	1	0.0	0	0.0	0	0.1	1
Plastic	0.6	9	0.5	8	0.5	8	0.5	8	0.6	8	1.1	12
Putrescibles	3.8	53	3.1	55	3.0	51	2.4	39	4.6	57	5.5	60
Textiles	0.1	1	0.2	4	0.1	1	0.3	6	0.2	3	0.2	2
Other	1.1	15	0.7	13	1.2	21	1.3	21	1.2	15	0.9	10
TOTAL	**7.1**		**5.7**		**5.9**		**6.2**		**8.1**		**9.1**	

In locations A and B, the 'other' fraction was the next largest fraction, which varied from 15% to 13% for the Winter and Summer classifications at locations A, and 21% for both Winter and Summer classifications at locations B. This was mainly as a result of the presence of fines, which arise from coal household heating, and also due to the presence of nappies.

Paper and card was also a significant component of the residual waste stream, which represented 12%, 9% and 13% for the Winter study in locations A, B and C respectively, and 8%, 12% and 10% respectively for the Summer study. Again, much of this material could be diverted via the kerbside recycling scheme. Similarly glass, metals and plastics remain in the residual waste stream, and much of this could also be diverted via the kerbside recycling scheme.

Given the significant quantity of recyclable and organics remaining in the residual waste stream, this again emphasises the need for targeted awareness and education in order to segregate this material via the kerbside recycling scheme.

3.4.4 Total Household Waste

Table 3.24 highlights the average household waste arisings for each sampling location, the results varied from 12.5kg in location C, to 14.8kg in location B during the winter, and from 14.0kg in location C, to 19.1kg in Location B during the summer study. The results highlight that the most rural area, i.e. location B generated the greatest amount of waste of all three study areas in both the winter and summer analysis. The weighted average for all three sampling locations varied from 13.5kg to 16.5kg between the winter and summer analysis respectively.

Table 3.24: Average Household Waste Arisings for Sampling Locations

Sampling Location	Household Waste Arisings (kg/hh/wk)		
	Winter 2005	Summer 2006	Average
A	13.6	15.8	14.7
B	14.8	19.1	17.0
C	12.5	14.0	13.3
Weighted Average	13.5	16.5	15.0

Households in all three sampling locations produce less waste than was found in a study carried out in RCT in 2000 (19.4 kg/hh/wk) (Emery et al., 2000b). The average household waste arising for Wales was found to be 17 kg/hh/wk, which again was greater than the weighted average results found for the case study area in this investigation. However, a study in an English authority in the Summer of 2003 found the average household waste arisings to be 17-18 kg/hh/wk, and in this investigation the arisings for location B was 19.1 kg/hh/wk during the summer period. Other studies have also found more comparable results, for example a study carried out in Eastleigh in 2000/2001 determined the average household waste arisings to be 14-15 kg/hh/wk which is more in line with the results for the case study authority (as discussed in National Assembly for Wales, 2003).

Table 3.25 shows the household waste composition for the collected waste streams in each sampling location. The Table shows that the paper and card, and putrescibles fractions (i.e. the biodegradable portion) were the two largest fractions in all three sample location for both the Winter and Summer classification exercise. In the Winter classification, the biodegradable fraction was similar in all three sampling locations, varying from 66 to 68%. This proportion increased markedly in the Summer classification for locations A and B to

82% and 78% respectively. However, the Summer biodegradable fraction for location C remained similar to that in the winter, increasing from 66% to 69%. In terms of the statutory requirement to divert BMW from landfill, the Landfill Allowance Scheme (Wales) Regulations 2004 (Statutory Instrument Number 1490) defines MSW in Wales as containing 61% BMW. Hence, it can be seen that in all three sampling locations, the value of 61% was exceeded in both the winter and summer classifications.

Fractions of glass, ferrous metals, non-ferrous metals, and textiles were comparable in all three sampling locations. There was almost double the proportion of glass present in the waste stream in location C in the Winter classification compared to all of the other results. An anomaly can also be seen in terms of the proportion of plastics in the household waste stream, the proportion was greater in the Summer classification at location C, compared to all of the other results.

The 'other' component is a significant contributor to the waste composition and arisings in each sampling location. In the Winter classification, the 'other' category represented 19% at location B, which was significantly greater than the other two sampling locations being 12% and 10% for locations A and C respectively. The 'other' category consisted of fines, inert material, nappies and miscellaneous, and had a substantial impact on the waste stream in both locations A and B. Indeed, at location A the fines and miscellaneous sub-divisions constituted 9% of the total waste stream, and the miscellaneous sub-division constituted 14% of the total waste stream in Location B. In the Summer classification, 'other' fraction was similar for locations B and C being 11% and 10% respectively. At location A this fraction was half of that in the other Summer sampling locations, representing only 5% of the household waste stream.

Comparing the results for location A, with the average Welsh composition as shown in Table 1.1 (National Assembly for Wales, 2003), it can be seen that for the winter classification, paper and card, metals and textiles were present in similar quantities to the Welsh average proportions of 25%, 5% and 2% respectively. Glass was lower than the Welsh average of 7%, this may be due to the use of bottle banks. The significant difference, was the putrescible fraction, which was significantly higher in location A, than the Welsh average figure of 36%. For the Summer classification, the results highlight that although the paper and card fraction was present in similar quantities to the Wales figure of 25%, the remaining categories showed marked variations. For example, putrescibles constituted a significantly larger fraction at 57%, compared to the Welsh Average of 36%. Plastics represented considerably less of the waste stream in location A being 7% compared to the Welsh Average of 11%. Metals constituted only 2% of the waste stream in location A compared to the Welsh figure of 5%.

Comparing the data for location B to the Wales composition (National Assembly for Wales, 2003), highlights that in the Winter classification paper and card levels were similar in proportion to the figure for Wales at 25%. Glass was lower which again may be due to the use of bottle banks. Also, metals were half the figure of 5% quoted for Wales. Again, the putrescible fraction was significantly greater than the Welsh average. The Summer classification data highlights that paper and card level at 29% was slightly greater than the values quoted for Wales and RCT which was 25%. Again, glass and metals were significantly lower than the Welsh figures, and the putrescible fraction was greater than the Welsh average.

The winter classification data for location C, highlights that paper and card make up more of the waste stream at 30% than the Welsh average of 25%. The total metal content was less than the Wales figure of 5%. Furthermore, putrescibles and textiles were found in similar proportions to the Wales study. The Summer classification data highlights again that the putrescible component of the household waste stream was 39%, only slightly greater than the Wales value of 36%. Similarly, the plastics component in the Location C waste stream was similar to the Wales at 12%. The glass and metal contents were lower than the figures quoted for Wales being 4.2% and 3.0% respectively.

Table 3.26 highlights the weighted average mass of eight major components analysed in the household waste stream within the case study authority for the Winter and Summer classifications. The Winter classification data highlights that there was approximately 8% more paper and card present in the household waste stream than in studies conducted for Wales and RCT. The results highlight that there was significantly more putrescibles in the waste stream at 41%, compared to the figures quoted for Wales and RCT, being 36% and 30% respectively. The results also show that there was less metals, glass and plastic in the Case Study household waste stream, compared to figure produced for Wales. The Summer classification data shows that there were similar proportions of paper and card, and textiles present in the household waste stream as in studies conducted for Wales. A significant difference however between the data is that the putrescible element of the waste stream was significantly greater for the case study authority than was found in other studies. The results also show that there were less proportions of metals, glass and plastics present in the household waste stream compared to Wales and RCT (National Assembly for Wales, 2003; Emery *et al.*, 2000b; Owen *et al.*, 2007a).

Table 3.25: Total Waste Composition for Sampling Locations

Category	Location A				Location B				Location C			
	Winter 2005		Summer 2005		Winter 2005		Summer 2005		Winter 2005		Summer 2005	
	kg/hh/wk	%	kg/hh/wk	%	kg/hh/wk	%	kg/hh/wk	%	kg/hh/wk	%	kg/hh/wk	%
Paper & Card	3.4	25	3.9	25	3.8	26	5.5	29	3.8	30	4.2	30
Glass	0.7	5	0.6	4	0.6	4	0.5	3	1.1	9	0.6	4
Ferrous Metals	0.4	3	0.2	1	0.3	2	0.6	3	0.4	3	0.3	2
Non-Ferrous	0.0	0	0.1	0	0.0	0	0.1	0	0.1	1	0.1	1
Plastic	1.2	9	1.1	7	1.0	7	1.2	6	1.1	9	1.7	12
Putrescibles	5.8	43	9.0	57	6.2	42	8.7	46	4.5	36	5.5	39
Textiles	0.4	3	0.2	1	0.0	0	0.4	2	0.3	2	0.2	2
Other	1.6	12	0.8	5	2.8	19	2.1	11	1.3	10	1.4	10
TOTAL	**13.6**		**15.8**		**14.8**		**19.1**		**12.5**		**14.0**	

Table 3.26: Total Weighted Average Household Waste Composition for Case Study Area

Category	Winter 2005		Summer 2005		Average	
	kg/hh/wk	%	kg/hh/wk	%	kg/hh/wk	%
Paper & Card	3.6	26.7	4.2	25.2	3.9	25.8
Glass	0.8	5.9	0.5	3.0	0.7	4.3
Ferrous Metals	0.4	3.0	0.3	2.1	0.4	2.5
Non-Ferrous Metals	0.1	0.7	0.1	0.5	0.1	0.6
Plastic	1.1	8.1	1.2	7.1	1.1	7.6
Putrescibles	5.5	40.7	8.7	52.7	7.1	47.3
Textiles	0.2	1.5	0.3	1.5	0.2	1.5
Other	1.8	13.3	1.3	8.0	1.6	10.4
TOTAL	**13.5**	**100.0**	**16.5**	**100.0**	**15.0**	**100.0**

The results also highlight that there was an increase in household waste arisings in the summer classification compared to the winter classification, being 16.5 kg/hh/wk compared to 13.5 kg/hh/wk. This increase was mainly observed in the paper and card, and putrescible fractions, which are the biodegradable components of MSW. An increase in the putrescible fraction was expected as the amount of garden waste produced was greater during the summer than the winter. The Biodegradable Municipal Waste (BMW) fraction is defined as putrescible, wood, paper and card. The average BMW fraction for the case study authority was 72.4%, which was significantly greater than the 61% BMW fraction stated for Wales. Thus, a greater pool of material was available which can be targeted to meet their Landfill Allowance Scheme Targets.

3.4.5 Townsend Index

Townsend Index is used as a measure of affluence/ socio-economic activity, and a negative value shows greater affluence and a positive score less affluence. Further information on the derivation of the Townsend Index is highlighted in Appendix A. Figure 3.1 highlights that a typical linear relationship exists between set out rate (from the Winter study) and Townsend Index in the case study authority. The Figure also highlights that this trend was observed in another study conducted in RCT. Indeed the results for RCT and the case study authority are similar in that areas of the same Townsend Index score have similar weekly set out rates. For example, from Figure 3.1 a Townsend score of -2, would relate to a weekly set out rate of 47% in the case study authority and a figure of 48% in RCT; while a Townsend score of +2, would relate to set out rates of 42% and 38% for the case study authority and RCT respectively (Woollam, 2006).

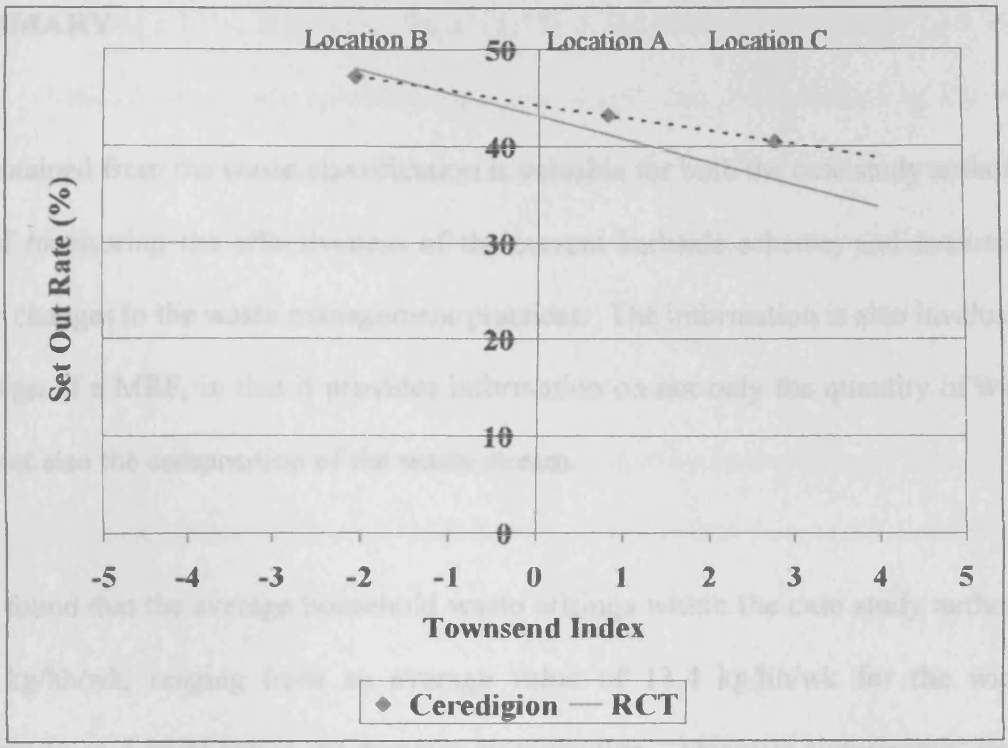


Figure 3.1: Relationship between Set Out Rate and Townsend Index Score for the Case Study Authority

Figure 3.2 highlights the relationship of waste arisings, recyclables, and organics with Townsend Score. Again the relationship follows the trend observed in similar studies, that is the more affluent the area, the greater the amount of household waste produced.

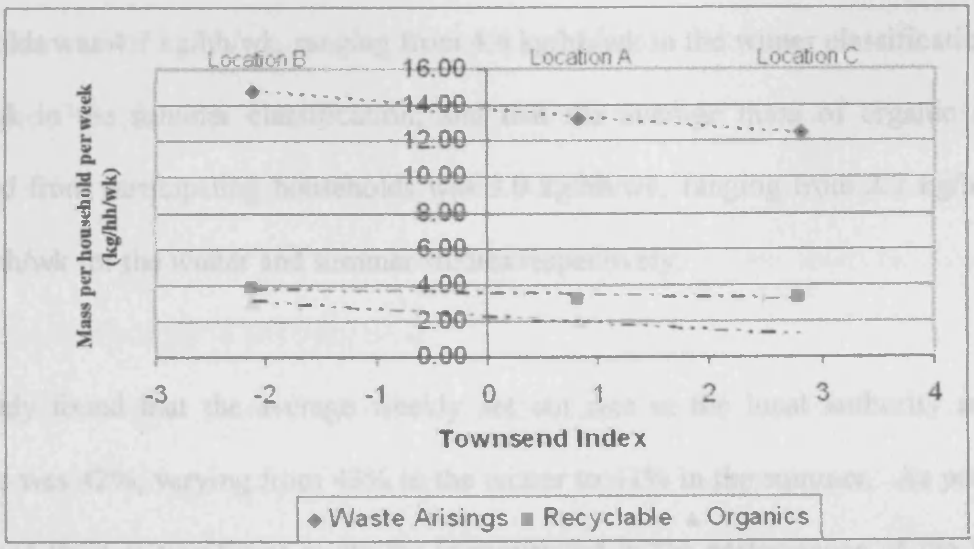


Figure 3.2: Relationship between household waste arisings, recyclable and organics with the Townsend Index

3.5 SUMMARY

The data obtained from the waste classification is valuable for both the case study authority in terms of monitoring the effectiveness of the current kerbside scheme, and evaluating options for changes to the waste management practices. The information is also invaluable for the design of a MRF, in that it provides information on not only the quantity of waste produced but also the composition of the waste stream.

The study found that the average household waste arisings within the case study authority was 14.9 kg/hh/wk, ranging from an average value of 13.4 kg/hh/wk for the winter classification to 16.5 kg/hh/wk in the summer classification. This was significantly lower than was found in a similar study conducted in RCT (19.4 kg/hh/wk) (Emery *et al.*, 2000b), and also lower than the Welsh average figure of 17 kg/hh/wk (National Assembly for Wales, 2003).

The study also found that the average dry recyclable collected from participating households was 4.7 kg/hh/wk, ranging from 4.4 kg/hh/wk in the winter classification to 4.9 kg/hh/wk in the summer classification; and that the average mass of organic material collected from participating households was 3.0 kg/hh/wk, ranging from 2.7 kg/hh/wk to 3.2 kg/hh/wk for the winter and summer studies respectively.

The study found that the average weekly set out rate in the local authority recycling schemes was 42%, varying from 43% in the winter to 41% in the summer. As previously mentioned there is significant scope for improvement in the performance of the kerbside recycling scheme. Non-requested material/ contamination present in the dry recyclable stream was on average 11%, and varied from 12.5% in the winter classification to 10% in the summer classification. This contamination was largely due to the misuse of the clear bags; these bags were provided free of charge to householders while black bags were not. Thus, many householders used the clear bags for general household waste. This has an impact on the quality of material available for recovery, and the case study authority must impose stricter controls at the kerbside to reduce the level of contamination within this dry recyclable stream. Similarly, non-requested material or contamination was an issue in the putrescible stream i.e. green bags, and ranged from 8.3% in the winter classification to 1.3% in the summer classification.

It was interesting to note that the biodegradable content of household waste was found to be 72%, which was significantly greater than the 61% used to define the Landfill Allowance Scheme figures for Wales; hence, the case study authority has a larger pool of organic material to target in order to comply with the stringent Landfill Allowance targets. However, much of this biodegradable material remained in the residual waste stream. Thus, two options are available for the case study authority, these are:

- The case study authority could significantly improve its performance in terms of the Landfill Allowance scheme by increasing the number of households participating in the scheme, and also increasing the amount of organic material being segregated at the kerbside by the householder. This could be achieved by targeted education and awareness.
- Alternatively, processing of residual waste could recover material from householders that do not participate in the scheme, i.e. participation in a residual waste processing route would be 100% by definition. Hence, significant quantities of recyclables and organics could be segregated by processing this stream.

CHAPTER 4:
Material Recovery Facilities

4.1 INTRODUCTION

Material Recovery Facilities (MRFs) (sometimes called Material Recycling Facilities or Material Reprocessing Facilities) can be defined as "a central operation where source-segregated, dry recyclable materials are sorted, mechanically or manually, to market specifications for processing into secondary materials" (CIWM, 2000). This definition however only covers a MRF that is commonly referred to as 'clean', that is one which processes source segregated dry recyclable. This definition by CIWM does not cover other types of facilities such as 'dirty' MRFs or mixed solid waste sorting facilities (MSWSF), i.e. processes which recover material for recycling from mixed household waste and commercial and industrial waste.

There are potentially many possible designs which could be used. Therefore, it is difficult to define a 'typical' process. Broadly speaking MRFs can be split into two categories, these being 'clean' and 'dirty'. Within these categories however processes can range from a 'low-tech' to a 'high-tech' facility. At its simplest a 'low-tech' process can simply be a raised conveyor on which the materials pass and are handsorted, while a 'high-tech' facility can consist of a fully automated system and utilise various unit operations which exploit the differences in the properties of the recyclable. The decision as to whether to install a 'low-tech' or 'high-tech' operation can be difficult as there are benefits to each type.

The advantages of a 'low-tech' operation are:

- lower capital cost than a 'high-tech' MRF; and,

- increased flexibility in terms of the segregated material, i.e. if there are changes in the market, operatives can be instructed to pick in a different manner.

The disadvantages of a 'low-tech' operation are:

- higher operating costs than a 'high-tech' MRF; and,
- lower throughput and efficiency than a 'high-tech' MRF.

The advantages of a 'high-tech' operation are:

- lower operating costs than a 'low-tech' MRF;
- generally have greater throughput of material than a 'low-tech' MRF; and,
- have higher efficiencies than a 'low-tech' MRF.

The disadvantages of a 'high-tech' operation are:

- higher capital costs than a 'low-tech' MRF; and,
- risk that material would have to be stockpiled in the event of equipment failure.

4.2 EQUIPMENT

The main types of equipment used in MRFs are those for:

- material preparation, e.g. bag splitters, and feed hoppers;
- material transportation, e.g. conveyors; and,
- material separation, e.g. overband magnets, ballistic separators and disc screens.

4.2.1 Material Preparation

The key pieces of equipment which are used for material preparation include: bag splitters, shredders, balers and compactors. Bag splitters as the name suggests are used to open bagged material which enters the MRF. Bag splitters usually consist of a hopper with a conveyor system at the bottom, this feeds the material towards a rotating drum, this drum traps, opens and empties the bag, without damaging the contents of the bags. As well as opening bags, the bag splitter also acts as a metering system for the infeed into the plant, to ensure a continuous smooth flow of material (Okay Engineering Services Ltd., 2005).

4.2.2 Material Transportation

The key piece of equipment which are used for material transportation are conveyors. There are a variety of different type of conveyors, ranging from infloor conveyors, which can be used to load material into the MRF or used in an automated baling system, to picking belts, which as the name suggests are used at sorting stations, to enable operatives to sort material.

4.2.3 Sorting Equipment

There is a huge variety of different technologies utilised for material separation. These differing pieces of equipment have the same ultimate purpose, that is to utilise the differing properties of different material types in order to separate material from the incoming waste stream. The main equipment groups for material separation are:

- air classifiers;
- magnetic separation;
- size classifiers; and,
- optical sorting.

Air classifiers utilise differences in size and density of various materials within the input stream, essentially lighter elements such as paper and plastic film, can be separated away from the denser material such as glass (Shapiro and Galperin, 2005). The principle of separation is based on the fact that the particles suspended in a flowing gas, usually air move towards different points under the influence of different forces so that they can be separated from one another. Particles experience gravity and drag forces acting in opposite directions (Eswaraiah *et al.* 2008). They are typically installed at a transfer point in the MRF, for example at the exit point of a screen, or between two conveyors. At these points, an air knife can be mounted which then either imparts a blowing or sucking action on the mixed material, this action is only strong enough to displace the light material in the waste stream, therefore facilitating its separation (Okay Engineering Services Ltd., 2005; WRAP, 2006a).

Magnetic separation utilises the force of a magnetic field acting upon ferrous material in order to separate this material from the input stream. There are a number of different types of magnetic separators, these range from overband magnets, magnetic rollers on conveyors, and magnetic drum separators (WRAP 2006a).

Eddy current separators also use magnets to induce separation. Eddy current separators are able to remove non-ferrous metal, e.g. aluminium, copper and zinc from the input stream. In an eddy current separator a rotor which contains magnet blocks (rare earth magnet or a standard ferrite ceramic magnet) is spun at an angular velocity in excess of 3000 revolutions per minute to produce an 'eddy current'. These eddy currents are caused by Faraday's induction law, and are induced in the nonferrous materials within the active zone of the separator as a response to the magnetic field. The interaction between the eddy currents and the magnetic field results in repulsive electrodynamic forces on the nonferrous materials within the active zone, thus allowing the nonferrous metals to be separated from the input stream (Alumatter 2007; WRAP 2006a; Lungu, 2005). The magnitude of these repulsive forces is dependant on the electrical conductivity of the nonferrous material, as the conductivity influences the size of the eddy currents induced (Zhang *et al.* 1998).

Size classifiers utilise the different sizes of materials in the waste stream in order to separate material from the input stream. There are various means of achieving this, ranging from trommels, vibrating screens, to disc screens. A trommel screen is basically a large rotating cylinder, which is set on an incline. As material tumbles within the trommel it travels down the inclined screen, and as it does some of the material is able to pass through the apertures. Thus the input stream is split into two fractions, these being the oversize, i.e. material which is larger at least in one dimension than the aperture size, and the undersize, which are those that are smaller than the aperture size in at least one dimension (WRAP 2006a).

Vibrating screens work in a similar manner, again they have a set aperture size but instead of tumbling the material, the vibrating action of the screen agitates the material on the screen thereby facilitating the separation into two fractions (WRAP 2006a).

Disc screens consist of several rows of discs, and these range in shape depending on the manufacturer, but are typically oblong in shape. These discs spin in the direction of material flow, and the aperture size between each disc governs the size of the material segregated. Large surface size (or two-dimensional) material such as newspapers and cardboard, move up the incline of rotating discs, while smaller material such as containers are bounced in the air and roll off the screen (OKay Engineering 2005; WRAP 2006a).

Ballistic separators sort material by shape and weight, that is they are able to sort two dimensional material and light material, e.g. paper, and plastic film, which travel up the inclined ballistic separator from three dimensional and heavy material such as containers which tend to roll back over the end of the ballistic separator. Figure 4.1 shows a view of the paddles used on a ballistic separator; as can be seen in this Figure there are holes in the paddles, which allow a third stream to be separated, referred to as a 'fines' fraction (Okay Engineering Services Ltd. 2005; WRAP 2006a).

Figure 4.1: Ballistic Separator Paddles (Okay Engineering Services Ltd., 2005)

Optical sorters are commonly used to separate various plastic types from a mixed stream; however, they can also be used to sort paper. Optical sorters can be used to segregate plastics by plastic type, for example PET and HDPE, and also by colour; hence, this equipment can be used to segregate natural HDPE from coloured HDPE (TiTech 2006; Zeiger 2004; Tachwali *et al.* 2007). Optical sorters employ a laser technique using Raman scattering spectroscopy to scan the contents of a moving conveyor belt to identify the constituents of the targeted material. Visible light is used to determine the colour of the material, and near infrared (NIR) light is used to determine the plastic type or composition. NIR is invisible to the human eye, and when plastic bottles are exposed to NIR signals, each plastic resin absorbs specific wavelengths, and transmits others, therefore each plastic compound has its own unique characteristic response, which can then be detected by sensors. Once the targeted material has been identified, a signal is sent to a computer. This computer is able to calculate the position and speed of the target item, and then activates a mechanism to remove the item, this mechanism is commonly a jet of compressed air which blows the material from the waste stream; however, other mechanisms have been developed, for example robotic arms (TiTech 2006; WRAP 2006a). Figure 4.2 shows the application of optical sorters being used to sort plastic and paper.

Figure 4.2: Plastic and Paper Optical Sorters (Okay Engineering Services Ltd., 2005)

The key aspect for successful sorting or separation, is material presentation. This is vital to ensure the effectiveness of any piece of equipment. For example, in the case of optical sorters, it is key to ensure that the material is well distributed and that there is no overlapping to maximise the recovery of desired material, and also to ensure that segregated material has minimum contamination.

4.3 MANUAL OPERATIONS

Pickers are commonly used in MRFs, although the extent to which they are used vary from MRF to MRF, and also how they are utilised in MRFs vary. Generally manual picking operations in MRFs can either be classed as positive or negative sorting. However, one key aspect to effective and efficient sorting is material presentation, that is, it is important to ensure that material is distributed evenly on the belt with no overlap, so that all material is clearly visible.

Positive sorting may be defined as where the desired material is removed from the mixed stream on the picking belt, and placed into a bunker or alternatively to another conveyor, for example newspaper is picked from a mixed paper and cardboard stream, to segregate this material. Conversely, negative sorting is where unwanted material is removed from the picking belt, and placed into a bunker or onto another conveyor, leaving the desired material on the picking belt, for example for the segregation of newspaper from a mixed paper and cardboard stream, the cardboard and any other paper type is removed from the picking belt (WRAP 2006a).

Both types of sorting are commonly used in MRFs, and their usage is dependant on the quality and quantity of material on the picking belt. Some MRFs have had quality problems with segregated streams which are negatively sorted.

Picking operations have the advantage of being highly flexible, as if there are changes in the recyclable market, the pickers can simply be instructed to sort differently. However, they are generally less efficient than automated sorting equipment, due to reaction times, the ability to distinguish materials, certainly in the case of the different plastic polymer types, material presentation and so forth.

Table 4.1 gives an indication of the reaction times for selecting various materials from a mixed stream, and Table 4.2 shows the typical quantities of various materials which a sorter can be expected to remove per hour. Both aspects are important factors in the design of any MRF.

Table 4.1: Reaction Times for Various Material Types in Different Stream Types (Mancer and Keeling, 1996)

Material Mix	Target Material	Reaction Time (seconds)
Metals/ Plastics/ Paper and Card	PET	1
	Paper	3
	Card	3
	PVC	2
Paper and Card	Paper	2
	Card	2
Mixed Plastics	PET	1
	PVC	3
	Plastic Film	2

Table 4.1 highlights that the reaction time required for the manual segregation of materials vary depending on the incoming feedstock. For example, if paper is the target material, the reaction time is 2 seconds in a feedstock consisting of only paper and card, but reaction time increases to 3 seconds in a feedstock consisting of metals, plastics, paper and card (i.e. a single stream feedstock). In the instance of PVC, the reaction time is 2 seconds within a single stream feedstock, but 3 seconds in a mixed plastics stream. Hence, this factor must be considered in the design of MRFs to ensure that picking staff have sufficient time to identify and segregate the target materials.

Table 4.2 indicates the typical sorting rates per person for a variety of material types. Studies have shown that paper and card typically have the greatest sorting rates, with both material types ranging from 680 to 4,545 kg per person per hour. Plastics tend to have the lowest sorting rate with PET ranging from 160 to 250 kg per person per hour, and plastic film only having a sorting rate of 20 to 36 kg per person per hour (Mancer and Keeling, 1996; Dubanowitz, 2000; and Siegler and Perkins, 1999). This is an important factor in deciding whether to segregate materials manually or automatically, or if at all, depending on the market rate of the material type.

Table 4.2: Sorting Rates per Person for Various Material Types (Mancer and Keeling, 1996; Dubanowitz, 2000; and Siegler and Perkins, 1999)

Material	Sorting Rate (kg/hr) per person
PET	160-250
Paper	680-4545
Card	680-4545
PVC	240
Glass	409-818
Plastic Film	20-36
Textiles	180

Another important aspect for any MRF which utilises manual labour is the working environment. It is vitally important, that conditions comply with health and safety requirements, and that action is taken to minimise exposure to dust, and also to minimise exposure to hazardous items in the feedstock such as broken glass, needles and so forth.

4.4 DIRTY vs. CLEAN MRF SCENARIOS

Clean MRFs are facilities which recover material for recycling from source segregated mixed dry recyclable. The incoming material may be presented in a number of different formats, these can be grouped as follows:

- single stream, i.e. mixed paper, cardboard and containers, which may or may not include glass; and,
- two stream, i.e. one stream containing paper and cardboard, and the other containing mixed containers, which are then fed into different locations in the MRF.

As well as the above, material can also be presented to the MRF bagged or loose.

Typically clean MRFs recover in excess of 90% of the feedstock as recyclable, which is then sold to reprocessors. There will always be some material which is rejected, for example material such as some types of plastics which cannot be easily recycled and therefore go to landfill.

The advantages of a clean MRF are:

- recover higher quality materials for recycling as the material is free from food waste etc.;
- high processing efficiency;
- health and safety conditions within a clean MRF are generally better than in a dirty MRF; and,
- proven around the world.

The disadvantages of a clean MRF are:

- a source segregated kerbside collection system is needed to provide the feedstock required for the MRF; hence, there are increased collection rounds with associated impact on traffic movement and air quality; and,
- the performance of the MRF is highly dependant on participation within the kerbside scheme.

Dirty MRFs are facilities which recover recyclable material from municipal solid waste (MSW). Some more advanced facilities may also recover biodegradable material which may be sent for anaerobic digestion or in-vessel composting, or a high calorific value stream which can be converted to produce a refuse derived fuel (RDF). Typically a dirty MRF generally recover approximately 15-20% as dry recyclable, which are then sold to reprocessors.

The advantages of a dirty MRF are:

- a dirty MRF utilises the existing MSW collection infrastructure; hence, collection rounds are unchanged and environmental impacts in terms of air quality and transportation remain the same; and,
- performance is not dependant on householder participation as householders are not required to change their behaviour, therefore participation in the scheme is 100% by definition.

The disadvantages of a dirty MRF are:

- contamination of potentially recyclable material with food waste, garden waste etc. impacts on the performance of the MRF;

- generally lower income is obtained for the sale of the recovered recyclable as they are generally of lower quality; and,
- use of dirty MRFs does not encourage householders to change their behaviour in terms of waste minimisation and recycling.

4.5 PROCESS REVIEWS

Reviews were carried out at a number of facilities both in the UK and overseas. These covered both 'clean' and 'dirty' MRFs, which also ranged from 'low-tech' to 'high-tech' operations. All detailed reviews for the 16 MRFs reviewed can be found in Appendix C.

The following 'clean' MRFs were reviewed:

- City and County of Cardiff MRF, Cardiff, UK;
- Norfolk Environmental Waste Services (NEWS) MRF, Norfolk, UK;
- Cutts Recycling MRF, Milton Keynes, UK;
- R U Recycling, Billingham, UK;
- Recycle America MRF, Greyslake, Illinois, USA;
- Pacific Rim Recycling, Benicia, California, USA;
- Upper Valley Waste Disposal Services, Napa Valley, California, USA;
- West County Resource Recycling, Richmond, California, USA;
- Rumpke MRF, Columbus, Ohio;
- Blue Mountain Recycling, Philadelphia, Pennsylvania, USA;

- Recycle America, York, Pennsylvania, USA;
- Guelph Wet Dry + Facility, Guelph, Ontario, Canada; and,
- International Paper Industries (IPI) Ltd., Winnipeg, Manitoba, Canada.

Similarly, reviews were also carried out on 'dirty' MRFS, those reviewed were:

- Yorwaste MRF, Seamer Carr, Scarborough, UK;
- Albacete MRF, Albacete, Spain; and,
- Meddill MRF, Chicago, Illinois, USA.

The process reviews undertaken at MRFs were invaluable as they enable a better understanding of the capabilities and limitations of each of the processes, quality and durability of the equipment and quality of the processed recyclable. As well as operational problems experienced with equipment, any improvements planned and also an indication of costs associated with the facility can be gained.

4.5.1 Clean MRFs

The clean facilities reviewed varied in terms of the feedstock they processed, and also in the level of technology used. By reviewing a range of equipment a better understanding of the variation in MRFs can be developed.

Of the MRFs reviewed, the UK MRFs which stood out were the Milton Keynes MRF operated by Cutts Recycling, and the NEWS MRF in Norfolk. The Cutts Recycling Facility is a highly flexible process as it is able to process a variety of feedstocks, which is shown in Table 4.3 (a more detailed process review can be found in Appendix C4). As is shown in this Table, the MRF is able to process single stream material (excluding glass), two stream material, that is mixed papers and mixed containers, and also commercial recyclable. The single stream material and mixed paper from the two stream material can either be loose or bagged, which adds another element of flexibility, and also mixed containers can be loose or baled, as the MRF contains a debaler for this material.

Table 4.3: Summary of Cutts Recycling MRF Features

MRF Type	Clean		
Equipment Manufacturer	Bulk Handling Systems (BHS)		
Throughput:			
Design Capacity (tph)	10		
Actual Capacity (tph)	8		
Number of Pickers per Shift	20		
Residue (%)	11		
Material Type	**Currently Processes**	**Could Process**	**Could not Process**
Clean Stream:			
Single Stream Material (excluding glass)	√		
Single Stream Material (including glass)			√
Two Stream Material – paper and containers	√		
Bagged Material	√		
Loose Material	√		
Baled Material	√		
Dirty Material i.e. MSW			√
Commercial Recyclable	√		

Although the MRF does not have a very high throughput at around 8-10 tonnes per hour (tph), this is currently sufficient for the needs of the operation, as the MRF is operated 24 hours per day, five days per week. By operating in this manner the cost of equipment is less than for the same MRF layout with a higher throughput; but, labour costs are greater.

In terms of performance, Cutts Recycling would not disclose the percentage of the feedstock which was sent to landfill for commercial reasons; however, at the time of the visit, the MRF was processing single stream material and by visual inspection, it is estimated that less than 10% of the feedstock is sent to landfill.

The process flowsheet for the Cutts Recycling MRF is shown in Figure 4.3. This Figure highlights that the key piece of separation equipment used at the MRF is a Bulk Handling Systems (BHS) disc screen which is used to separate the two dimensional fraction from the three dimensional fraction, i.e. essentially split the feed into two streams: paper and containers. Sorting of the paper stream is a manually intensive operation. While the sorting of the container stream is highly automated, with manual picking only used for polyvinyl chloride (PVC), and to remove any non-requested material from the stream. At the end of the container line, manual pickers remove any missed material which is then sent around the container line again. Ferrous metal is removed by means of an overband magnet, and non-ferrous metals is removed by means of an eddy current separator. Plastic bottles are sent through a bottle flattener which apparently aids the performance of optical sorting equipment, prior to being sent through two twin block optical sorters which segregate PET and HDPE, and sorts them into two colour grades as shown in the flowchart.

To summarise, twelve materials were able to be segregated in the MRF for reprocessing, six streams were segregated manually, these were predominantly the two dimensional streams of:

- cardboard;
- plastic recycling sacks;
- newspapers and magazines;
- mixed paper;

- office paper; and,
- PVC.

While the other six streams were subjected to automated sorting, these were:

- ferrous metals;
- non-ferrous metals;
- clear PET;
- other PET;
- natural HDPE; and,
- coloured (jazz) HDPE.

By using a combination of manual and automated sorting in this manner, the MRF retains an element of flexibility to respond to changes in the recyclable market. This flexibility is predominantly in the paper fractions, although there is potential to segregate further plastic types.

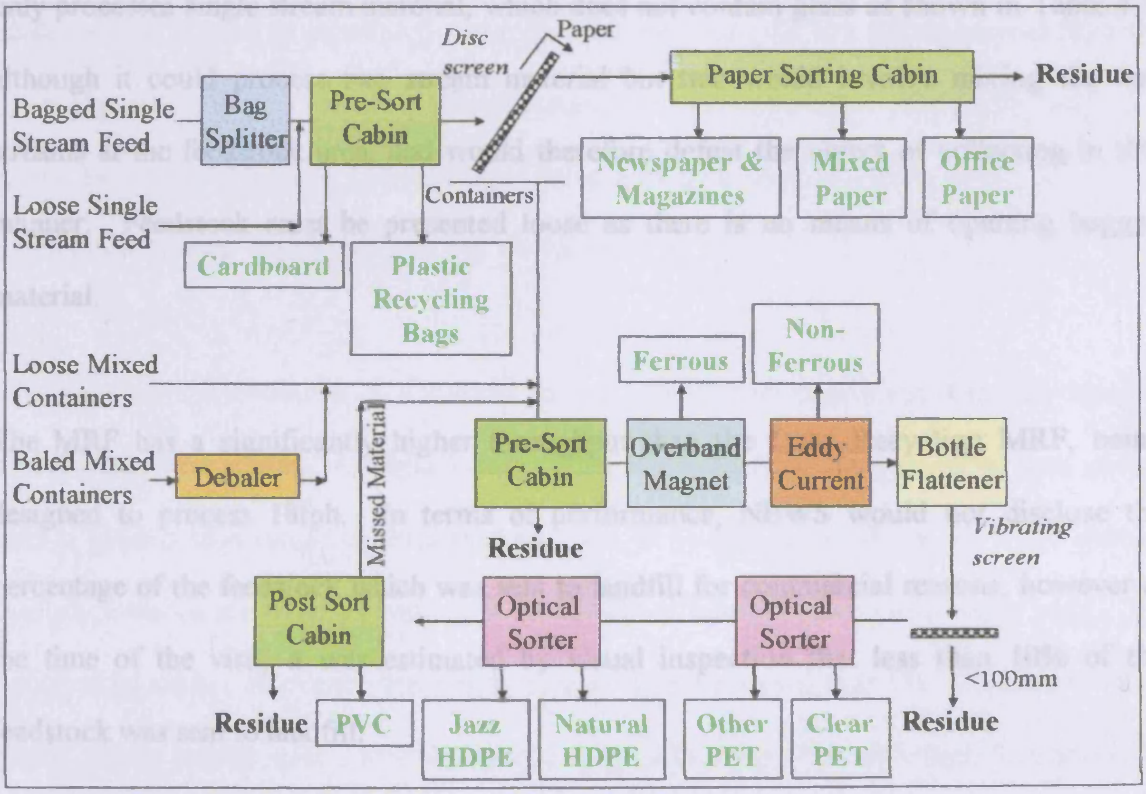


Figure 4.3: Cutts Recycling MRF Layout

An improvement which could be made to the MRF is the installation of a glass or debris screen prior to the disc screen, which breaks the glass and allows it to pass through the screen, which would then add a further recyclable stream which could be recovered. This would enable the MRF to increase its flexibility and be able to process single stream material which contains glass. Also the installation of a glass or debris screen on the container line would similarly enable mixed containers including glass to be processed at the MRF. The installation of this equipment may also reduce operating costs, as glass is often an item which is placed in recycling containers incorrectly. Hence, glass which is present would be removed, thereby minimising wear and tear on the existing equipment.

The NEWS MRF in Norfolk is operated by the local authority waste disposal company (LAWDC) and is a highly automated process. The detailed process review can be found in Appendix C3. It is a much less flexible process than that of Cutts Recycling, as it currently only processes single stream material, which does not contain glass as shown in Table 4.4, although it could process two stream material but this would involve mixing the two streams at the feedstock area, and would therefore defeat the object of collecting in this manner. Feedstock must be presented loose as there is no means of opening bagged material.

The MRF has a significantly higher throughput than the Cutts Recycling MRF, being designed to process 18tph. In terms of performance, NEWS would not disclose the percentage of the feedstock which was sent to landfill for commercial reasons; however at the time of the visit, it was estimated by visual inspection that less than 10% of the feedstock was sent to landfill.

Table 4.4: Summary of NEWS MRF Features

MRF Type	Clean		
Equipment Manufacturer	CP		
Throughput:			
Design Capacity (tph)	18		
Actual Capacity (tph)	14		
Number of Pickers per Shift	12 (Mostly Quality Control)		
Residue (%)	<10		
Material Type	**Currently Processes**	**Could Process**	**Could not Process**
Clean Stream:			
Single Stream Material (excluding glass)	√		
Single Stream Material (including glass)		√	
Two Stream Material – paper and containers		√	
Bagged Material			√
Loose Material	√		
Baled Material			√
Dirty Material i.e. MSW			√
Commercial Recyclable			√

The process flowsheet for the NEWS MRF is shown in Figure 4.4. This Figure highlights that the key piece of separation equipment used at the MRF is a CP Manufacturing V-screen which is used to separate the two dimensional from the three dimensional fraction, i.e. essentially splits the feed into two streams: paper and containers. The paper fraction is sorted by means of optical sorters before being sent to a manual sorting cabin for a final quality control step which removes any contamination.

The container stream moves to a manual sorting cabin where operatives manually remove mixed paper and residual material from the stream. The remaining material then passes over a glass screen which enables broken glass to be segregated from the input stream. Ferrous metal is removed by means of an overband magnet, and non-ferrous metals are removed by means of an eddy current separator. The remaining material is then classed as mixed plastic bottles which are then sent through a bottle perforator which facilitates the baling of this material.

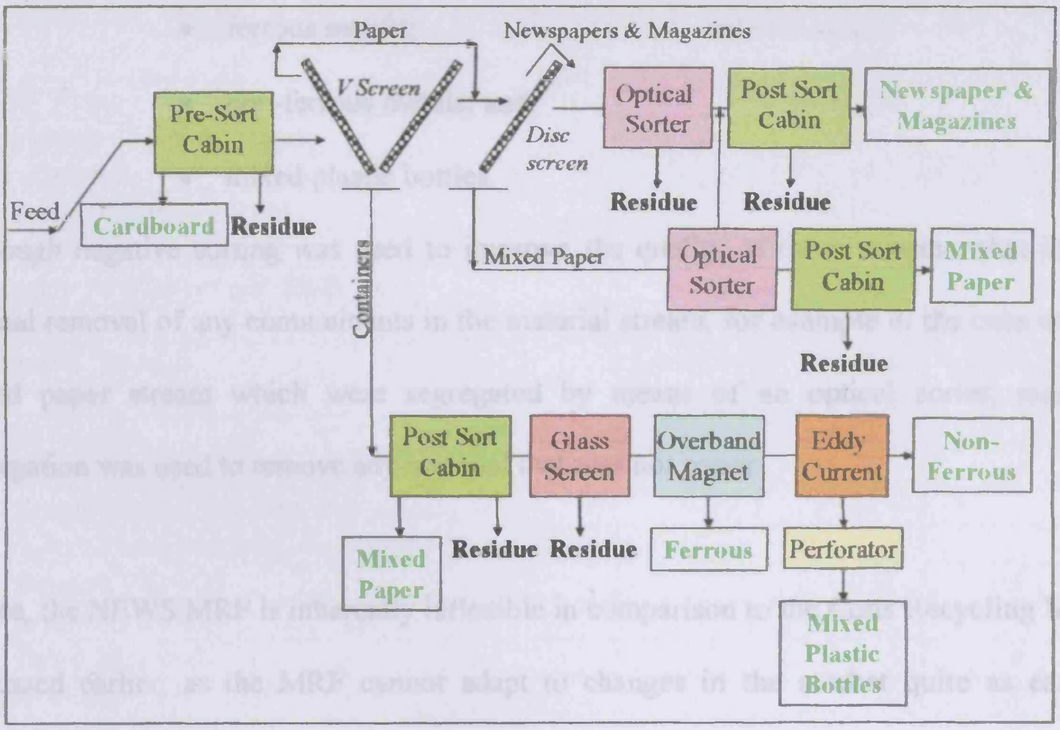


Figure 4.4: NEWS MRF Layout

The MRF would be able to process single stream material which contained glass as it already has a glass screen in place. However, as this is installed after the sorting cabin on the container line, in terms of health and safety concerns would have to be raised. If it was moved from its current location and placed in front of the V-screen, it would reduce wear and tear on this piece of equipment, as its installation in a MRF which does not accept glass does imply that this is a significant contaminant within the feedstock.

To summarise, seven materials were able to be segregated in the MRF for reprocessing, two streams were segregated manually, these were cardboard and mixed paper (from the container line only). While the remaining five streams were subjected to automated sorting, these were:

- newspapers and magazines;
- mixed paper;

- ferrous metals;
- non-ferrous metals; and,
- mixed plastic bottles.

Although negative sorting was used to improve the quality of these streams, that is the manual removal of any contaminants in the material stream, for example in the case of the mixed paper stream which were segregated by means of an optical sorter, manual segregation was used to remove any material that was not paper.

Hence, the NEWS MRF is inherently inflexible in comparison to the Cutts Recycling MRF discussed earlier, as the MRF cannot adapt to changes in the market quite as easily. However, changes could be made to the settings on the optical sorters to alter the characteristics of the segregated streams, for example the mixed paper stream could be altered to segregate office paper.

R U Recycling is a waste management company which operates a highly automated process for the segregation of material from a mixed container stream. It was a highly inflexible operation as it was only able to process mixed containers as shown in Table 4.5 and Appendix C5.

The MRF has a high throughput at 10tph considering that it only processes mixed containers. In terms of performance, R U Recycling would not disclose the percentage of the feedstock which was sent to landfill for commercial reasons; however, at the time of the visit, it was estimated by visual inspection that less than 10% of the feedstock was sent to landfill.

Table 4.5: Summary of R U Recycling MRF Features

MRF Type	Clean		
Equipment Manufacturer	Andela		
Throughput:			
Design Capacity (tph)	10		
Actual Capacity (tph)	10		
Number of Pickers per Shift	0		
Residue (%)	<10		
Material Type	**Currently Processes**	**Could Process**	**Could not Process**
Clean Stream:			
Single Stream Material (excluding glass)			√
Single Stream Material (including glass)			
Two Stream Material – paper and containers	√		
Bagged Material			√
Loose Material	√		
Baled Material			√
Dirty Material i.e. MSW			√
Commercial Recyclable			√

The process flowsheet for the R U Recycling facility is shown in Figure 4.5. This Figure highlights that the key piece of separation equipment used at the MRF was a trommel which allows broken glass to be separated from the rest of the containers. Ferrous metal is removed by an overband magnet, non-ferrous metal is removed by means of an eddy-current separator, while PET and HDPE were removed by means of optical sorters. No pickers are utilised in this purely automatic process, which was of benefit considering the amount of glass present.

To summarise, five materials were segregated in the MRF for reprocessing, all streams were segregated by automated means. There was no manual sorting in any capacity in this MRF. Hence, the R U Recycling MRF is unable to adapt the materials segregated for reprocessing without adding additional equipment, and as a result it is unable to adapt easily to market forces. Also, this MRF being able to process only mixed containers, relies on local authorities collecting in this manner, and also the paper fraction being baled as is or processed elsewhere. The MRF could be developed into a single stream facility by adding a screen, ballistic separator or trommel at the front end of the plant to split paper and containers, and the segregated containers could then be processed on the existing container line, while a new line would have to be added to process the paper. This would be a significant investment, and is theoretically possible; however, space constraints in the building would not allow this development to occur on this site.

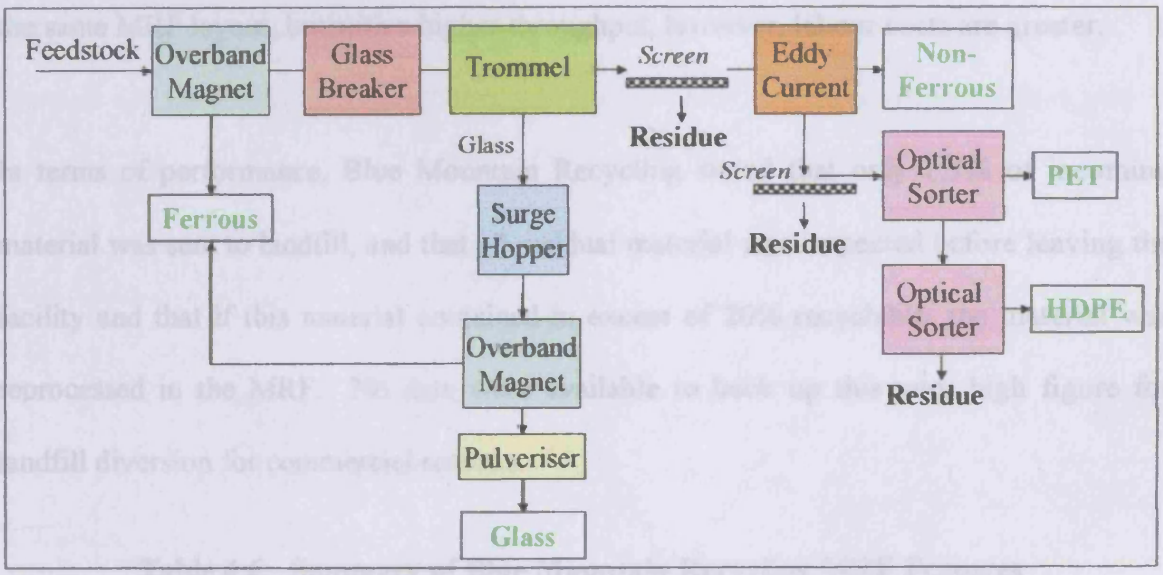


Figure 4.5: R U Recycling MRF Layout

Of the MRFs reviewed, the overseas facilities which stood out were the Blue Mountain Recycling MRF in Philadelphia, Recycle America MRF at York, IPI MRF at Winnipeg, and the Guelph Wet Dry+ Facility in Ontario. These MRFs were very different in their design and operation; however, these are examples of good practice in terms of the design and/ or operation of each of these facilities.

The Blue Mountain Recycling MRF located in Philadelphia was similar to the Cutts Recycling operation in that it was a highly flexible operation as it was able to process a variety of feedstocks as shown in Table 4.6 and Appendix C11.

Although the MRF does not have a very high throughput at around 7-9tph, this was sufficient for the needs of the operation, as the MRF is operated 24 hours per day, five days per week. Again, by operating in this manner the cost of equipment was less than for the same MRF layout, but with a higher throughput, however, labour costs are greater.

In terms of performance, Blue Mountain Recycling stated that only 1.3% of incoming material was sent to landfill, and that all residual material was inspected before leaving the facility and that if this material contained in excess of 20% recyclable, the material was reprocessed in the MRF. No data were available to back up this very high figure for landfill diversion for commercial reasons.

Table 4.6: Summary of Blue Mountain Recycling MRF Features

MRF Type	Clean		
Equipment Manufacturer	CP		
Throughput:			
Design Capacity (tph)	9		
Actual Capacity (tph)	7-9		
Number of Pickers per Shift	15		
Residue (%)	1.3		
Material Type	**Currently Processes**	**Could Process**	**Could not Process**
Clean Stream:			
Single Stream Material (excluding glass)		√	
Single Stream Material (including glass)	√		
Two Stream Material – paper and containers	√		
Bagged Material			√
Loose Material	√		
Baled Material			√
Dirty Material i.e. MSW			√
Commercial Recyclables	√		

The process flowsheet for the Blue Mountain Recycling facility is shown in Figure 4.6. This Figure highlights that the key pieces of separation equipment used at the MRF were cardboard screens to remove the large pieces of cardboard from the stream, and also a V-screen as shown in Figure 4.7, which splits the feedstock into two streams: paper and container. The remainder of the operation is mainly manual, with operatives used to sort the mixed paper fraction, and also plastic bottles. Ferrous metal was removed by means of an overband magnet, and non-ferrous metal was removed by an eddy-current separator. A trommel was used to remove glass from the stream, this glass was crushed and then sold as an aggregate.

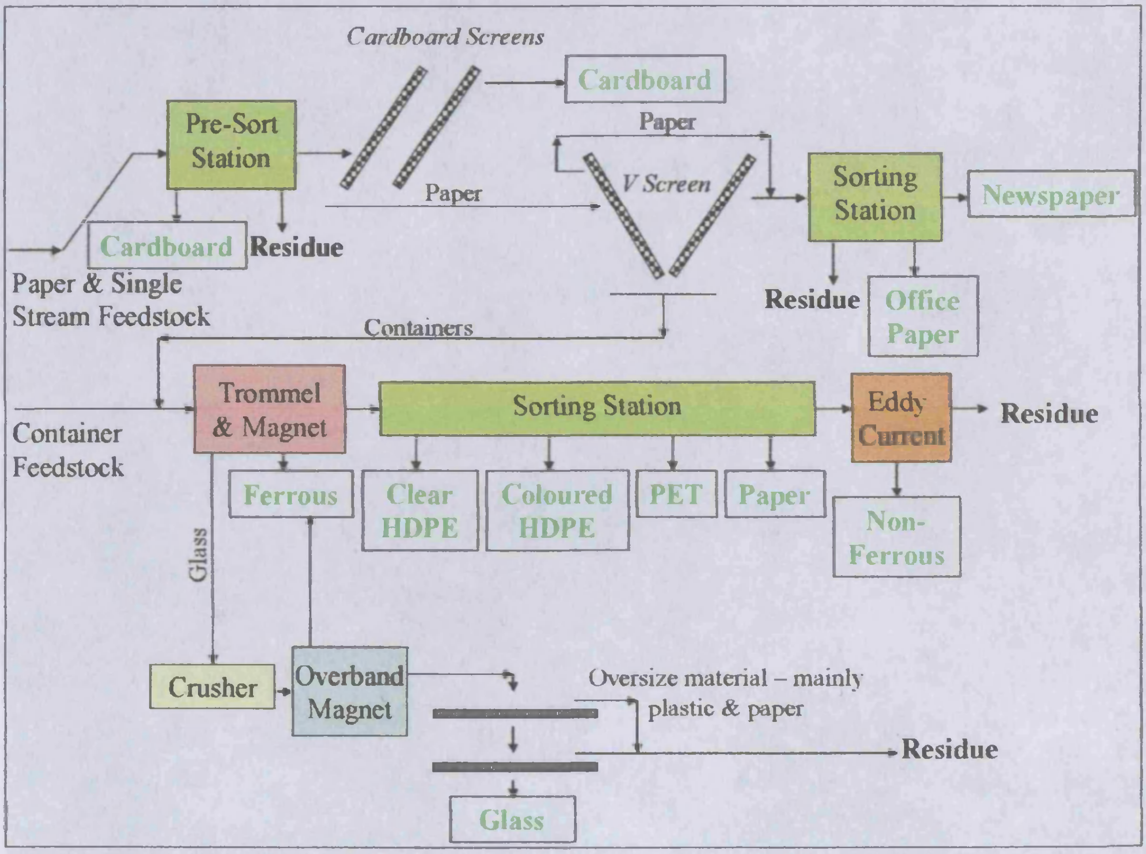


Figure 4.6: Blue Mountain Recycling MRF Layout

Figure 4.7: V-Screen at Blue Mountain Recycling MRF

An improvement which could be made to the MRF is the installation of a glass or debris screen prior to the screens, which would minimise wear and tear on the screens as the discs wear much quicker when glass is contained in the material that passes through them.

To summarise, eleven materials were able to be segregated in the MRF for reprocessing, four streams were segregated by automated means, these were cardboard, glass, ferrous and non-ferrous metals; while the remaining seven streams were segregated manually, these were:

- cardboard (pre-sort station only);
- newspaper;
- office paper;
- clear HDPE;

- coloured HDPE;
- PET; and
- mixed paper.

Hence, the Blue Mountain MRF is able to adapt quite easily to changing market conditions particularly in relation to the container line, for example, if it became economically unfeasible to sort HDPE into clear and coloured grades, they could simply instruct the pickers to segregate mixed HDPE. There is also some scope to alter the materials segregated in the paper stream also, for example changing office paper to mixed paper.

The Recycle America MRF at York, Pennsylvania (Appendix C12), and the IPI MRF at Winnipeg (Appendix C14), were very similar in that the feedstock being processed was single stream material which contained glass and also the equipment was manufactured by Bollegraaf with screens being used as the key pieces of separation equipment. Both MRFs had found that maintenance costs were much higher than anticipated, and as a result innovation was a strong part of the operation. Both MRFs had developed their own stars to use on the Bollegraaf screens as shown in Figure 4.8, which they stated lasted longer, thereby minimising down time for replacement of stars, hence reducing maintenance costs.

The Guelph Wet Dry+ facility in Ontario is a three stream system, which contains a single stream MRF. Essentially residents of Guelph have three bags, one being used for organic waste, another for single stream dry recyclable including glass, and the remaining bag being used for residual waste. The collected dry recyclable stream is processed at the MRF, which also accepts mixed containers from other parts of Ontario. Therefore, the operation is flexible in that it was able to process both single and two stream material which contain glass, and commercial recyclable, and also it was able to process both bagged and loose material as shown in Table 4.7 and Appendix C13.

Figure 4.8: 12 Pronged Stars for use in Angled Screen at Recycle America MRF, York

Table 4.7: Summary of Guelph MRF Features

MRF Type	Clean		
Equipment Manufacturer	BHS		
Throughput:			
Design Capacity (tph)	15-20		
Actual Capacity (tph)	15-20		
Number of Pickers per Shift	20		
Residue (%)	40		
Material Type	**Currently Processes**	**Could Process**	**Could not Process**
Clean Stream:			
Single Stream Material (excluding glass)		√	
Single Stream Material (including glass)	√		
Two Stream Material – paper and containers	√		
Bagged Material	√		
Loose Material	√		
Baled Material			√
Dirty Material i.e. MSW			√
Commercial Recyclable	√		

The performance of the MRF was very disappointing in that 40% of the incoming mixed recyclable was sent to landfill. Based on visual inspection, this was due to a lack of maintenance, as the discs on the BHS disc screen were highly worn and clearly needed replacing. As a result, the screen was not performing as it should, and this affected the performance of the downstream equipment. It also seemed that the equipment was not set up correctly. The whole MRF needs to be looked at closely as the loss of this much recyclable to landfill is a considerable cost, and maintaining the system correctly would reduce this cost.

The process flowsheet for Guelph MRF is shown in Figure 4.9. This highlights that the key separation equipment were the disc screens which were used to split the material into container and paper fractions. Much of the remaining operation was manual with the exception of ferrous metal being removed by means of an overband magnet, and non-ferrous metal removed by means of an eddy-current separator. A glass screen was also used in the latter stages to break the glass and remove the glass from the container line.

To summarise, nine materials were segregated in the MRF for reprocessing, the vast majority of these were manually segregated, with only steel, glass and aluminium segregated by automated means. Hence, the Guelph facility is able to adapt quite easily to changing market conditions as the pickers can simply be instructed to alter their picking regimes.

An improvement which could be made to the MRF, is that another glass screen could be installed before the disc screens. This would minimise wear and tear on the screens as the discs wear much quicker when glass is contained in the material that passes through them.

This would then lengthen the life of the discs on the screens, thereby reducing maintenance costs.

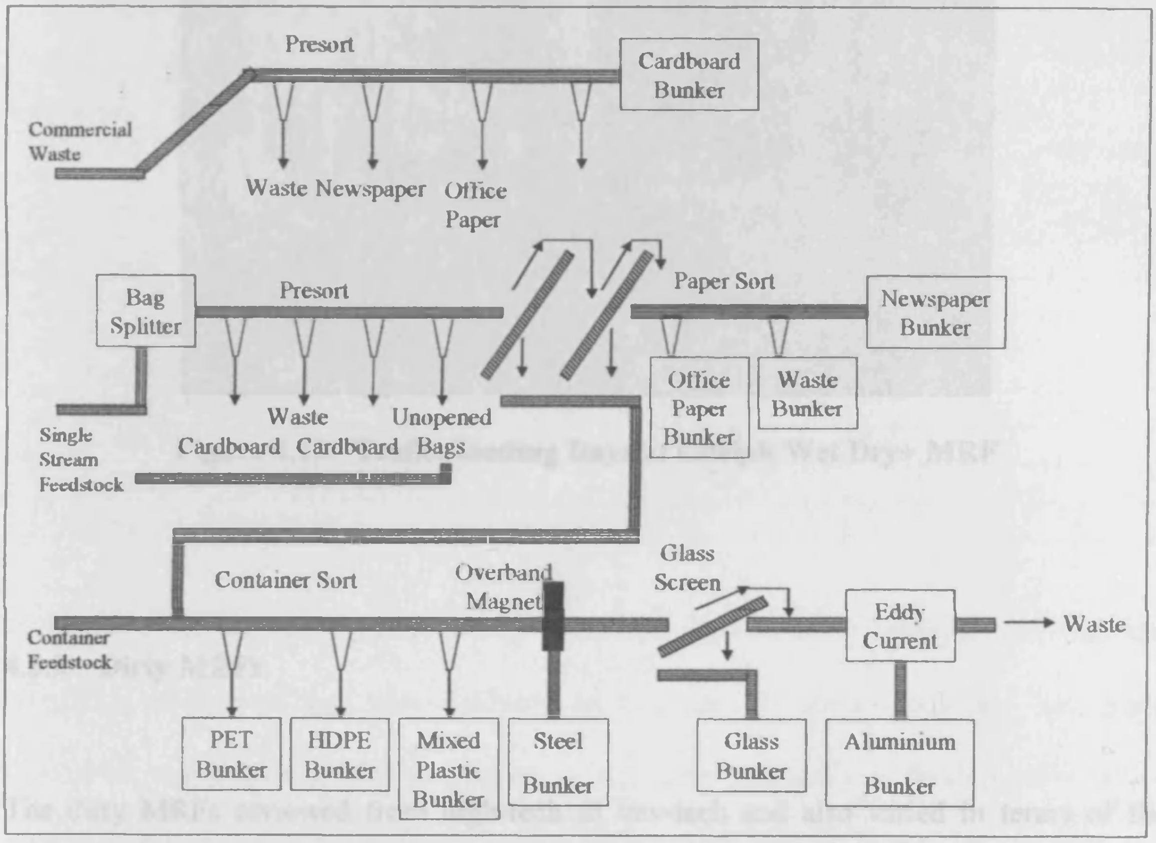


Figure 4.9: Guelph Wet Dry+ MRF Layout

A successful aspect of the operation at the Guelph facility was that baled paper and card was taken from the baler and placed immediately in a trailer, thereby reducing the storage capacity needed at the site. Lorries came to site with an empty trailer, and then simply hitched up to a full trailer and transported the paper to the reprocessors. As well as minimising the space needed for storage, this also minimised the time on site for the transportation company, and also placed less pressure on fork lifts to load vehicles. Figure 4.10 shows a photograph of this operation at the facility.

Figure 4.10: Trailer loading Bays at Guelph Wet Dry+ MRF

4.5.2 Dirty MRFs

The dirty MRFs reviewed from high-tech to low-tech and also varied in terms of the feedstock that they were able to process. Of the three dirty MRFs reviewed, the Albacete MRF in Spain and Meddill MRF at Chicago were able to process both mixed MSW and also recyclable, while the Yorwaste MRF only processed household waste.

Table 4.8 shows a summary of the main features of the Yorwaste MRF, as mentioned earlier the facility only processed mixed household waste, and as the equipment used was very different to that seen in other MRFs it was difficult to assess whether dry recyclable could be processed effectively in the facility. A more detailed process review of this MRF can be found in Appendix C15.

Table 4.8: Summary of Yorwaste MRF Features

MRF Type	Dirty		
Equipment Manufacturer	Wastec		
Throughput:			
Design Capacity (tph)	15		
Actual Capacity (tph)	15		
Number of Pickers per Shift	0		
Residue (%)	No Data Available		
Material Type	**Currently Processes**	**Could Process**	**Could not Process**
Clean Stream:			
Single Stream Material (excluding glass)			√
Single Stream Material (including glass)			√
Two Stream Material – paper and containers			√
Bagged Material			√
Loose Material			√
Baled Material			√
Dirty Material i.e. MSW	√		
Commercial Recyclable			√

Figure 4.11 shows the process flowsheet for the MRF. This highlights that the key separation equipment was very different to that used at other facilities. The main separation occurs at the kinetic streamer, which was essentially a shaking table which separated the mixed material into a stream which contained the paper, plastic film and biodegradable organic material, and a second stream which contained glass, cans and plastic bottles. The remaining equipment used is commonly found in MRFs. However, the paper and cardboard separated in the MRF was pelletised and was marketed as a refuse derived fuel (RDF).

No information was available for the diversion form the MRF from Yorwaste, as this was deemed sensitive information, and as some of the material was diverted to a Hotrot in-vessel composting system it was difficult to get a visual estimation on the diversion from this plant.

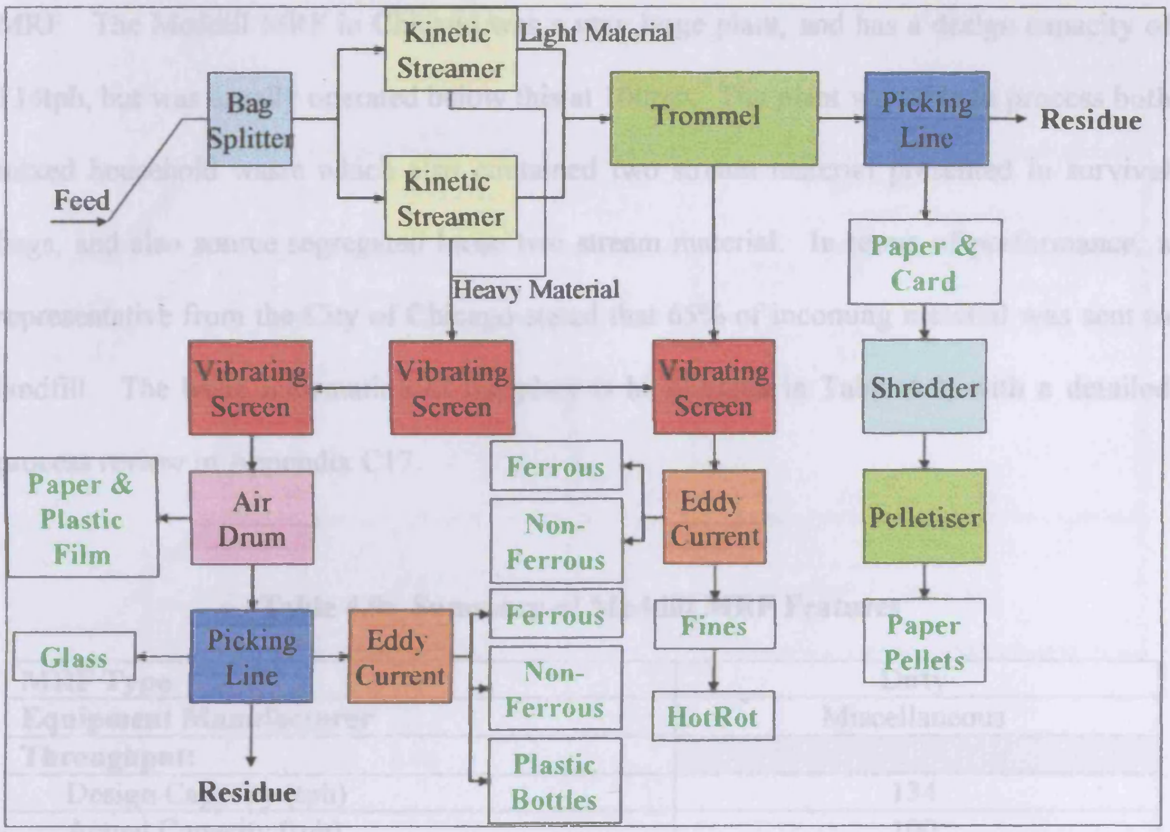


Figure 4.11: Flowsheet for Yorwaste MRF

The kinetic streamers in the plant were very large pieces of equipment, and it was evident that this space could be better used with a trommel, ballistic separator or screen to achieve a better level of separation.

To summarise, seven materials were segregated in the MRF for reprocessing, the majority of these were subject to automated segregation; however, manual sorting was conducted on the glass stream (positive sorting), and paper and card stream (negative sorting). Hence, the MRF facility was unable to adapt rapidly to changing market conditions as additional equipment would be required.

Both the Albacete and Meddill MRFs process both household waste and dry recyclable, although the Meddill MRF is a much more manually intensive operation than the Albacete

MRF. The Meddill MRF in Chicago was a very large plant, and has a design capacity of 134tph, but was usually operated below this at 100tph. The plant was able to process both mixed household waste which also contained two stream material presented in survival bags, and also source segregated loose two stream material. In terms of performance, a representative from the City of Chicago stated that 65% of incoming material was sent to landfill. The basic information of the plant is highlighted in Table 4.9, with a detailed process review in Appendix C17.

Table 4.9: Summary of Meddill MRF Features

MRF Type	Dirty		
Equipment Manufacturer	Miscellaneous		
Throughput:			
Design Capacity (tph)	134		
Actual Capacity (tph)	100		
Number of Pickers per Shift	35-40		
Residue (%)	65		
Material Type	**Currently Processes**	**Could Process**	**Could not Process**
Clean Stream:			
Single Stream Material (excluding glass)		√	
Single Stream Material (including glass)		√	
Two Stream Material – paper and containers	√		
Bagged Material	√		
Loose Material	√		
Baled Material			√
Dirty Material i.e. MSW	√		
Commercial Recyclable		√	

The process flowsheet for Meddill MRF is shown in Figure 4.12. This Figure highlights that the key pieces of separation equipment used at the MRF were trommels, these were used to remove fine material from the waste stream, and also to segregate containers from the mixed household waste. The remaining material was mainly hand sorted, with the exception of metals which were removed using an overband magnet and eddy current separator.

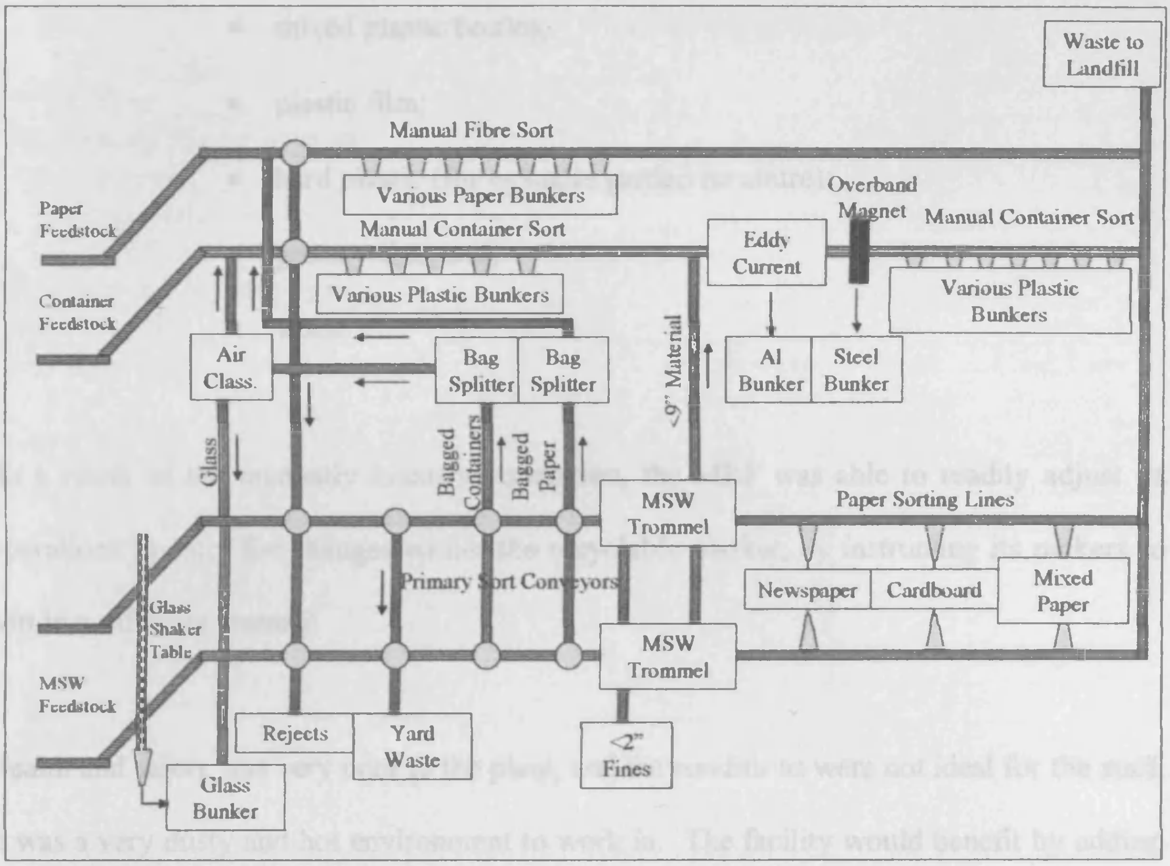


Figure 4.12: Flowsheet for Meddill MRF

Thirteen materials were segregated in the MRF for reprocessing, those segregated by automated means were:

- glass;
- steel;
- aluminium; and
- fines fraction (less than 2 inches).

The remaining streams were manually segregated, and consisted of:

- cardboard;
- newspapers;
- magazines;
- mixed paper;

- mixed plastic bottles;
- plastic film;
- hard plastic (for example garden furniture);
- green waste; and,
- wood.

As a result of the manually intensive operation, the MRF was able to readily adjust its operations to cater for changes within the recyclable market, by instructing its pickers to sort in a different manner.

Health and safety was very poor in the plant, and the conditions were not ideal for the staff. It was a very dusty and hot environment to work in. The facility would benefit by adding dust extraction and air conditioning systems for the sorting cabins. In terms of improvements, the MRF would benefit from increased automation, for example the use of an optical sorter for sorting plastic bottles.

The Albacete MRF was a much smaller facility than the Meddill MRF; it had a throughput of 30tph. Again, the plant processed both mixed household waste and mixed containers; however, this was in a different manner to the Meddill MRF, as mixed containers were batched through the dirty MRF line on 1 day per week. In terms of performance, a representative from the MRF stated that 44% of incoming material was sent to landfill, which was significantly better than the performance of Meddill MRF. Again, the basic features are highlighted in Table 4.10, with a more detailed review in Appendix C16.

Table 4.10: Summary of Albacete MRF Features

MRF Type	Dirty		
Equipment Manufacturer	Stadler		
Throughput:			
Design Capacity (tph)	30		
Actual Capacity (tph)	30		
Number of Pickers per Shift	5 (Quality Control)		
Residue (%)	44		
Material Type	**Currently Processes**	**Could Process**	**Could not Process**
Clean Stream:			
Single Stream Material (excluding glass)		√	
Single Stream Material (including glass)		√	
Two Stream Material – paper and containers	√		
Bagged Material	√		
Loose Material	√		
Baled Material			√
Dirty Material i.e. MSW	√		
Commercial Recyclable		√	

The process flowsheet for Albacete MRF is shown in Figure 4.13. This Figure highlights that the key pieces of separation equipment used at the MRF were again trommels which were used to remove fine organic material from the waste stream, and also to segregate the containers and paper fractions from the mixed household waste. The container and paper fractions were then conveyed to a ballistic separator which further cleaned up the streams, enabling all the paper and plastic film to be removed. The remaining mixed containers were then sorted in a highly automated operation with an overband magnet, eddy current separator and optical sorters were utilised to segregate the ferrous metals, non-ferrous metal and various plastic types respectively. It was disappointing to note that no sorting was carried out on the mixed paper and film fraction; however, there was not a market for this material in Spain at the time of visit.

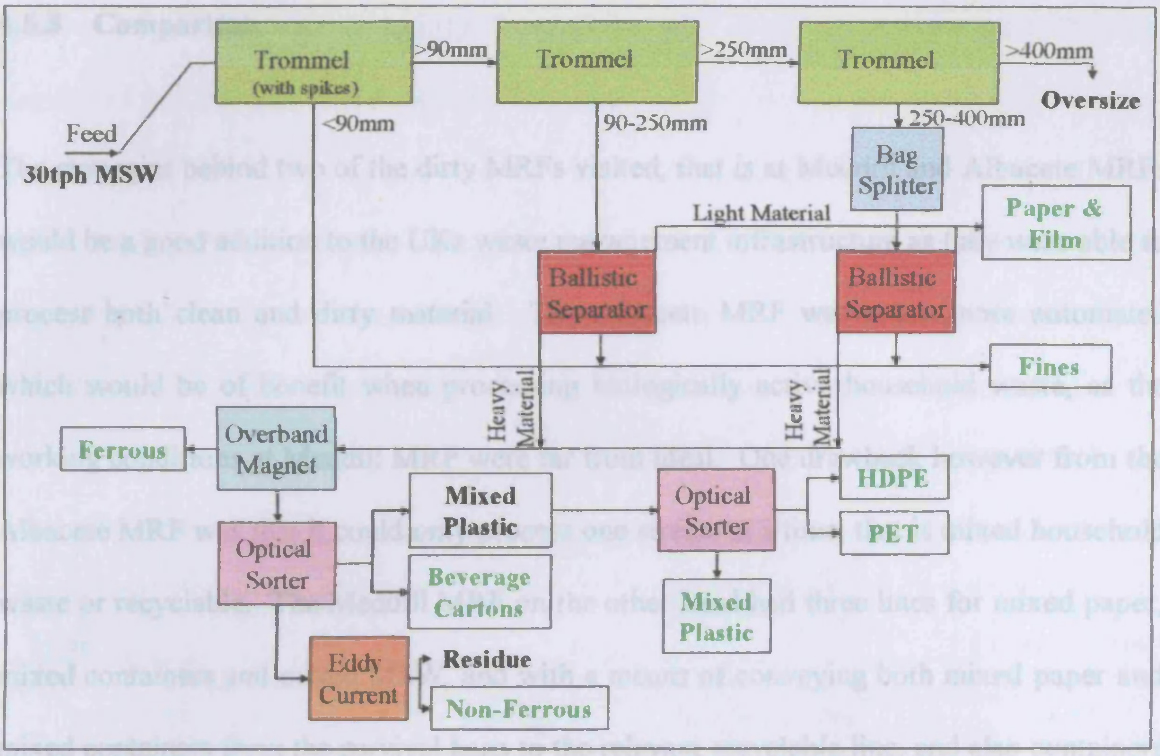


Figure 4.13: Flowsheet for Albacete MRF

To summarise, eight materials were segregated automatically in the MRF for reprocessing; however, staff were employed in a quality control role to remove any contaminants from the segregated streams. The MRF would be limited in its response to changing market conditions, as a result of the minimal manual operations in place; however, a limited number of changes could be made to the settings of the optical sorters in relation to plastics. Other than this, additional investment would be required to purchase other equipment, such as conveyors and picking platforms for sorting of the paper and cardboard streams.

4.5.3 Comparison

The strategies behind two of the dirty MRFs visited, that is at Meddill and Albacete MRFs would be a good addition to the UKs waste management infrastructure as they were able to process both clean and dirty material. The Albacete MRF was much more automated which would be of benefit when processing biologically active household waste, as the working conditions at Meddill MRF were far from ideal. One drawback however from the Albacete MRF was that it could only process one stream at a time, that is mixed household waste or recyclable. The Meddill MRF on the other hand had three lines for mixed paper, mixed containers and mixed MSW, and with a means of conveying both mixed paper and mixed containers from the survival bags to the relevant recyclable line, and also containers from the mixed household waste to the container line. Hence, it was able to process mixed household waste and recyclable at the same time.

As is clearly highlighted in the process reviews, there was considerable variation in the operation of MRFs, in terms of the level of automation in the process, throughput and also recovery performance. As part of the process reviews, information gained from the MRFs has enabled a mathematical comparison of each of the MRFs to be carried out.

One method of mathematical comparison is the calculation of the throughput through the plant per picker (T_P), this is shown below. The denominator used is the number of pickers plus one, as some MRFs operate without any pickers, and it is not possible to divide by zero.

$$T_P = \frac{T}{(P+1)}$$

Where 'T' is the average throughput through the MRF in tonnes per hour, and 'P' is the number of pickers employed at the MRF per shift.

The formula returns a value, which give an indication of the level of automation in the plant. Generally, the value increases as a MRF operation becomes more automated. Table 4.11 shows the T_P values for a selection of the MRFs reviewed in this section.

Table 4.11: Throughput per Picker (T_P) for Reviewed MRFs

MRF Type	MRF	Feedstock Type	T_P (T/hr/Person)
Clean	NEWS, Norfolk	Single Stream	1.08
	Cutts Recycling, Milton Keynes	Single Stream	0.38
	Recycle America Grayslake	Single Stream	0.77
	West Coast Recycling	Single Stream	1.42
	Blue Mountain Recycling	Single Stream	0.56
	Guelph Wet Dry+	Single Stream	0.95
	City of Cardiff MRF	Single Stream	0.54
	Rumpke MRF, Columbus, Ohio	Single Stream	0.65
	R U Recycling, Darwen	Mixed Containers	10.00
Dirty	Yorwaste	Mixed MSW	15.00
	Albacete MRF	Mixed MSW & Recyclable	5.00
	Meddill MRF, Chicago	Mixed MSW & Recyclable	2.44

It can clearly be seen that the values for T_P are lower for single stream MRFs reviewed than the mixed container and dirty MRFs reviewed, which indicates that these are generally less automated than other operations, although values vary significantly from 0.38 to 1.42.

However, this index cannot be used in isolation, as a MRF with a high T_P value could simply be underperforming, i.e. the residue remaining from the process may be very high as the MRF is simply not employing enough pickers. Hence, it is vitally important to consider the T_P values together with percentage of processed material lost as residue.

Figure 4.14 shows a graph of T_P plotted against the percentage residue per picker from the single stream MRFs reviewed as part of this study. The correlation coefficient (R^2) value of 0.1006 indicates little correlation between the two data sets. However, if the outlying values for Guelph Wet Dry+ Facility and the Cutts Recycling MRF are omitted the trend line differs dramatically as shown in Figure 4.15. This Figure highlights the same overall trend, however the correlation coefficient (R^2) value of 0.6207 indicates a moderate correlation between the two data sets. The trendline shown in Figure 4.15 for single stream MRFs can be expressed as an equation, where R_P represents the Residue in percentage format.

$$R_P = 0.3846T_P + 0.0195$$

This could also be used as a benchmarking tool if data from other single stream MRFs were also obtained, in order to compare a MRF operation with the predicted performance for a MRF with its T_P value.

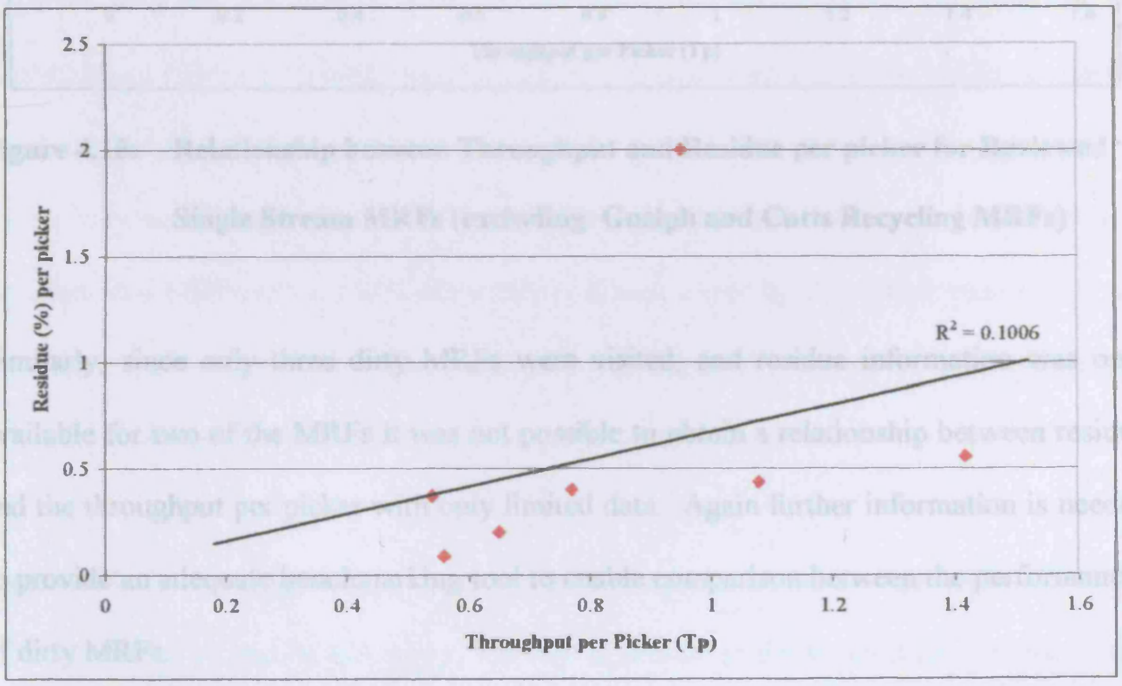


Figure 4.14: Relationship between Throughput and Residue per picker for Reviewed Single Stream MRFs

It was not possible to obtain a relationship between residue and throughput per picker for MRFs that processed containers only as only one of these types of MRF was visited (R U Recycling); but similarly if information was obtained from other MRFs of this type the same benchmarking practice could take place.

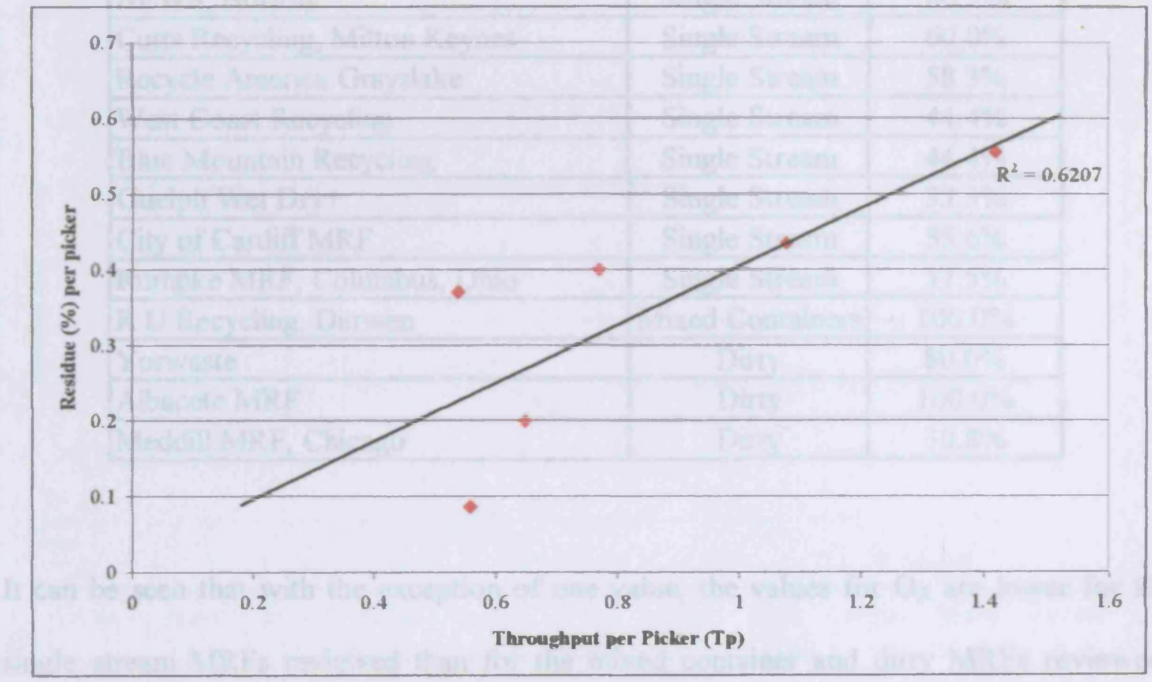


Figure 4.15: Relationship between Throughput and Residue per picker for Reviewed Single Stream MRFs (excluding Guelph and Cutts Recycling MRFs)

Similarly, since only three dirty MRFs were visited, and residue information was only available for two of the MRFs it was not possible to obtain a relationship between residue and the throughput per picker with only limited data. Again further information is needed to provide an adequate benchmarking tool to enable comparison between the performances of dirty MRFs.

Another method of mathematical comparison is the calculation of the proportion of output streams that were sorted by means of an automated separation process (O_A), for example optical sorters, overband magnet, eddy current separators etc. Table 4.12 highlights the results for this calculation for a selection of the MRFs reviewed.

Table 4.12: Proportion of Output Streams Segregated by Automated Means

MRF	MRF Type	O_A (%)
NEWS, Norfolk	Single Stream	66.7%
Cutts Recycling, Milton Keynes	Single Stream	60.0%
Recycle America Grayslake	Single Stream	58.3%
West Coast Recycling	Single Stream	44.4%
Blue Mountain Recycling	Single Stream	44.4%
Guelph Wet Dry+	Single Stream	33.3%
City of Cardiff MRF	Single Stream	55.6%
Rumpke MRF, Columbus, Ohio	Single Stream	37.5%
R U Recycling, Darwen	Mixed Containers	100.0%
Yorwaste	Dirty	80.0%
Albacete MRF	Dirty	100.0%
Meddill MRF, Chicago	Dirty	30.8%

It can be seen that with the exception of one value, the values for O_A are lower for the single stream MRFs reviewed than for the mixed container and dirty MRFs reviewed, which indicates that these are generally less automated than other operations, although values vary significantly from 33.3% to 66.7%. Again, these values cannot be used in isolation, as a MRF with a 100% of its output stream sorted by automated means does not necessarily have a very low residue value. Hence, it is vitally important to consider these values in conjunction with the percentage of processed material lost as residue.

Figure 4.16 shows a graph of the O_A values plotted against the percentage residue from the MRFs reviewed as part of this study. On first appearances the graph indicates that as the level of automation increases, the proportion lost as residue declines. The correlation coefficient (R^2) value of 0.1536 indicates little correlation between the two data sets. However, if the outlying values in terms of residue of Guelph Wet Dry+ Facility (40%

residue) and Blue Mountain Recycling (1.3% residue), are taken out the trend line differs dramatically as shown in Figure 4.17. Figure 4.16 indicates a reversal of the previous trend, in that as MRFs become more automated, the proportion of input material lost as residue increases. The correlation coefficient (R^2) value of 0.5649 indicates a moderate correlation between the two data sets.

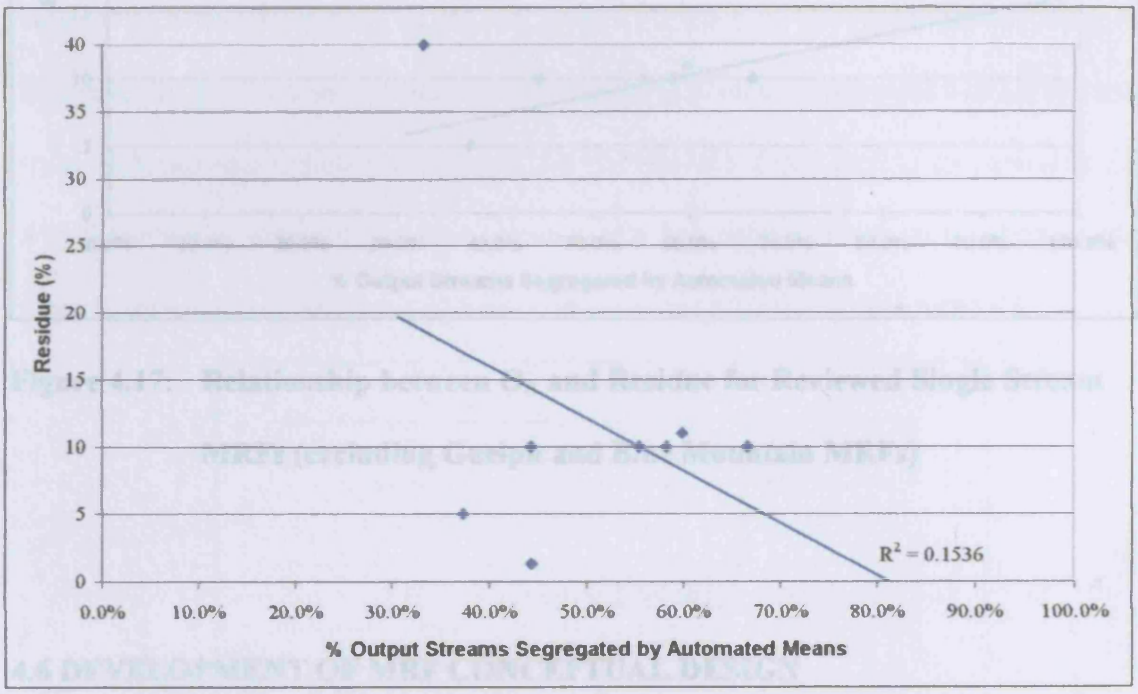


Figure 4.16: Relationship between O_A and Residue for Reviewed Single Stream MRFs

It was not possible to obtain a relationship between O_A values and proportion of residue for MRFs processing mixed containers and dirty MRFs as there was insufficient information from the MRFs reviewed as part of this study.

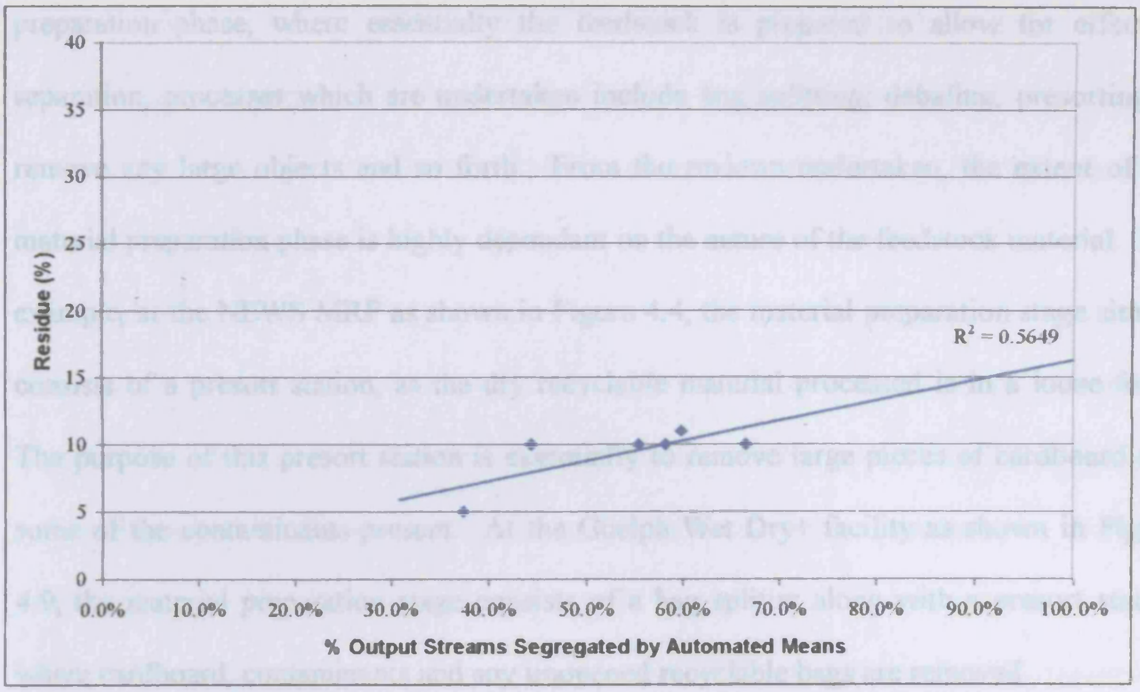


Figure 4.17: Relationship between O_A and Residue for Reviewed Single Stream MRFs (excluding Guelph and Blue Mountain MRFs)

4.6 DEVELOPMENT OF MRF CONCEPTUAL DESIGN

The process reviews undertaken, have assisted in the development of a conceptual design for a MRF. In any MRF, the key to a successful operation is process flexibility, as during the operational life of a MRF many changes are likely, for example waste composition, waste collection methods, material presentation and so forth. Also, process flexibility would allow other materials to be processed in the MRF without significant changes. Hence, it is vitally important to consider these factors in the design.

From the reviews undertaken, it can be seen that the process can be broken down into three key components, which are identified in Figure 4.18. The first component is the material preparation phase, where essentially the feedstock is prepared to allow for effective separation, processes which are undertaken include bag splitting, debaling, presorting to remove any large objects and so forth. From the reviews undertaken, the extent of the material preparation phase is highly dependant on the nature of the feedstock material. For example, at the NEWS MRF as shown in Figure 4.4, the material preparation stage simply consists of a presort station, as the dry recyclable material processed is in a loose form. The purpose of this presort station is essentially to remove large pieces of cardboard and some of the contaminants present. At the Guelph Wet Dry+ facility as shown in Figure 4.9, the material preparation stage consists of a bag splitter along with a presort station where cardboard, contaminants and any unopened recyclable bags are removed

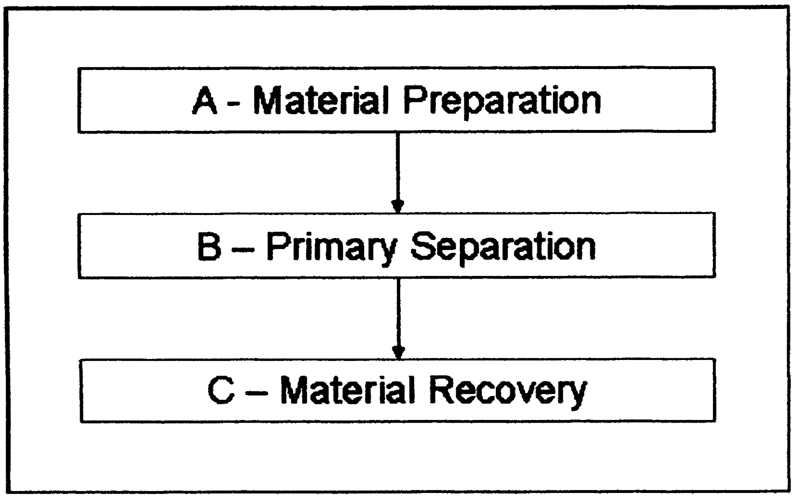


Figure 4.18: Key Components of MRF Processes

The second component is the primary separation phase, whereby crude separation is undertaken in order to make the final material recovery phase more effective and efficient. The primary separation phase varied significantly among the process reviews undertaken, from the use of primarily disc screen technology in clean MRFs, for example at the Cutts Recycling, NEWS and Blue Mountain Recycling and Guelph MRFs (as shown in Figures 4.3, 4.4, 4.6 and 4.9). While in dirty MRFs, the primary separation phase tends to be a bit more complex. In the dirty MRFs reviewed, the primary separation phase ranged from the use of kinetic streamers, a trommel and vibrating screens at the Yorwaste facility (as shown in Figure 4.11), to the use of trommels and ballistic separators at the Albacete MRF as can be seen in Figure 4.13.

The final material recovery phase essentially is the separation of the materials required for reprocessing, the extent of which is highly dependant on market conditions but also on the type of segregation utilised. Segregation can either be manual or automated as discussed previously, and the MRFs reviewed ranged from being fully automated, to being intensively manual operations. For example at the NEWS, R U Recycling, Yorwaste and Albacete MRFs as shown in Figures 4.4, 4.5, 4.11 and 4.13 respectively, the material recovery phase was fully automated and consisted of sorting equipment such as overband magnets, eddy current separators, optical sorters, and air classifiers. In contrast, the material recovery phase at the Blue Mountain Recycling, Guelph and Meddill MRFs utilise more manual sorting. The manual sorting was used for segregating the paper and plastic streams, while automated sorting was used for the segregation of steel and aluminium.

Figure 4.19 shows the flowsheet for the conceptual design of the MRF which highlights the three component phases of the process.

The material preparation phase indicated by the letter A in Figure 4.19 consists of a presort station and bag splitter. At the presort station bulky items are removed, which allows large bulky objects (such as microwaves, furniture and so forth) which could cause damage to the equipment to be removed. The remaining material then continues to a bag opener, which opens any bagged material and liberates the contents. The addition of a bag splitter within the conceptual design enables the MRF to be more flexible in terms of the feedstock processed, as loose and bagged material could be processed.

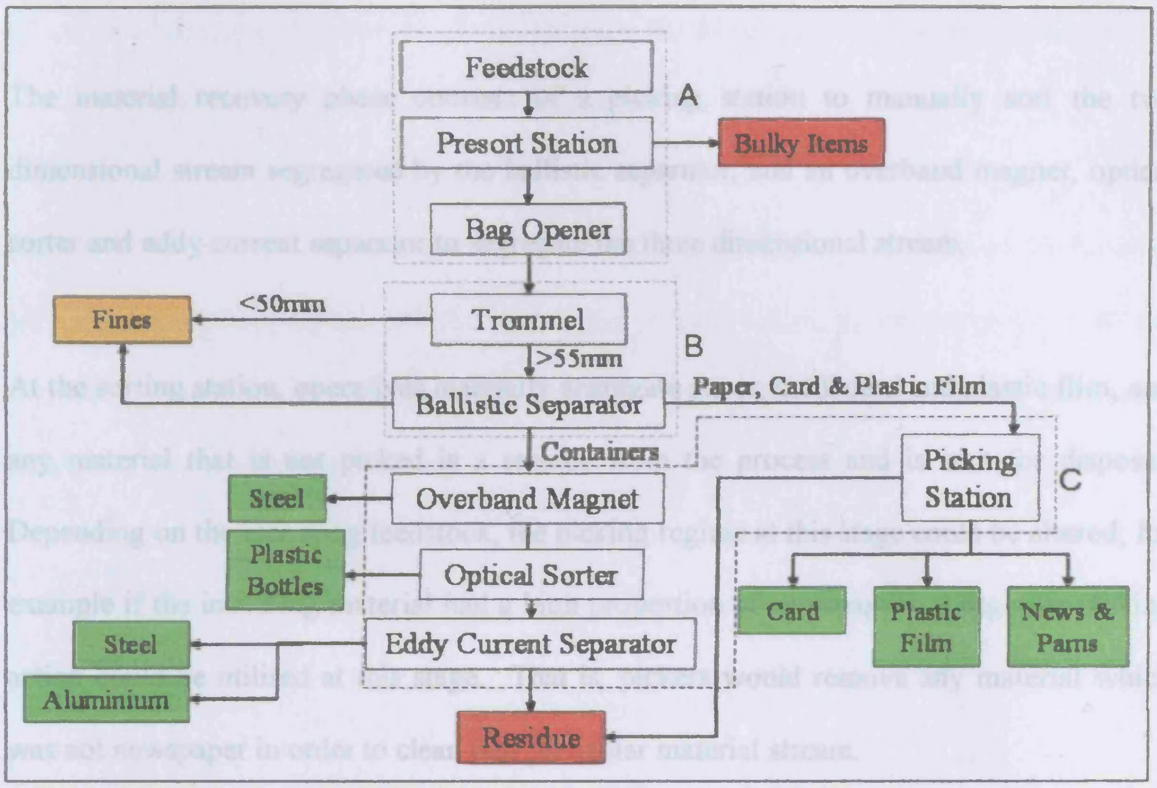


Figure 4.19: Conceptual MRF Design Flowchart highlighting process components

The primary separation phase (identified by the letter B in Figure 4.19), consists of a trommel and bag splitter. The material from the bag splitter enters a trommel which screens at 55mm, which removes the finer fraction of the feedstock, for example organic material, bottle tops, shredded paper, broken glass and so forth. The inclusion of a trommel screening at 55mm within the conceptual design enables the MRF to process household waste which contains a large organic fraction, and thereby clean the recyclable stream contained within waste stream.

The oversize fraction from the trommel, i.e. material greater than 55mm, then continues to a ballistic separator. The ballistic separator sorts material by shape and weight; and hence, splits the material into two streams, these being a two dimensional and light material stream, such as paper, cardboard, plastic film etc., and a three dimensional and heavy material stream, namely containers, for example.

The material recovery phase consists of a picking station to manually sort the two dimensional stream segregated by the ballistic separator, and an overband magnet, optical sorter and eddy current separator to segregate the three dimensional stream.

At the sorting station, operatives manually segregate paper, cardboard and plastic film, and any material that is not picked is a residue from the process and is sent for disposal. Depending on the incoming feedstock, the picking regime at this stage could be altered; for example if the incoming material had a high proportion of newspapers, a negative picking action could be utilised at this stage. That is, pickers would remove any material which was not newspaper in order to clean that particular material stream.

The container stream from the ballistic separator then continues to a series of automated unit operations, these being an overband magnet to remove the steel cans from the stream, an optical sorter to remove mixed plastic bottles, and an eddy current separator to remove the aluminium stream, and also to remove any missed steel. Any remaining material is sent for disposal.

This design is flexible in that a variety of materials could be processed, namely:

- single stream dry recyclable that is either loose or bagged;
- municipal solid waste; and,
- two stream dry recyclable that is either loose or bagged.

To further improve process flexibility, other feedpoints could include:

- loose mixed containers could be fed into the plant onto the container line after the ballistic separator; and,
- loose mixed paper could be fed into the MRF onto the paper, cardboard and plastic film line after the ballistic separator.

Hence, if there were any changes to the collection operation, these could be handled without the need for significant changes to the process. Also, as the paper and card are manually sorted, any changes in these markets could be readily addressed by instructing pickers to sort in a different manner.

CHAPTER 5: Operational Aspects of the Materials Recovery Facility

5.1 INTRODUCTION

This chapter will look at the critical aspects of the MRF, and identify the crucial parameters considered in the design as discussed in chapter 4. The results of an efficiency study conducted following the installation of the MRF is also considered. The main thrust of the discussion will look at the performance of the MRF, and identify areas for process improvement in order to maximise the diversion of material away from landfill.

The facility was used to process the case study authority's household waste and dry recyclable streams. Thus the plant was used to process two distinctly different streams of material, ranging from the 'dirty' stream of household waste, and the 'clean; stream of segregated dry recyclable. The facility aimed to divert material from landfill, by recovering the following:

- paper;
- cardboard;
- plastic bottles;
- plastic film;
- steel cans;
- scrap metal;
- aluminium;
- source segregated garden waste; and,
- mechanically segregated putrescible material.

5.2 PROCESS DESIGN AND IMPLEMENTATION

The conceptual design of the MRF has already been discussed in section 4.6; however, it was important that this conceptual design was discussed with the parties involved in the project, primarily the waste management contractor, and also the case study authority albeit at a lesser extent.

It soon became apparent that the waste management contractor, wished to develop the MRF in a phased manner, so as to stage the costs of the installation. The contractor made a decision that they wished to install and commission the MRF in two phases (Saunders, 2007). Hence, the MRF conceptual design as shown in Figure 5.1 needed to be adapted to consider the phased implementation, as well as taking into account various parameters such as throughput.

In addition to the design criteria, the decision was also taken to allow sufficient additional capacity to process increased quantities of material in the future, and decided that the MRF should be able to process 50,000 tonnes per annum of household waste. Hence, based on the operation cycle of 20 hours per day, 5 days per week, and 50 weeks of the year the MRF needed to be able to process 10 tonnes per hour in order to meet the desired annual output.

During the planning stage, when discussing plans with various manufacturers, the Company was given the opportunity to acquire second hand equipment from a MRF which was processing dry recyclable, and deemed this too good an offer to refuse. This equipment consisted of a trommel, a number of conveyors, and picking platforms. Hence, the design of the MRF needed further adaption to consider this equipment. The crucial aspect was that the second hand conveyors were operated at fixed not variable speed. This was not ideal particularly when wishing to process two different material streams. This was an opportunity not to be missed however, and a decision would be taken at a later date based on the success of the MRF project as to whether variable speed conveyors would be purchased to further improve the performance of the MRF.

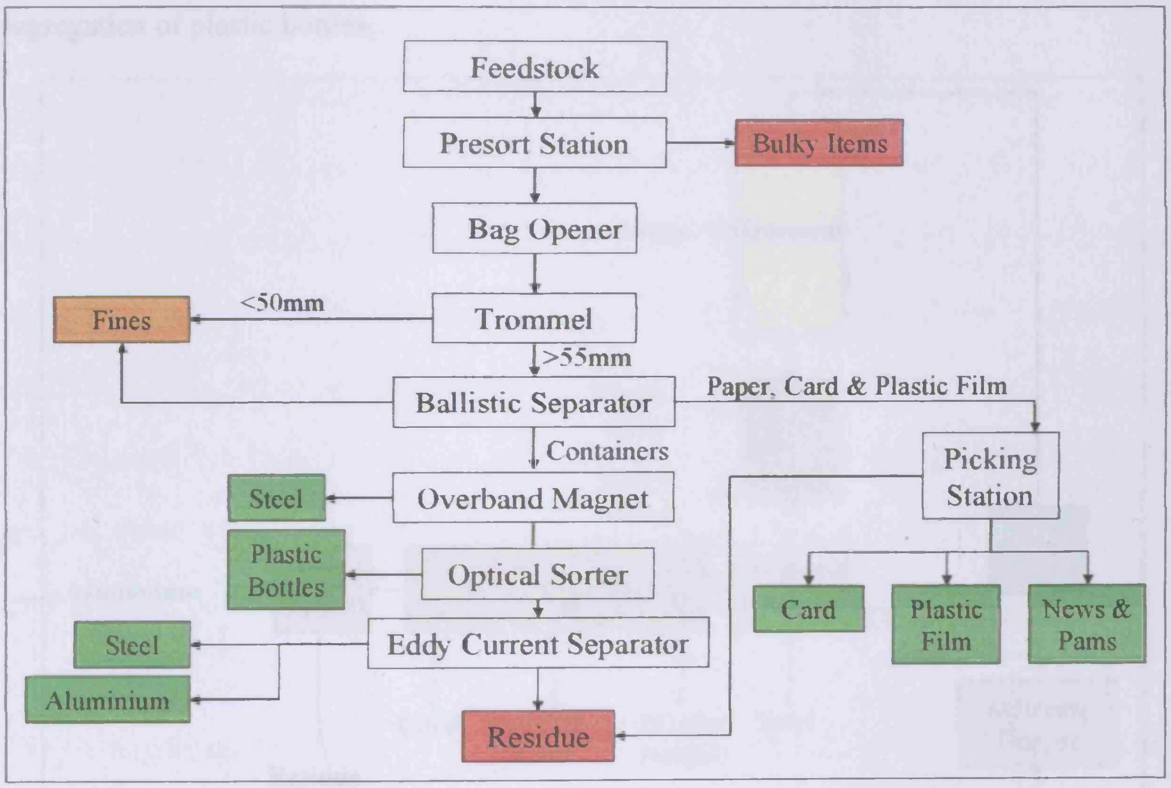


Figure 5.1: MRF Conceptual Design

As a result of these constraints, the conceptual design was split to allow the development to occur in two phases. Essentially phase 1 would greatly increase the capacity of processing in the facility, and phase 2 would have a beneficial impact in terms of both the quantity and quality of the material segregated.

Figure 5.2 highlights the flowchart for phase 1 of the MRF development. This diagram highlights that essentially the main changes in terms of equipment to the MRF were the installation of a metering hopper, bag splitter and trommel. In comparison to the MRF conceptual design shown in Figure 5.1, the phase 1 development essentially differs in that the ballistic separator is not installed, and as result there is no separation of the two and three dimensional materials within the MRF, which is a fundamental part of the overall MRF conceptual design. Also, there is no optical sorter installed for the automated segregation of plastic bottles.

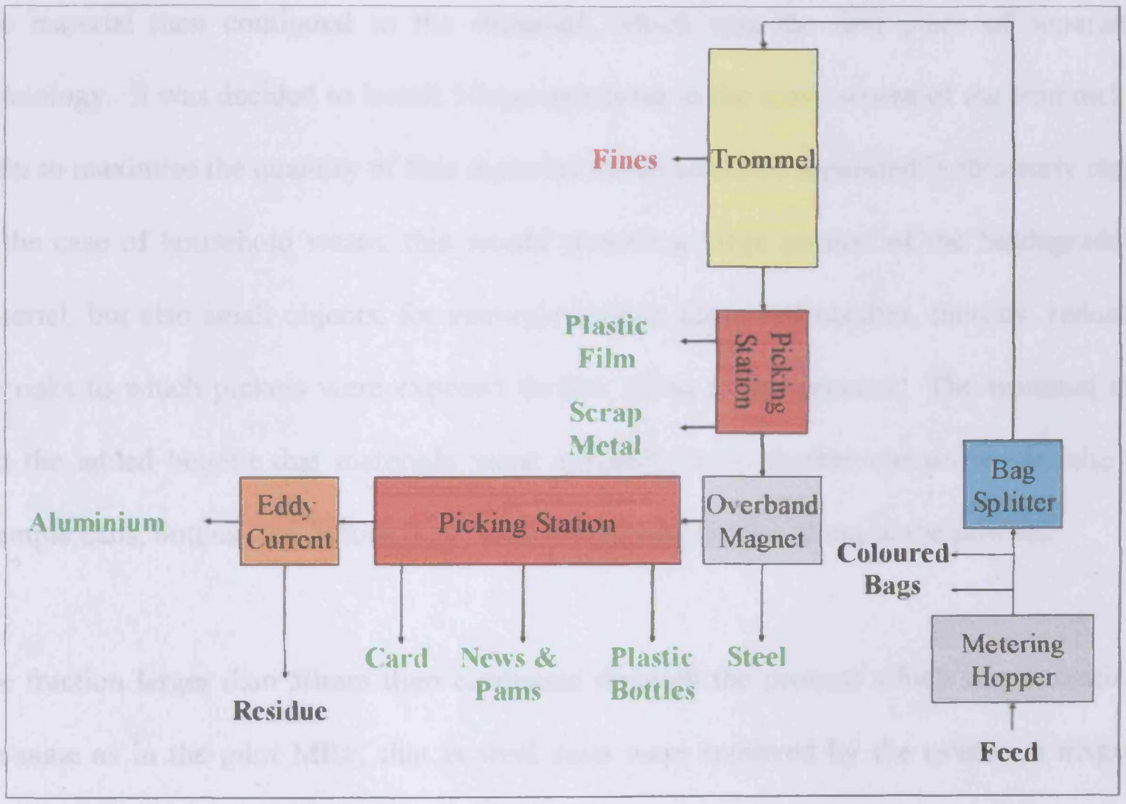


Figure 5.2: MRF Development Phase 1

The metering hopper enabled a large volume of material to be loaded into the MRF, and regulation of the flow to ensure that a steady stream of material continued from the hopper to the remainder of the plant (Matthiesen Lagertechnik, 2007b). The material then continued to a picking station where the coloured survival bags were removed (i.e. clear dry recyclable bags, and green garden waste bags), and the remaining black bag stream continued onto the bag splitter. The bag splitter was essentially a large drum with a comb above it – the distance between the comb and the drum could be adjusted to allow for different bag sizes to be opened. The bags were conveyed towards the drum, where they were then carried upwards towards the comb, which tore open the bags allowing the contents of the bags to continue past the comb, but the bag was then held by the teeth on the comb, thereby emptying the contents of the bags (Matthiesen Lagertechnik, 2007a). The materials and bags then continued through the MRF.

The material then continued to the trommel, which was the first piece of separation technology. It was decided to install 50mm apertures in the mesh screen of the trommel, in order to maximise the quantity of fine material which could be separated in this early stage. In the case of household waste, this would remove a large portion of the biodegradable material, but also small objects, for example broken glass and needles, thereby, reducing the risks to which pickers were exposed further along in the process. The trommel also had the added benefit that materials were agitated which further cleaned materials, for example cans, bottles, etc. before they were segregated further along in the process.

The fraction larger than 50mm then continued through the process which was essentially the same as in the pilot MRF, that is steel cans were removed by the overband magnet, plastic bottles, newspapers and magazines, and cardboard were then manually removed, and finally aluminium removed by the eddy current separator. The remaining material was classed as residue and was sent to landfill.

Phase 2 of the MRF development is highlighted in Figure 5.3, in this phase the key change is the installation of a ballistic separator into the MRF. The ballistic separator segregates the incoming material into three streams, a fines fraction, a two dimensional stream (flat object such as paper, cardboard, plastic film etc.) and a three dimensional stream (cans, bottles, shoes etc.) stream (Okay Engineering, 2005). This piece of equipment would have a significant impact in terms of the quality and quantity of material segregated, as it would allow two picking stations to be installed after the ballistic separator, one for the sorting of two dimensional material, and one for the sorting of three dimensional material. As a result, it would be far easier for the pickers to retrieve their chosen material for segregation; and hence, they would become more efficient, and also the quality of the mechanically sorted fractions (i.e. steel and aluminium) would be far greater.

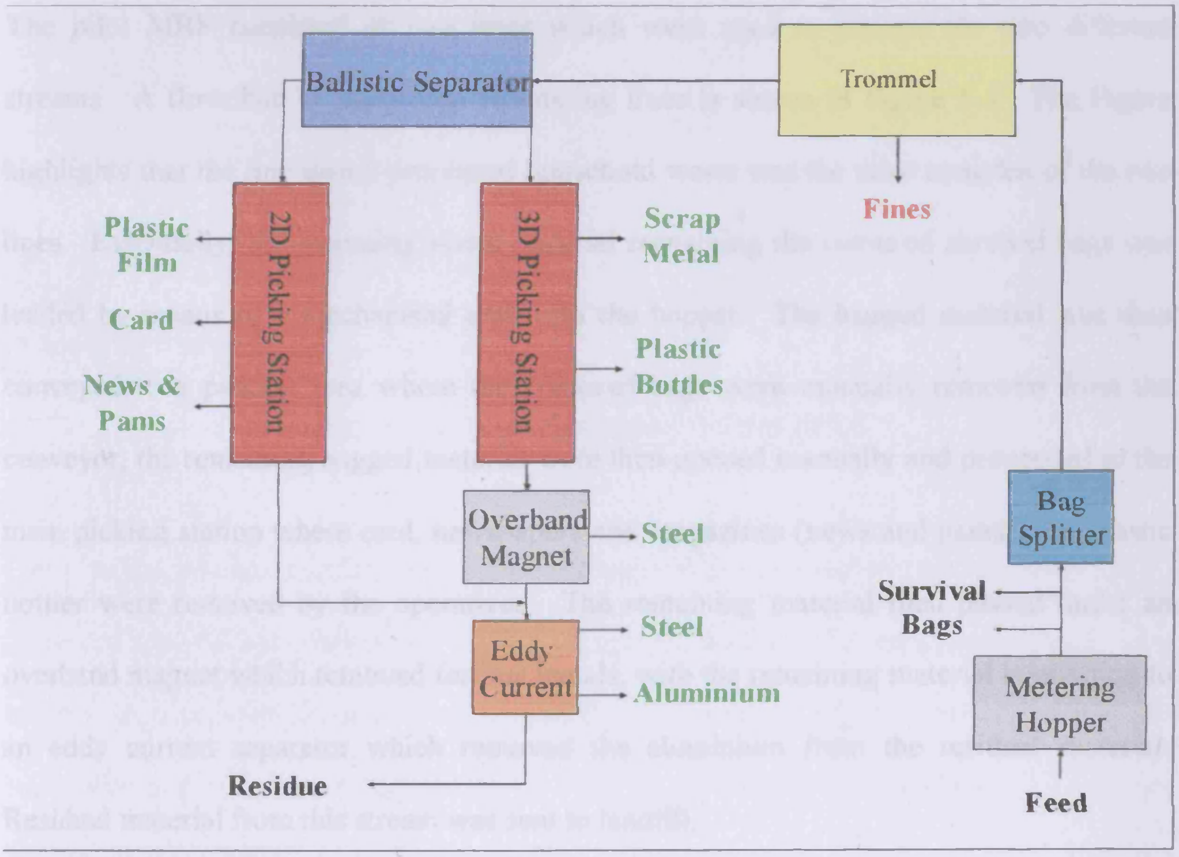


Figure 5.3: MRF Development Phase 2

5.3 MRF DEVELOPMENT STAGES

A pilot MRF had been in place at the contractor's site since 2003, in order to assess whether a facility could be utilised to divert household waste from the case study authority away from landfill. The MRF was used to process both unsegregated household waste, and segregated dry recyclable collected by means of survival bags. The material processed in the MRF came from a trial area within the case study authority which covered approximately 3000 households.

The pilot MRF consisted of two lines which were used to process the two different streams. A flowchart of these two processing lines is shown in Figure 5.4. The Figure highlights that the line which processed household waste was the most complex of the two lines. Essentially, the incoming waste material containing the coloured survival bags was loaded by means of a mechanised grab into the hopper. The bagged material was then conveyed to a picking area where the coloured bags were manually removed from the conveyor, the remaining bagged material were then opened manually and proceeded to the main picking station where card, newspapers and magazines (news and pams), and plastic bottles were removed by the operatives. The remaining material then passed under an overband magnet which removed ferrous metals, with the remaining material continuing to an eddy current separator which removed the aluminium from the residual material. Residual material from this stream was sent to landfill.

The survival bags containing dry recyclable (clear bags) were processed on the second line. Again, material was fed onto a conveyor with a small hopper fitted, and the bags were manually opened by an operative. Card, newspapers and magazines, plastic bottles and mixed metals were then manually segregated for recycling by the picking staff. Residual material from the clear bags was sent to landfill.

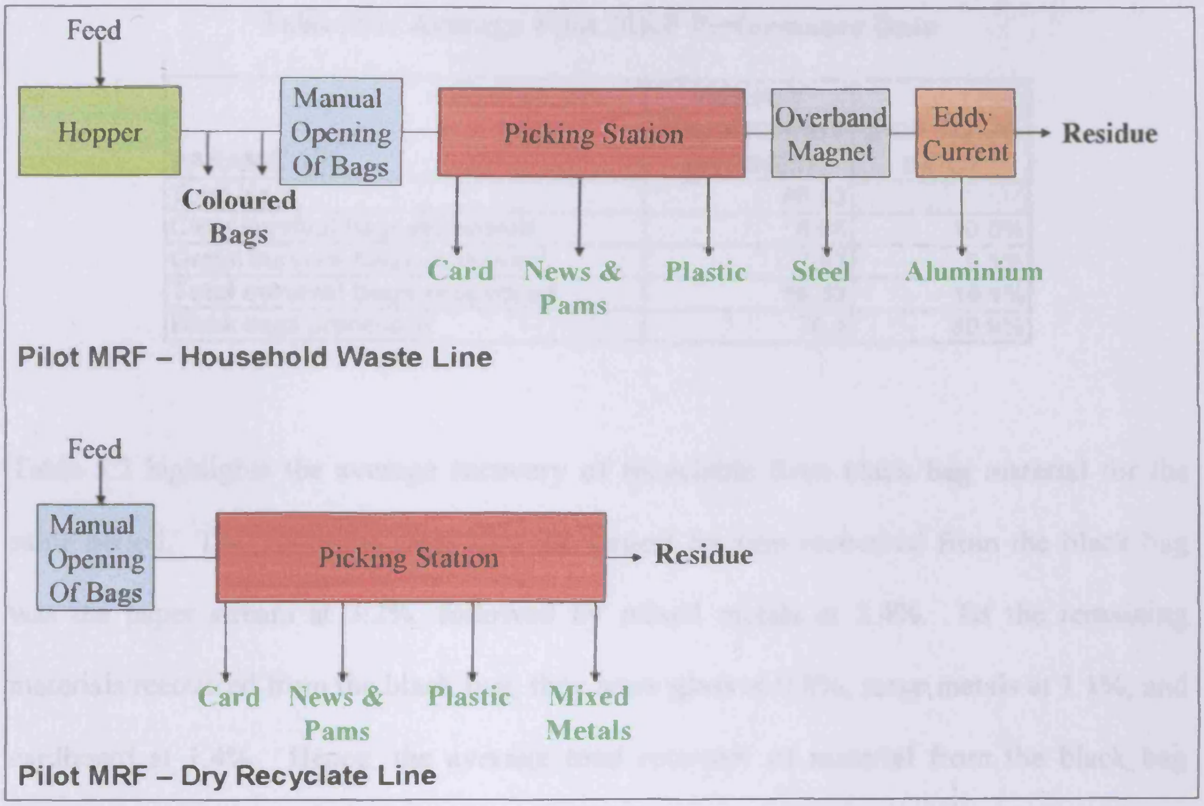


Figure 5.4: Flow Diagram for Pilot MRF

Performance records for the pilot MRF highlight that the MRF typically processed 80 tonnes of material per week which equates to approximately 4100 tonnes per annum. This material consisted of household waste and the two survival bag streams containing dry recyclable and segregated kitchen and garden waste. Table 5.1 highlights the average recovery performance for survival bags from household waste in the pilot MRF for June 2004 to June 2005. This Table highlights that on average 10.0% of the input material was present in the form of dry recyclable (clear) survival bags, and that 9.1% of the input material was present in the form of kitchen and garden (green) survival bags. On average this amounted to 16.53 tonnes of survival bags being recovered each week, that is 19.1% of the total incoming household waste stream. Hence, the remaining material (80.9%) was in the form of residual (black bag) household waste.

Table 5.1: Average Pilot MRF Performance Data

PARAMETER	WEEKLY THROUGHPUT (TONNES)	% OF TOTAL INPUT
Total Input	86.63	
Clear survival bags recovered	8.66	10.0%
Green survival bags recovered	7.87	9.1%
Total survival bags recovered	**16.53**	**19.1%**
Black bags processed	70.1	80.9%

Table 5.2 highlights the average recovery of recyclable from black bag material for the same period. The Table indicates that the largest fraction recovered from the black bag was the paper stream at 3.2%, followed by mixed metals at 2.4%. Of the remaining materials recovered from the black bag, they were glass at 0.8%, scrap metals at 1.1%, and cardboard at 1.4%. Hence, the average total recovery of material from the black bag amounted to 8.7%, or an average of 6.13 tonnes of recyclable per week. No data were available on the performance of the pilot MRF on segregated dry recyclable (clear bags), as the infrastructure was not in place to record the quantity of materials recovered.

As a result of the performance of the pilot MRF, the case study authority wished to expand its kerbside recycling scheme to cover the south of the county, but in order to achieve this, the material either had to be processed at another facility, or alternatively their waste management contractor had the option to invest in a new MRF in order to process the additional material. The waste management contractor made the decision to invest in a new MRF.

Table 5.2: Average Recovery of Recyclable from Black Bags in Pilot MRF

PARAMETER	WEEKLY TONNAGE	% OF BLACK BAG INPUT
Black bags processed	70.1	
RECOVERED MATERIALS FROM BLACK BAG		
Glass	0.55	0.8%
Scrap Metals	0.74	1.1%
Mixed Metals	1.65	2.4%
Paper	2.21	3.2%
Cardboard	0.96	1.4%
Plastic Bottles	0.01	0.0%
Plastic Film	0.01	0.0%
TOTAL BLACK BAG RECOVERY	6.13	8.7%

5.4 PERFORMANCE OF THE NEW MRF

5.4.1 Introduction

This section discusses the performance of Phase 1 of the MRF development (as seen in Figure 5.2), and identifies the improvements made to the operation, and also highlights areas where further improvements to operational efficiency were possible. Unfortunately, Phase 2 of the MRF development did not occur within the time constraints of this project; hence, it was not possible to discuss the performance of that aspect of the MRF design.

5.4.2 Methodology

Prior to carrying out the efficiency study, a set out survey was carried out in August 2006 in areas which had previously had set out surveys carried out in order to assess if any changes had occurred. Set out surveys were also carried out in similar areas which were new to the kerbside recycling scheme in order to compare performance between the existing and new areas.

The methodology for the set out survey was the same as that used previously in this study, see section 3.2.2.2. After the set out surveys had been completed, the MRF efficiency analysis was carried out, the method for this is shown in steps I to XX.

I. Ensure the facility is empty of material i.e. all cages and belts are empty, and residual waste area is clear of material.

II. Segregate approximately 25 tonnes of incoming weighed commingled waste ready for use in the efficiency study. Record the weight of this material.

III. Load some of this material into the metering hopper.

IV. Begin operating MRF as normal. Note the time that the MRF begins operating.

V. All operators are to work at their normal stations, at their normal pace and in the normal way.

VI. The metering hopper is to be topped up as normal to allow a continuous feed in to the MRF.

VII. Cages and other containers are to be removed and replaced when they are full, ensuring that the weight of the removed container is recorded, and the recovered material is to be placed in the designated sorting area ready for further analysis.

VIII. Samples of the residual waste are to be taken on a regular basis, these samples are to be weighed and placed in the designated sorting area for further analysis.

IX. Samples of the fines material recovered by the trommel are to be taken on a regular basis, these samples are to be weighed and placed in the designated sorting area for further analysis.

X. Once the material has finished going through the MRF, note the time.

XI. Remove all cages, weigh them and take to the designated area for sorting.

XII. Remove all residual waste from the residual waste bay and record the mass via the weighbridge.

XIII. Contamination of each dry recyclable is to be measured by removing any contamination from the material, and weighing the contamination in order to calculate the % by weight of contamination in each dry recyclable stream.

XIV. The residual sample is then to be sorted in the designated sorting area. This is to be handsorted into the relevant bin for the categories used in the sorting methodology discussed in section 3.2.2.4 part IV. Weigh the contents of each component bin (remembering to take account of the mass of the bin) to obtain the mass of each fraction present. A 75kg balance with an accuracy of 50g was used. Once weighed the sorted material was removed from the bins,

XV. Clear the sorting area ready to sort the fines sample.

XVI. Hand sort the fines sample into a smaller set of categories, these are:

- Organic Material
- Glass
- Batteries
- Metals
- Plastic
- Cork

Weigh the contents of each component fraction (remembering to take account of the mass of the container) to obtain the mass of each fraction present. A 75kg balance with an accuracy of 50g was used. Once weighed the sorted material was removed from the containers.

XVII. The next step is to carry out the steps III to XVI for the dry recyclables (clear bags) feed. The clear bag material segregated from the commingled feed are to be used, topped up to approximately 5 tonnes with other Ceredigion clear bags. The weight of the additional clear bags are to be recorded to enable a known weight of clear bags input into the MRF to be calculated.

XVIII. Repeat steps III to XVI for the clear bag material.

XIX. The next stage was to enter the results into a spreadsheet to determine the performance of the MRF, and to indicate what proportion of materials were being missed in both the commingled and clear bag feeds. Recovery rates as a percentage of the total potential recyclables available will also be determined.

XX. A comparison was made of the weighbridge results with the summation of each segregated material fraction as a check to ensure accuracy of the results.

5.4.3 Results and Discussion

5.4.3.1 Introduction

This section discusses the findings of the set out survey and efficiency study carried out in September 2006.

5.4.3.2 Set Out Survey

Tables 5.3 and 5.4 highlight the raw data collected for the weekly set out data, and include data for existing and new kerbside recycling scheme areas.

Table 5.5 shows the summary of the set out survey carried out in three areas for which previous data was available. These areas were the same as those used in the waste classification study discussed in Chapter 3 and are indicated on the map of the case study authority shown in Figure 2.2, and were as follows:

- location A (Cardigan Mwldan) – urban survival bag scheme area;
- location B (Gwbert and Y Ferwig) – rural survival bag scheme area; and,
- location C (Lampeter) – urban recycle in the bag scheme area.

Table 5.3: Raw Weekly Set Out Data for Existing Kerbside Recycling Scheme Areas

	Existing Area			
Place Name	Cardigan	Gwbert & Ferwig	Lampeter	TOTAL
Electoral District	Cardigan Mwldan	Penparc	Lampeter	
Townsend Index Score	0.83	-2.11	2.80	
No. Households	169	79	147	395
No. Black Bags	209	106	301	616
No. Clear Bags	82	60	102	244
No. Green Waste Bags	50	13	0	63
No. Households Participating in Clear Bag Scheme	41	36	86	163
No Household Participating in Green Bag Scheme	7	4	0	11
No. Households Participating in Clear & Green Box Scheme	23	6	0	29
Clear Bag Recycling Scheme Set Out Rate	24.3	45.6	58.5	41.3
Green Bag Recycling Scheme Set Out Rate	4.1	5.1	0.0	2.8
Clear and Green Bag Set Out Rate	13.6	7.6	0.0	7.3
Recycling Scheme Set Out Rate	42.0	58.2	58.5	51.4

Table 5.4: Raw Weekly Set Out Data for New Kerbside Recycling Scheme Areas

	New Area			
Place Name	Tregaron	Mydroilyn & Dihewyd	Llandysul	TOTAL
Electoral District				
Townsend Index Score				
No. Households	144	104	149	397
No. Black Bags	230	129	251	610
No. Clear Bags	62	69	50	181
No. Green Waste Bags	1	0	12	13
No. Households Participating in Clear Bag Scheme	37	51	35	123
No Household Participating in Green Bag Scheme	1	0	4	5
No. Households Participating in Clear & Green Box Scheme	0	0	2	2
Clear Bag Recycling Scheme Set Out Rate	25.7	49.0	23.5	31.0
Green Bag Recycling Scheme Set Out Rate	0.7	0.0	2.7	1.3
Clear and Green Bag Set Out Rate	0.0	0.0	1.3	0.5
Recycling Scheme Set Out Rate	26.4	49.0	27.5	32.7

The data show that on the whole there seems to have been a general increase in weekly set out from February 2005 until August 2006. This was generally true for two of the sampling areas also, namely sampling locations B and C. However, in sampling location A, weekly set out seems to have increased from 43.2% in February 2005 to a peak of 52.1% in October 2005, and then reverted to around its original level at 42.0% in August 2006. This peak may have been as a result of a trial of separate collection of recycling bags being carried out in the area.

Table 5.5: Weekly Set Out Survey Results for Existing Kerbside Recycling Scheme Areas

Sampling Location	Weekly Set Out (%)		
	Winter 2005	Summer 2005	Summer 2006
A	43.2	52.1	42.0
B	47.2	47.2	58.2
C	40.4	42.2	58.5
Weighted Average	43.1	47.4	51.4

Table 5.6 shows a weekly set out comparison between existing areas (i.e. those listed above) and areas in which kerbside recycling is a new service (roll out commenced in February 2005). These new areas where weekly set out was assessed are highlighted on the map of the case study authority shown in Figure 2.2, and were:

- location D (Tregaron) – urban survival bag scheme area;
- location E (Mydroilyn and Dihewyd) – rural survival bag scheme area; and,
- location F (Llandysul) – urban survival bag scheme area.

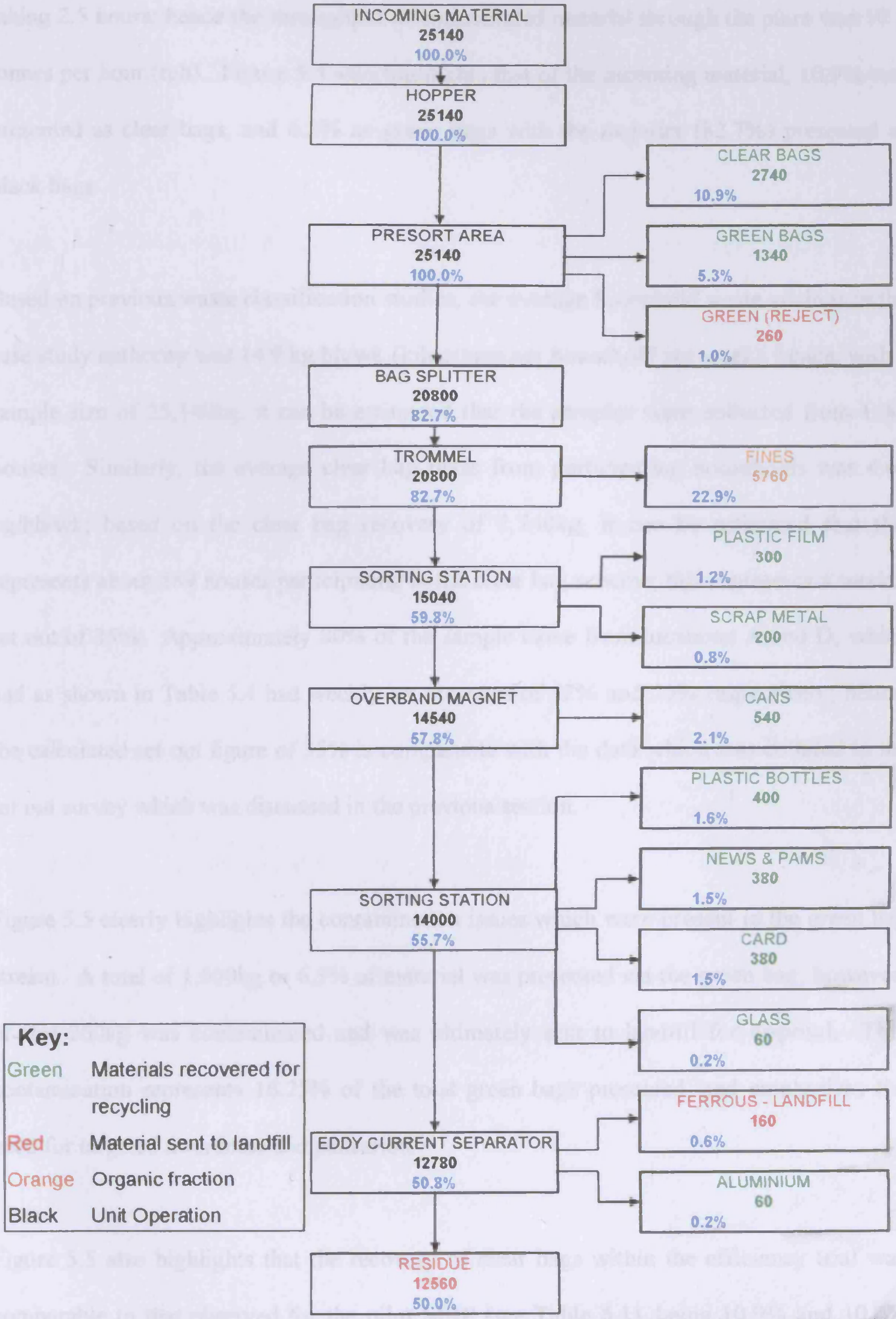
The Table highlights the percentage of households setting out clear bags only, those setting out green bags only, and also those households that set out both clear and green survival bags. The results highlight that on average the set out was significantly greater in the existing areas in comparison to the new areas, 51.4% compared to 32.7%. In the new areas, the total weekly set out was more than 1.8 times greater in the rural areas of sampling location E at 49.0%, compared to the more urban towns of sampling location D and F at 26.4% and 27.5% respectively. However, this trend was not reflected in the existing areas, although the set out between sampling location E was of the same order as that for sampling location B, the set out rate for the town of sampling location C was similar. Green bags are under utilised within the new recycling scheme areas, this is likely to be as a result of the charge for the bags which is now imposed by the council.

Table 5.6: Comparison of Set Out for Existing and New Kerbside Recycling Areas (Aug 2006)

Existing Kerbside Recycling Scheme Areas					New Kerbside Recycling Scheme Areas				
Sampling Location	Clear Bag Set Out (%)	Green Bag Set Out (%)	Clear & Green Bag Set Out (%)	Total Weekly Set Out (%)	Sampling Location	Clear Bag Set Out (%)	Green Bag Set Out (%)	Clear & Green Bag Set Out (%)	Total Weekly Set Out (%)
A	24.3	4.1	13.6	42.0	D	25.7	0.7	0.0	26.4
B	45.6	5.1	7.6	58.2	E	49.0	0.0	0.0	49.0
C	58.5	0.0	0.0	58.5	F	23.5	2.7	1.3	27.5
Weighted Average	41.3	2.8	7.3	51.4	Weighted Average	31.0	1.3	0.5	32.7

5.4.3.3 Commingled Feed Operation

The raw data for the MRF efficiency study can be found in Appendix D. Figure 5.5 shows an overview of the commingled feed operation. The Figure shows a flowchart which depicts the MRF operation, and highlights input material, unit operations and outputs. Also included in the flowchart is a mass balance, this essentially identifies of the material initially input into the MRF (25,140kg), what quantity of material is present in the various output streams, that is in the form of fines, plastic bottles, cans and so forth. As well as the mass of material, the flowchart also shows the percentage of material segregated as a particular output stream in relation to the input material.



(All data in kg unless otherwise stated and all percentages refer to input figure of 25140kg)

Figure 5.5: Commingled Input Summary

Figure 5.5 highlights that 25.14 tonnes of commingled material was processed in the plant, taking 2.5 hours; hence the throughput of commingled material through the plant was 10.1 tonnes per hour (tph). Figure 5.5 also highlights that of the incoming material, 10.9% was presented as clear bags, and 6.3% as green bags with the majority (82.7%) presented as black bags.

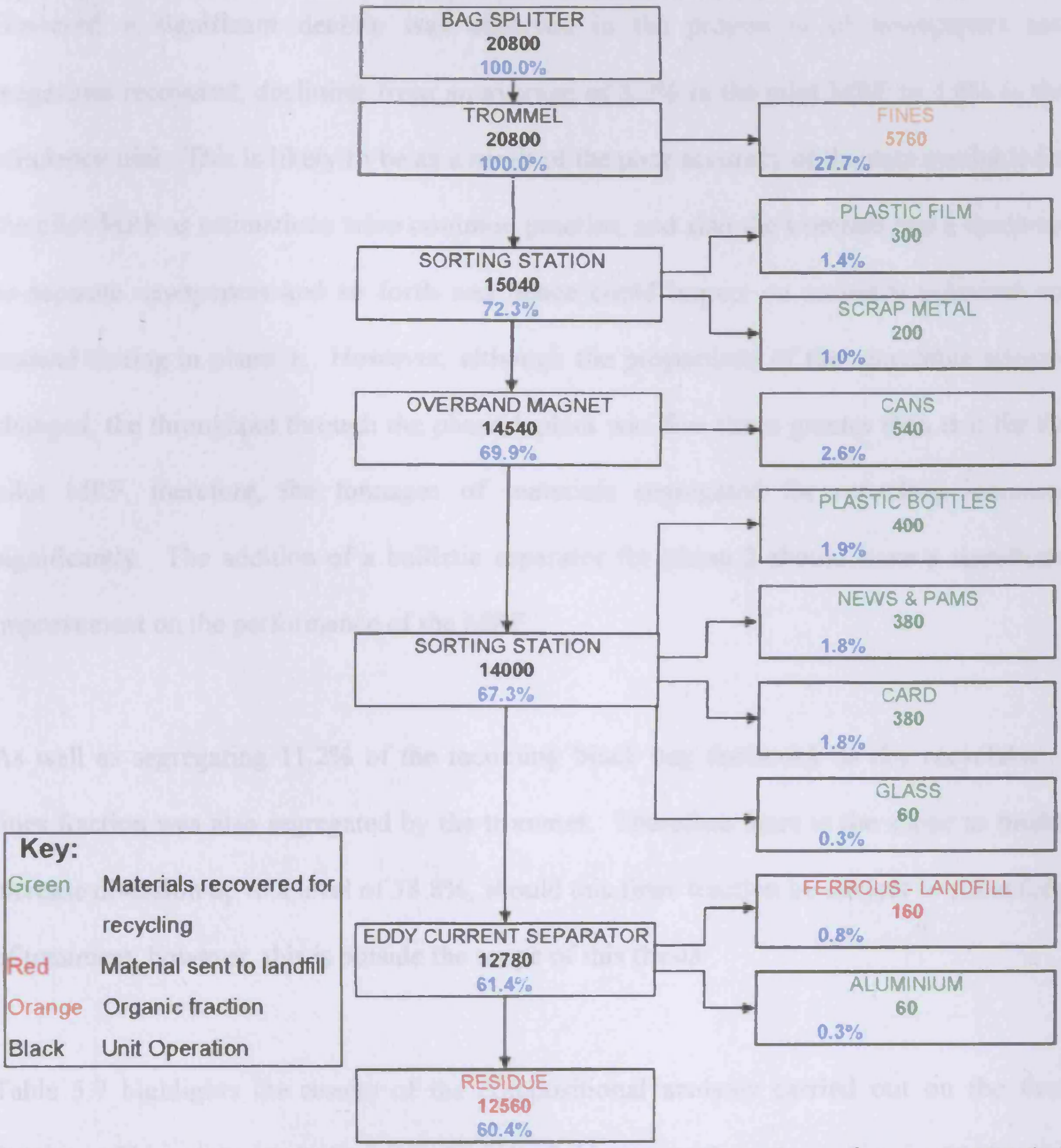
Based on previous waste classification studies, the average household waste arisings in the case study authority was 14.9 kg/hh/wk (kilograms per household per week); hence, with a sample size of 25,140kg, it can be estimated that the samples were collected from 1687 houses. Similarly, the average clear bag mass from participating households was 4.65 kg/hh/wk; based on the clear bag recovery of 2,740kg, it can be estimated that this represents about 589 houses participating in the clear bag scheme; this represents a weekly set out of 35%. Approximately 80% of the sample came from locations A and D, which had as shown in Table 5.4 had weekly set out rates of 42% and 26% respectively; hence, the calculated set out figure of 35% is comparable with the data which was collated in the set out survey which was discussed in the previous section.

Figure 5.5 clearly highlights the contamination issues which were present in the green bag stream. A total of 1,600kg or 6.3% of material was presented via the green bag; however, of this 260kg was contaminated and was ultimately sent to landfill for disposal. This contamination represents 16.25% of the total green bags presented, and emphasises the need for targeted awareness and education.

Figure 5.5 also highlights that the recovery of clear bags within the efficiency trial was comparable to that observed for the pilot MRF (see Table 5.1), being 10.9% and 10.0% respectively. However, the proportion of green bags has declined, the average data for the pilot MRF highlights that on average 9.1% of the incoming material was presented in this manner; however during the efficiency trial a figure of 6.3% was observed. This was likely to be as a result of the case study authority implementing a charge for the purchase of the green survival bags, as opposed to providing them free of charge to householders.

Figure 5.5 further highlights that 22.9% of the incoming commingled material was segregated by the trommel and that 51.6% of the incoming commingled material is sent to landfill. 1.0% was in the form of contaminated green bags which were landfilled, 0.6% was in the form of highly contaminated ferrous material from the eddy current separator, with the remaining 50.0% unsegregated during the process and coming out of the end of the process as residue, making a total of 51.6%. However, since all material which passes the presort station is black bag material, it is better to express this as a separate flowsheet, this is shown in Figure 5.6.

Figure 5.6 shows an overview of the black bag stream. This Figure highlights that 61.2% of the black bag material is sent to landfill, and that 27.7% of the material was recovered by the trommel as fines (material with a diameter of less than 50mm). In terms of performance, this Figure highlights that excluding the fines, the MRF was able to recover 11.2% of the incoming black bag material as dry recyclable, compared to 8.7% for the pilot MRF (as shown in Table 5.2); hence, the recovery performance of the phase 1 MRF in terms of dry recyclable was 1.3 times greater than that of the pilot MRF.



(All data in kg unless otherwise stated and all percentages refer to input figure of 20800kg)

Figure 5.6: Black Bag Stream Input Summary

In terms of the recovery of the various recyclable streams, a significant increase was observed in the quantity of plastic bottles recovered in the efficiency trial of the phase 1 MRF compared to the average performance of the pilot MRF (see Table 5.2), being 1.9% and 0.0% respectively. An increase in the proportion of plastic film was also observed, being 1.4% for the efficiency trial and 0.0% for the pilot MRF. Similarly, the proportion of cans recovered increased from 2.4% in the pilot MRF to 2.9% in the phase 1 plant.

However, a significant decline was observed in the proportion of newspapers and magazines recovered, declining from an average of 3.2% in the pilot MRF to 1.8% in the efficiency trial. This is likely to be as a result of the poor accuracy of the data available for the pilot MRF as estimations were common practise, and also the trommel had a tendency to separate newspapers and so forth and hence could impact on recovery achieved via manual sorting in phase 1. However, although the proportions of the recyclable streams changed, the throughput through the phase 1 plant was five times greater than that for the pilot MRF, therefore, the tonnages of materials segregated for recycling increased significantly. The addition of a ballistic separator for phase 2 should have a significant improvement on the performance of the MRF.

As well as segregating 11.2% of the incoming black bag feedstock as dry recyclable, a fines fraction was also segregated by the trommel. Therefore there is the scope to further increase diversion up to a level of 38.8%, should this fines fraction be subject to some form of treatment; however, this is outside the scope of this thesis.

Table 5.7 highlights the results of the compositional analysis carried out on the fines fraction. This analysis showed that 86.6% of this material was organic, i.e. paper and putrescible fraction, 10.2% was glass, and the remaining 3.2% was plastic, metals, batteries and cork. The biodegradable content of the fines material was 86.6%. Therefore, diverting this material from landfill could make a significant contribution to the case study authority's landfill allowance scheme targets.

An analysis was also carried out on a sample of the residual material from the black bag stream, i.e. that material which is not recovered in the process. Table 5.8 shows the results from this analysis. The Table highlights that large amounts of potential recyclables remain in the residual waste stream and are therefore being sent to landfill. The residual waste stream was mainly composed of putrescible material and paper. However much of this paper stream was unsuitable for recovery as it was contaminated with food waste and other putrescible material. This highlights that significant improvements are possible to the operation to both minimise the amount of residue sent to landfill and also to increase the revenue from the sale of recyclable.

Table 5.7: Black Bag Fines Stream Analysis

Category	% of Fines Composition
Organic Material	86.6
Glass	10.2
Batteries	0.2
Metals	1.3
Plastics	1.6
Cork	0.1

Table 5.8: Black Bag Residual Stream Analysis

Category	Mass (kg)	% of Black Bag Input (20.8t)
Paper	2610.5	12.5%
Glass	205.0	1.0%
Ferrous Metals	362.1	1.7%
Non-Ferrous Metals	94.03	0.5%
Plastics	1675.7	8.1%
Putrescibles	4676.0	22.5%
Textiles	1607.6	8.1%
Other	1239.1	6.0%
TOTAL	**12560.0**	**60.4%**

This analysis on the residual from the black bags identifies the streams being missed by the process and more importantly the quantity of material being missed. This enables the recovery percentages for each material stream to be calculated, thereby giving an efficiency value.

Table 5.9 indicates the recovery of dry recyclable from the black bag stream. A visual estimation was made for the newspaper and magazines, and cardboard streams, in that only 15% of the material in the residue was available for segregation due to contamination with food, material being too wet and so forth. Taking this estimation into account, the Table highlights that the MRF was recovering 56% of the total available dry recyclable in the black bag stream, hence there was significant scope for improving the process.

Table 5.9: Recovery of Material Streams from the Black Bag

Material Stream	Recovery
Plastic Film	31%
Scrap Metal	100%
Steel Cans	60%
Plastic Bottles	59%
Newspaper and Magazines*	73%
Card*	86%
Glass+	23%
Aluminium	39%
WEIGHTED AVERAGE	**56%**

* Estimated that only 15% of material in residue is available due to contamination

+ Glass was not actively picked in the process

The hand sorted streams of newspaper and magazines, card, and scrap metal were the streams with the greatest recovery, being 73%, 86% and 100% respectively; while the automated processes of removing steel cans and aluminium were generally underperforming being 60% and 39% respectively. It was evident that this poor performance was due to the presentation of the material at these points, i.e. plastic film and paper still covered much of the steel and aluminium cans and also some of were contained within carrier bags. There were significant financial implications as a result of this performance, namely in the loss of revenue from the missed recyclable and also landfill cost savings.

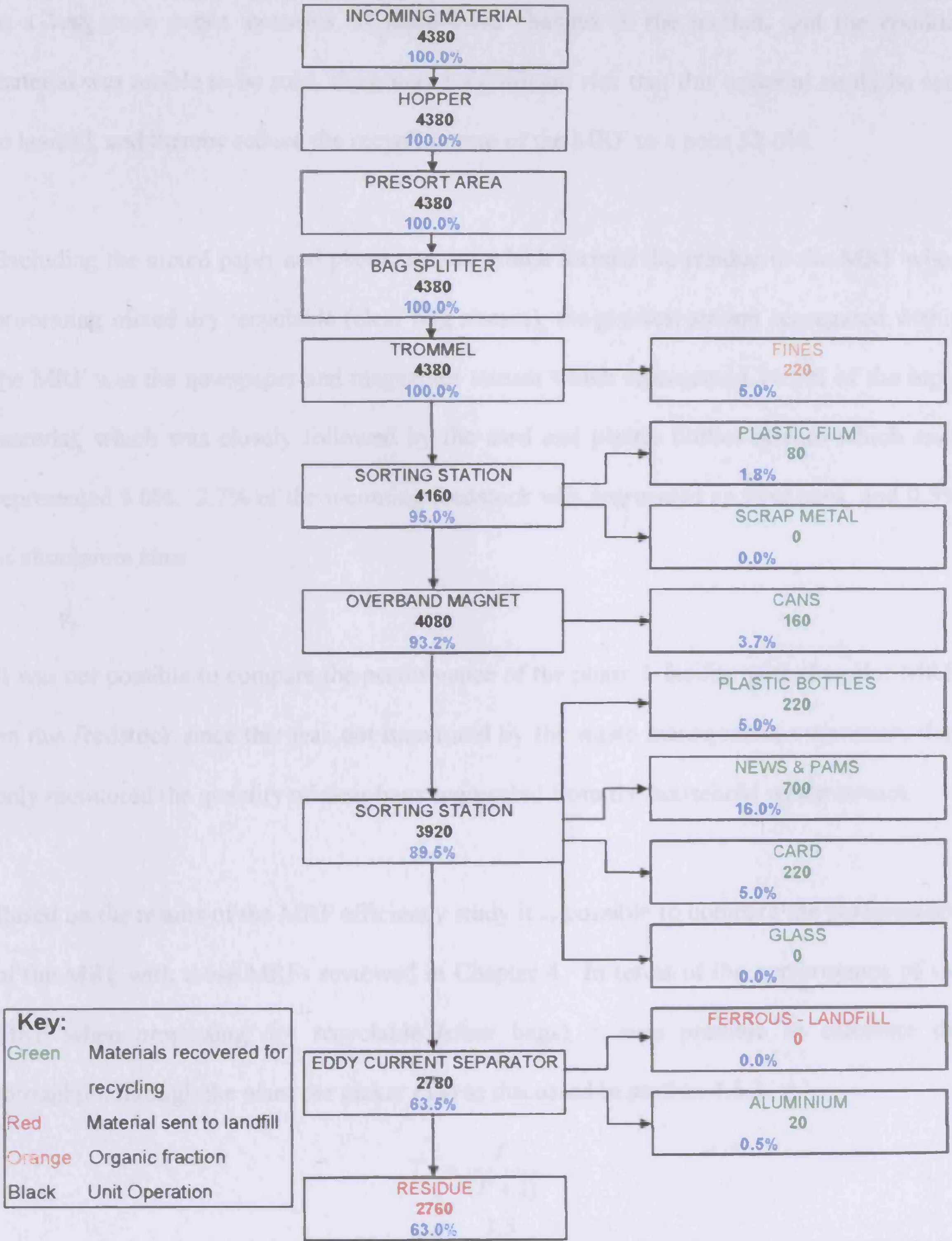
Table 5.10 summarises the performance of the MRF when processing black bag material. The Table highlights that 11.2% is segregated as dry recyclable, with 3.7% of the total input segregated for recycling in the form of biodegradable municipal waste (BMW) material, that is paper and cardboard. Also, 27.7% was segregated in the form of the fines fraction, with 61.2% not being recovered in the process and sent to landfill. However, 43.3% of the total input was BMW found in the residue stream, i.e. putrescibles, paper, cardboard and so forth, which emphasises that significant improvements are possible which could assist the case study authority to meet its Landfill Allowance Scheme Targets.

Table 5.10: MRF Efficiency Study Summary

Stream		Black Bag Stream	
		Mass (kg)	%
Recyclate	BMW	760	3.7%
	Non-BMW	1560	7.5%
	Total	2320	11.2%
Fines (<50mm)	BMW	4988	24.0%
	Non-BMW	772	3.7%
	Total	5760	27.7%
Residue - Landfill	BMW	9006	43.3%
	Non-BMW	3723	17.9%
	Total	12730	61.2%
TOTAL		**20800**	**100.0%**

5.4.3.4 Clear Bag Operation

Figure 5.7 shows an overview of the clear bag sorting operation. 4.38 tonnes of clear bag material was processed taking 1.25 hours; hence the throughput was considerably less than for commingled and black bag materials at 3.5 tph. This Figure also highlights that 63.0% of the clear bag material was residual material, which is sold as a mixed paper and plastic material. Also 5.0% of the clear bag material was recovered by the trommel as fines (material with a diameter of less than 50mm).



(All data in kg unless otherwise stated and all percentages refer to input figure of 4380kg)

Figure 5.7: Clear Bag Stream Input Summary

In terms of performance, this Figure highlights that excluding the fines, the MRF was able to recover 95.0% of the incoming clear bag material for recycling as the residue was sold as a low grade paper. however, if there were changes to the market, and the residual material was unable to be sold, there was a significant risk that this material could be sent to landfill, and thereby reduce the recycling rate of the MRF to a poor 32.0%.

Excluding the mixed paper and plastic stream which formed the residue in the MRF when processing mixed dry recyclable (clear bag stream), the greatest stream segregated within the MRF was the newspaper and magazines stream which represented 16.0% of the input material, which was closely followed by the card and plastic bottles stream which each represented 5.0%. 3.7% of the incoming feedstock was segregated as steel cans, and 0.5% as aluminium cans.

It was not possible to compare the performance of the phase 1 facility with the pilot MRF, on this feedstock since this was not monitored by the waste management contractor, they only monitored the quantity of clear bags segregated from the household waste stream.

Based on the results of the MRF efficiency study it is possible to compare the performance of the MRF with those MRFs reviewed in Chapter 4. In terms of the performance of the MRF when processing dry recyclable (clear bags), it was possible to calculate the throughput through the plant per picker (T_P) as discussed in section 4.5.3.

$$T_P = \frac{T}{(P+1)}$$

$$T_P = \frac{3.5}{(7+1)}$$

$$T_P = 0.44$$

Hence, this value lies within the range observed for the clean MRFs reviewed in Chapter 4, that is 0.38 to 1.42 tonnes per hour. A benchmarking relationship was discussed in

Chapter 4, which linked T_P to the residue per picker (R_P) from the MRF, this relationship is shown below:

$$R_P = 0.3846T_P + 0.0195$$

During this trial processing dry recyclable, the number of operatives working on the sorting stations was 7 as previously stated, and the residue (R) was 5%, hence the R_P value is 0.714. However, the calculated R_P value is 0.189, which based on the number of operatives equates to a calculated residue of 1.3%. Therefore, the MRF was not as effective as the calculated value, but was of a similar order.

Another benchmarking tool discussed in Chapter 4 was the proportion of output streams segregated by automated means (O_A). In the phase 1 MRF development, there are eight recyclable streams, and of these two are automated; hence the O_A value is 25%. Therefore, this value is significantly lower than in the MRFs reviewed, where the observed range was between 33.3% and 66.7%.

Table 5.11 highlights the results of the compositional analysis carried out on the fines fraction. This analysis showed that 63.7% of the fines material was organic, i.e. paper and putrescible material, 27.5% was glass, and the remaining 9.0% was plastic, metals, batteries and cork. Hence, the biodegradable content of the fines material was 63.7%.

An analysis was also carried out on a sample of the residual material from the clear bag stream, i.e. that material which is not segregated during the process. Table 5.12 shows the results from this analysis. Similar to the black bag operation, Table 5.12 highlights that large amounts of potential recyclables remain in the residual fraction of the clear bag stream and although this residual material is currently being sold as a low-grade paper, more revenue could be made if this material was diverted into other streams. The majority of this stream consists of paper, with the next largest stream being plastic, with the remaining composed of metals, textiles and other material.

Table 5.11: Clear Bag Fines Stream Analysis

Category	% of Fines Composition
Organic Material	63.7
Glass	27.5
Batteries	1.7
Metals	1.7
Plastics	5.0
Cork	0.6

Table 5.12: Clear Bag Residual Stream Analysis

Category	Mass (kg)	% of Clear Bag Input (4.38t)
Paper	2228.2	50.9%
Glass	0.0	0.0%
Ferrous Metals	4.1	0.1%
Non-Ferrous Metals	2.7	0.1%
Plastics	483.6	11.0%
Putrescibles	2.0	0.0%
Textiles	6.1	0.1%
Other	33.3	0.8%
TOTAL	**2760.0**	**63.0%**

This highlights that significant improvements are possible to the operation to increase the revenue from the sale of recyclable. As can be seen 2760kg was classed as residue compared to an input of 4380kg.

The analysis of the residual material from the clear bags identifies the material streams being missed by the process and more importantly the quantity of material being missed. This enabled the recovery percentages for each material stream to be calculated, these results are shown in Table 5.13.

Table 5.13 highlights that the facility was recovering on average 41% of the available material from the clear bag stream by means of positive sorting, that is excluding the residual material sold as a mixed paper and plastic stream; thus there was significant scope for improvement. In contrast to the black bag operation, the mechanically sorted streams of steel cans and aluminium had the greatest recovery being 98% and 86% respectively; while, the hand sorted streams were those with the lowest recovery being 67%, 36%, 32% and 31% for plastic bottles, newspapers and magazines, card, and plastic film respectively.

Table 5.13: Recovery of Material Streams from the Clear Bag

Material Stream	Recovery
Plastic Film	31%
Steel Cans	98%
Plastic Bottles	67%
Newspaper and Magazines	36%
Card	32%
Aluminium	86%
WEIGHTED AVERAGE	**41%**

Table 5.14 summarises the performance of the MRF when processing dry recyclable (clear bag) material. The Table highlights that 32.0% is segregated by positive sorting and by automated means, with 5.0%% segregated in the form of the fines fraction. The remaining 63.0% was the residual stream, and was sold as a mixed plastic and paper product. This further emphasises the importance of improving the performance of the MRF, as if the waste management contractor experienced problems in selling the residual stream, this stream may have to be disposed of via landfill, and therefore have a significant impact on the case study authority's LAS targets.

Table 5.14: MRF Efficiency Study Summary

Stream		Clear Bag Stream	
		Mass (kg)	%
Recyclate	BMW	920	21.0%
	Non-BMW	480	11.0%
	Total	1400	32.0%
Fines (<50mm)	BMW	140	3.2%
	Non-BMW	80	1.8%
	Total	220	5.0%
Residue - mixed paper & plastic product	BMW	2234	51.0%
	Non-BMW	526	12.0%
	Total	2759	63.0%
TOTAL		**4380**	**100.0%**

5.4.3.5 Cost Benefit Analysis

Based on the results of the MRF efficiency study a cost benefit analysis was undertaken to further analyse the impact of the second phase of the MRF development. The cost benefit analysis takes into account the capitol costs of the ballistic separator along with the additional maintenance, belt replacement and electricity usage costs. The cost benefit analysis estimated that the installation of a ballistic separator would generate an additional revenue of £111,633 per year, resulting in an overall payback period of 1.3 years (Owen 2007c). Hence, this analysis further reinforces that additional recovery in the MRF is required, and that this additional expenditure is economically viable.

5.5 SUMMARY

The results highlight that the first phase of the MRF development has enabled an increased amount of material to be segregated from MSW collected within the Case Study Authority. This efficiency study has also identified that the MRF has an increased throughput; however, along with this greater processing capacity, greater quantities of material are able to be recovered, thereby reducing the quantity of material sent to landfill.

The efficiency study highlighted that in terms of black bag material, the first phase of the MRF development was able to recover a greater proportion of dry recyclable, increasing from 8.7% for the pilot MRF to 11.2% for the phase one MRF. Along with the dry recyclable stream, the MRF was also able to segregate a further 27.7% as a fines fraction, that is material which is less than 50mm. This was a highly organic stream, and had a BMW content of 86.6%, and options for the processing of this material to divert this stream away from landfill were being considered, however, this was outside of the scope of this study.

The efficiency study also highlighted that the MRF was recovering 56% of the available material in the black bag stream, and therefore indicates that there was significant scope for improving the process. Greatest recovery was observed in the hand sorted streams of newspaper and magazines, card, scrap metal, and plastic bottles; while the automated processes of removing steel cans and aluminium were generally underperforming. The poor performance of the automated processes was as a result of the presentation of the material at these points, i.e. plastic film and paper still covered much of this material and also some of this material was in carrier bags. The installation of the ballistic separator in the phase two MRF development should have a significant impact upon the recovery rate within the MRF, particularly for these underperforming automated processes, as presentation of the material will be significantly improved. It is also important to note the variation in the belt speed between the pilot and phase 1 MRFs, the belt speed was considerably slower in the pilot MRF and therefore allowed pickers more opportunity to recover the paper and plastic film streams, which thereby improved the automated sorting of steel and aluminium.

The efficiency study also provided information on the performance of the MRF when processing dry recyclable (clear bag material), the first phase of the MRF development was able to recover 95% of the input material. However, this processing of dry recyclable resulted in a very large stream of low grade paper product (63% of input material), and as a result the waste management contractor was heavily reliant on favourable market conditions for the sale of this material. The further development of the MRF in line with phase two developments should result in improving the quality of this large stream and the other recovered streams, and therefore the processing of this dry recyclable material should be more secure in terms of being able to sell the recovered material.

The efficiency study further identified that the MRF was recovering 41% of the available material in the dry recyclable stream by means of manual and automated positive sorting, which again highlights that there was significant scope for improving the process. In contrast to the black bag operation, greatest recovery was observed in the automated segregation processes, i.e. the steel and aluminium cans streams, with the recovery rates being 98% and 86% respectively. While, the hand sorted streams of plastic bottles, newspapers and magazines, card, and plastic film were those with the lowest recovery rates.

The results from the efficiency study highlights that a further separation process is required in the MRF, as the presentation of material does not allow both manual and automated separation to occur to their potential. It is vital that another separation stage is installed in the MRF as is planned in Phase 2 in order to maximise the performance of the MRF. A ballistic separator would have the benefit of reducing the amount of material on the sorting belts, thereby improving the hand sorting stages and also the performance of the equipment in terms of presentation. As well as this, a cost benefit analysis undertaken found that a ballistic separator would generate an additional revenue of £111,633 per annum, resulting in an overall payback period of 1.3 years.

The next chapter will look at how the MRF development impacts upon the performance of the Case Study Authority in terms of recycling and composting performance, and also BMW diversion.

CHAPTER 6:
Effect of Increased Kerbside Provision & MRF Development

6.1 INTRODUCTION

This chapter will consider the impact of the MRF development and increased kerbside recycling provision within the case study authority and their impact on the recycling performance as well as biodegradable municipal waste (BMW) diversion. This chapter will also consider how changes to the kerbside provision could impact upon recycling rates and BMW diversion.

The main thrust of the discussion will look at the means by which the waste management contractor and the case study authority are able to improve their respective performances with reference to the stringent targets that the Case Study Authority are required to deliver in order to meet the requirements of the EU Landfill Directive (Audit Commission in Wales 2005, Griffiths *et al.* 2005).

The critical targets which the Authority must meet are the Landfill Allowance Scheme (LAS) targets, these are shown in Table 6.1. The Table highlights the significant decline in the quantity of BMW which can be landfilled. In conjunction with the LAS targets, there are also non-statutory recycling and composting targets imposed by the Welsh Assembly Government (WAG). The main target is to achieve 40% recycling and composting of MSW with a minimum of 15% composting and 15% recycling by 2009/10 (Friends of the Earth 2002, National Assembly for Wales 2002). It has also been announced by WAG, that targets are likely to increase post 2010 as follows:

- 52% recycling and composting by 2012/13;
- 58% recycling and composting by 2015/16;
- 64% recycling and composting by 2019/20; and,

- 70% recycling and composting by 2024/25 (Welsh Assembly Government, 2007).

Table 6.1: BMW Landfill Allowance for Case Study Authority (Griffiths *et al.* 2005)

Year	BMW Landfill Allowance (tonnes)
2005/6	18,620
2006/7	17,461
2007/8	16,303
2008/9	15,145
2009/10	13,987
2010/11	12,728
2011/12	11,583
2012/13	10,540
2013/14	9,592
2014/15	8,728
2015/16	7,943
2016/17	7,228
2017/18	6,577
2018/19	5,985
2019/20	5,446

6.2 METHODOLOGY

The data used in the analysis will be location wide data provided by the local authority (Keenan, 2007), in order to analyse the general trends, and also from the waste management contractor in order to assess the performance of the MRF.

The case study authority generates data on a quarterly basis for submission into the national WasteDataFlow system (WasteDataFlow 2003), which is used to monitor performance in terms of BMW diversion, and also in terms of Welsh Assembly

Government (WAG) recycling and composting targets. The waste management contractor also generates data on a quarterly basis for the Case Study Authority to aid in its submission for WasteDataFlow, this includes a separate section for the performance of the MRF. WasteDataFlow is also used by the Government in order to produce national statistics on waste and can also be used as an evidence base in order to guide future Government Policy (WasteDataFlow 2003). These data enable a profile of municipal waste within the Authority to be mapped, and the performance of the MRF based on the MRF efficiency study (see Chapter 5) to be superimposed onto the Authority data. This enables the impact of the MRF on the Authority's recycling rates to be evaluated.

6.3 RESULTS & DISCUSSION

6.3.1 Introduction

Table 6.2 highlights the total MSW generated within the Case Study Authority from the period 2003/04 to 2006/07 and its total recycling and composting rates for the same period. The data highlights that over the last four years, MSW generation within the Authority has been reasonably consistent at around 40,000 tonnes per annum, with the exception of 2004/05 when the MSW generation was 43,458 tonnes per annum. During this period the recycling and composting rate has increased dramatically from 28.6.9% to 43.3%, with the greatest increase occurring in 2006/07.

Table 6.2: MSW Generation, and Recycling and Composting Rates for Case Study Authority (Keenan. 2007)

Year	MSW Generation (Tonnes)	Recycling & Composting Rate (%)
2003/04	40,794	28.6
2004/05	43,459	35.9
2005/06	40,801	35.6
2006/07	40,140	43.3

As explained previously, the Case Study Region is effectively split in half in terms of kerbside waste management provision; that is, the services provided in the north differ to those provided in the south of the region. This is as a result of the fact that there is no single waste management contract for the Authority, there are in fact two separate contracts, one for the north and one for the south of the county; each of these contracts is managed by a different waste management company. Consequently, the kerbside services offered in the two regions of the Authority differ as a result of the variation in the facilities provided by the waste management companies.

To complement kerbside provision, a network of household waste recycling sites and community bring banks are located throughout the region to enable householders to take waste and recyclable to these sites. The Authority also offers a bulky waste collection to householders, whereby a small charge is levied for collecting large items of furniture, electrical appliances etc. from the householder and delivering the items to one of the two strategically sited transfer stations.

As well as the household waste facilities the Authority also collects other wastes such as public litter bins in town centres, it is also responsible for fly tipped material and street sweeping residues.

Municipal waste sources as described above, can more easily be interpreted in a pictorial form. Figure 6.1 highlights the routes taken by various types of MSW at the start of the research project in October 2004. The diagram highlights that MSW has two main destinations, these are landfill, or material is sent for recycling and composting. The Figure indicates that all non-household waste is sent to landfill, along with other household waste, e.g. bulky waste, and all material collected by Refuse Collection Vehicles (RCVs) in the north of the region. A portion of the material collected by RCVs in the south of the region and via the Household Waste Recycling Centres (HWRCs) is also sent to landfill. Only a fraction of the material collected by RCVs in the south of the region and material collected at HWRCs is sent for recycling and composting.

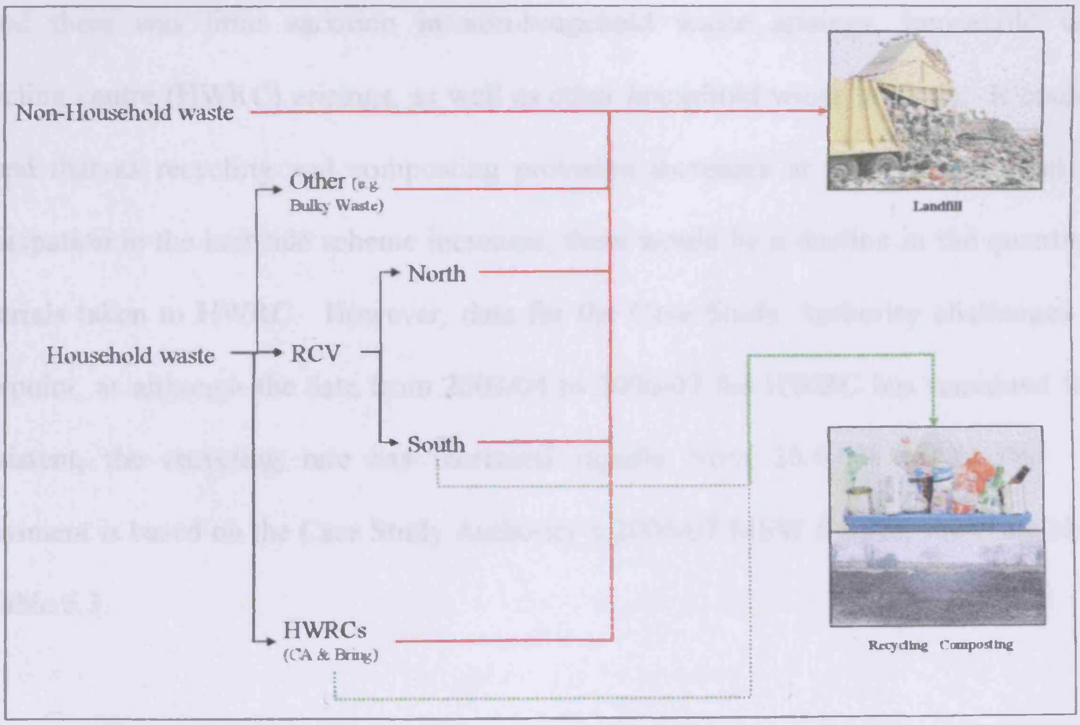


Figure 6.1: MSW Types and Destinations in Case Study Authority

At the start of the research project, only a trial area of 3000 households within the south of the Authority had kerbside recycling(that is, a portion of material collected in the south of the Authority was processed in the MRF); however, during the project the kerbside recycling had been expanded to cover the whole of the South of the region (survival bag scheme), and also the main town in the North of the region also had a kerbside recycling scheme (separately collected from RCV stream). Based on the results of the MRF efficiency study (see Chapter 5), the effect of the MRF on the Case Study Authority's recycling and composting performance can be assessed, along with the impact on BMW diversion.

A number of assumptions were made for this assessment, it was assumed that there would be no growth in MSW arisings, which is based on the fact that for the period 2003/04 to 2006/07 there was little change in arisings, as can be seen in Table 6.2. Also, during this period there was little variation in non-household waste arisings, household waste recycling centre (HWRC) arisings, as well as other household waste arisings. It could be argued that as recycling and composting provision increases at the kerbside, and also participation in the kerbside scheme increases, there would be a decline in the quantity of materials taken to HWRC. However, data for the Case Study Authority challenges this viewpoint, as although the data from 2003/04 to 2006/07 for HWRC has remained fairly consistent, the recycling rate has increased rapidly from 28.6.9% to 43.3%. The assessment is based on the Case Study Authority's 2006/07 MSW figures, these are shown in Table 6.3.

Table 6.3 highlights that 15,713 tonnes of material was diverted from landfill, the majority of this via household waste recycling centres. This diversion represents a recycling and composting rate of 43.3%. This Table also highlights that the collected household waste

(Refuse Collection Vehicle (RCV)) fraction has a large capacity to increase the diversion from landfill.

Table 6.3: 2006/07 MSW Arisings for Case Study Authority (Keenan. 2007)

Material		Refuse Collected (Tonnes)	Material Collected for Recycling & Composting (Tonnes)	Total (Tonnes)
Non-household waste		560	0	560
Household Waste	RCV - North	7868	681	8549
	RCV - South	12508	2053	14561
	Total RCV	20376	2734	23110
	HWRC	2595	12979	15574
	Other Household Waste	896	0	896
TOTAL		**24427**	**15713**	**40140**

From the MRF efficiency study (see Chapter 5), the results obtained highlight the proportion of materials recovered from the residual (black bag) waste and the survival bag streams. Table 6.4 summarises the performance of the MRF in terms of biodegradable municipal waste (BMW) diversion and also in terms of material recovered for recycling and composting.

Table 6.4 shows that the MRF recovered 11.2% of black bag material as dry recyclable and 27.7% in the form of fines, that is the fraction less than 50mm. In the clear bag stream, 32.0% are recovered as dry recyclable, with 63.0% of material left in the residue which was sold as a low grade paper product, and 5.0% fines recovered as fines. The Table also highlights that the black bag fines stream contained a significant amount of BMW representing 24.0% of total black bag input.

Table 6.4: MRF Efficiency Study Summary

Stream		Residual (Black Bag) Stream		Clear Bag Stream	
		Mass (kg)	%	Mass (kg)	%
Recyclate	BMW	760	3.7%	920	21.0%
	Non-BMW	1560	7.5%	480	11.0%
	Total	2320	11.2%	1400	32.0%
Fines (<50mm)	BMW	4988	24.0%	140	3.2%
	Non-BMW	772	3.7%	80	1.8%
	Total	5760	27.7%	220	5.0%
Residue - Landfill	BMW	9006	43.3%	2234	51.0%
	Non-BMW	3723	17.9%	526	12.0%
	Total	12730	61.2%	2759	63.0%
TOTAL		**20800**	**100.0%**	**4380**	**100.0%**

The performance of the MRF was mapped onto the current waste management practices within the Authority in order to determine the quantity of material diverted from landfill, and performance in terms of both the LAS and WAG targets. This is discussed in section 6.3.2.

A number of alternative scenarios were also considered in order to determine what strategies could be employed to meet the LAS and WAG targets. The scenarios considered were:

- scenario 1 - continue as per current scheme but fines from the MRF composted to achieve a 50% mass reduction;
- scenario 2 - kerbside scheme expanded to the whole Authority at same set out and recovery of targeted material;
- scenario 3 - kerbside scheme expanded to the whole Authority and increased weekly set out of 60%;
- scenario 4 - kerbside scheme expanded to the whole Authority at 80% weekly set out, and collection of kitchen waste (2 kg/hh/wk);

- scenario 5 – as scenario 4 but with collection of kitchen waste at 4 kg/hh/wk; and,
- scenario 6 – current kerbside scheme expanded to entire county with all RCV material processed in the MRF.

6.3.2 Current Scenario

Figure 6.2 shows the current scenario resulted to MSW management within the Case Study Authority. The Figure highlights that MSW is split into two distinct categories within the authority, these are household and non-household waste. The non-household waste category mainly consists of street sweeping waste generated within the Authority and amounts to 560 tonnes, and based on the 61% BMW definition used for LAS purposes, the BMW content is 342 tonnes. This non-household waste stream is sent to landfill without further processing or treatment.

The household waste stream, can be further split into household waste recycling centre (HWRC) and RCV streams. Material from the HWRC network across the Authority is either landfilled or recycled/ composted. The quantity of material from HWRCs which is sent to landfill amounts to 2595 tonnes, which equates to 1583 tonnes of BMW (based on 61% definition), while the quantity segregated for recycling and composting is much greater at 12,979 tonnes. The BMW fraction for this material was calculated based on information provided by the Authority, and amounted to 7,528 tonnes, that is 58% biodegradable (Keenan, 2007).

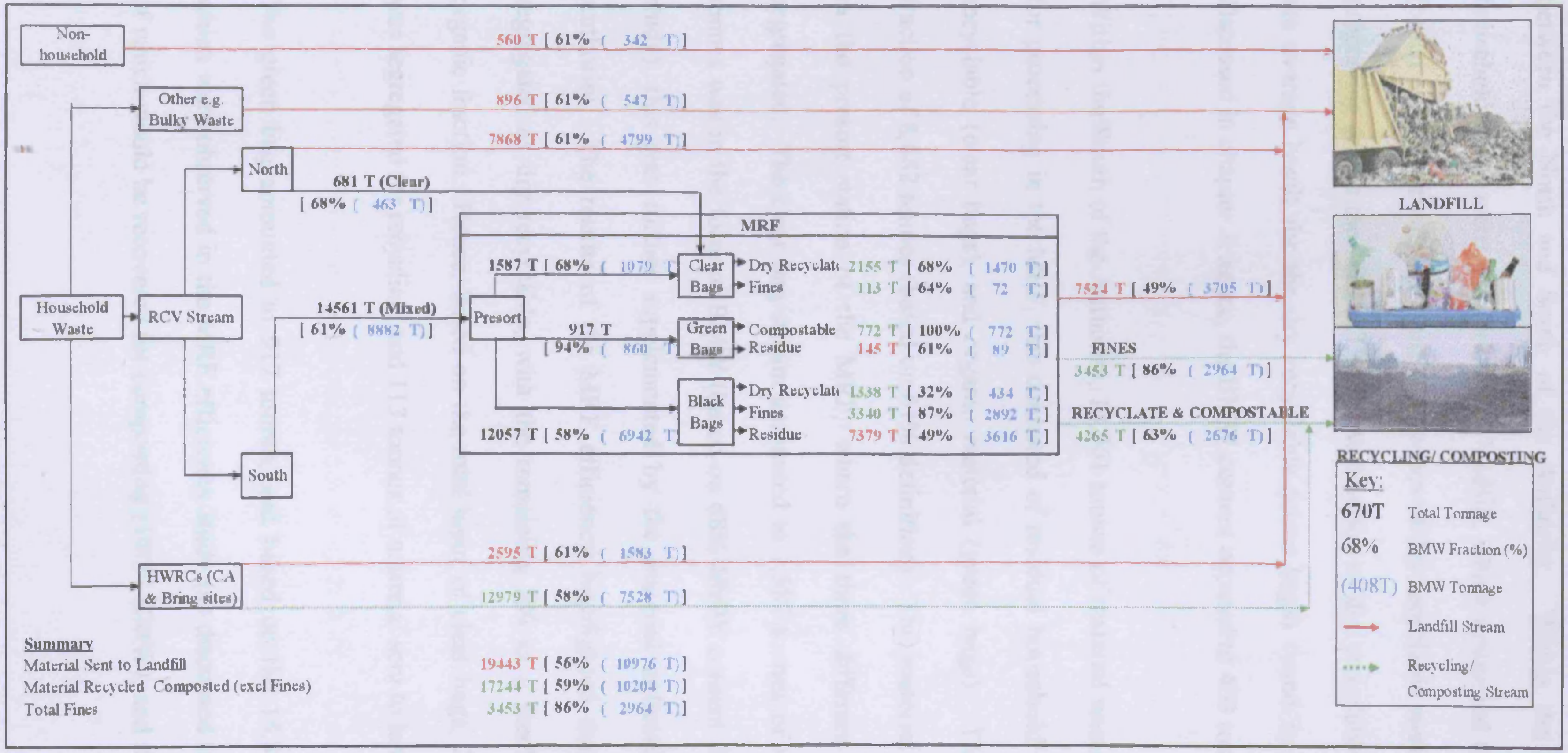


Figure 6.2: Annual assessment of current performance in Case Study Authority based on MRF efficiency study

The RCV stream is again split due to the differences in household waste management between the North and South of the Authority. Within the North, 7,868 tonnes of household waste were sent directly to landfill, which amounted to 4,799 tonnes of BMW (based on 61% definition), while 681 tonnes of dry recyclable were separately collected for processing within the MRF. The BMW fraction of dry recyclable was estimated to 68%, the average result for the dry recyclable (clear bags) found in the waste classification discussed in chapter 3; hence, the BMW content equated to 463 tonnes.

Within the South of the Authority, 14,561 tonnes of material was collected at the kerbside for processing in the MRF, this consisted of residual household waste (black bags), dry recyclable (clear bags), and organic material (green bags). This represented a BMW fraction of 8,882 tonnes (based on 61% definition). This material was initially segregated in the presort station of the MRF, where the three different material streams were segregated. The clear bag stream amounted to 1,587 tonnes of material of which 1,079 tonnes was in the form of BMW (based on 68% BMW content from waste classification study), this was further supplemented by the material collected in the North of the Authority. The results of the MRF efficiency highlighted that 95% of material was segregated as dry recyclable, with the remaining 5% as a mechanically separated fine organic fraction. Hence, based on the total input of clear bags, 2,155 tonnes of material was segregated for recycling, and 113 tonnes of material sent to landfill.

The green bag amounted to 917 tonnes, and based on the 15.8% contamination levels which were observed in the MRF efficiency study (as discussed in chapter 5), 772 tonnes of which would be recovered for composting (100% BMW), and the remaining 145 tonnes sent to landfill as contamination, which represented 89 tonnes of BMW landfilled (based on 61% definition).

The black bag stream contained materials from both households participating within the kerbside recycling scheme, and those that did not, and consisted of 12,057 tonnes of material. The data from the MRF efficiency study highlighted that 11.2% of black material is recovered in the form of dry recyclable, and 27.7% as a mechanically separated fines stream. Therefore, based on the annual input, 1,338 tonnes of dry recyclable was recovered for recycling, 3,340 tonnes of fine organic material was segregated, and 7,349 tonnes of material was sent to landfill.

Therefore, the Figure highlights that based on the current kerbside recycling regime and set out rate, 12,979 tonnes would be diverted from landfill from household waste recycling centres (HWRC), and the MRF could divert 4,265 tonnes in the form of dry recyclable and source segregated organics, with a further 3,453 tonnes of mechanically separated fine organic material. This is a total diversion of 20,697 tonnes of MSW from landfill, which represents a diversion of 51.6% (recycling and composting rate of 43.0% as fines fraction cannot be included as the material is not source segregated), with 19.2% of the material diverted being directly attributed to the MRF.

However, since the fines are currently used as landfill daily cover, the fines are not truly diverted from landfill. Hence, excluding the fines, the diversion from landfill would reduce to 17,244 tonnes or 43.0%. Based on the earlier assumption that there would be no growth in MSW arisings, this would result in the Case Study Authority meeting the WAG target of 40% by 2009/10.

In terms of BMW sent to landfill, based on MSW being defined as 61% biodegradable, 342 tonnes would be landfilled from non-household waste, 547 tonnes from other household waste, 1,583 tonnes from HWRCs, and 4,799 tonnes from the RCV fraction not processed in the MRF. As well, as these tonnages, the MRF residue sent to landfill amounts to 7,524 tonnes, of which 3,705 tonnes are BMW. Consequently, this scenario would result in the Authority landfilling 10,976 tonnes of BMW for the year, and thereby it would meet their 2009/10, 2010/11 and 2011/12 landfill allowance targets of 13,987, 12,728 and 11,583 tonnes respectively but would fail their targets after this point.

Again, due to the usage of the fines, which were effectively landfilled, this would increase the amount of BMW landfilled to 13,940 tonnes. Therefore, the Authority would just meet their landfill allowance target in 2009/10, but the safety margin is minimal. Hence, it would not be wise to continue in the same vain as failure could result in the authority being subjected to a significant fine. In Wales, the fine is set at £200 per tonne landfilled in excess of the landfill allowance target plus the infraction costs from the European Union if the county as a whole failed to meet its target (Audit Commission in Wales, 2005).

6.3.3 Alternative Scenarios

This section will consider the impacts of the various scenarios on the performance of the Authority in terms of both the LAS and WAG targets.

6.3.3.1 Scenario 1

Figure 6.3 highlights the changes if the fines stream from the MRF was composted and achieved a 50% mass reduction. The data within the figure highlight that this scenario could potentially allow the same quantity of material to be diverted from landfill, i.e. 51.6% diversion.

However, in the current scenario the fines were used as landfill daily cover, thus, they cannot contribute to the true diversion number; hence, by composting the fines 50% less material is used as landfill daily cover, and therefore contributes to the amount of material landfilled. That is, the 3,453 tonnes of fines segregated in the MRF, would be composted to obtain a 50% mass reduction, resulting in 1,727 tonnes of composted fines with a BMW tonnage value of 1,485 tonnes.

Therefore, 11,689 tonnes of BMW is effectively landfilled, and assuming no growth in waste arisings, this would allow the case study authority to meet its landfill allowance target until 2010/11. Also, since there is no change to the recyclable and source-segregated organic material recovered for recycling, the WAG recycling and composting rate remains at 43.0%, thus, the Case Study Authority would meet the WAG target of 40% by 2009/10.

This scenario depicted in Figure 6.3 meets both the WAG and LAS targets for 2009/10, but fails to meet the requirements of the landfill allowance scheme. However, options need to be considered in order to meet the LAS targets post 2011, and also the more stringent WAG targets after 2010.

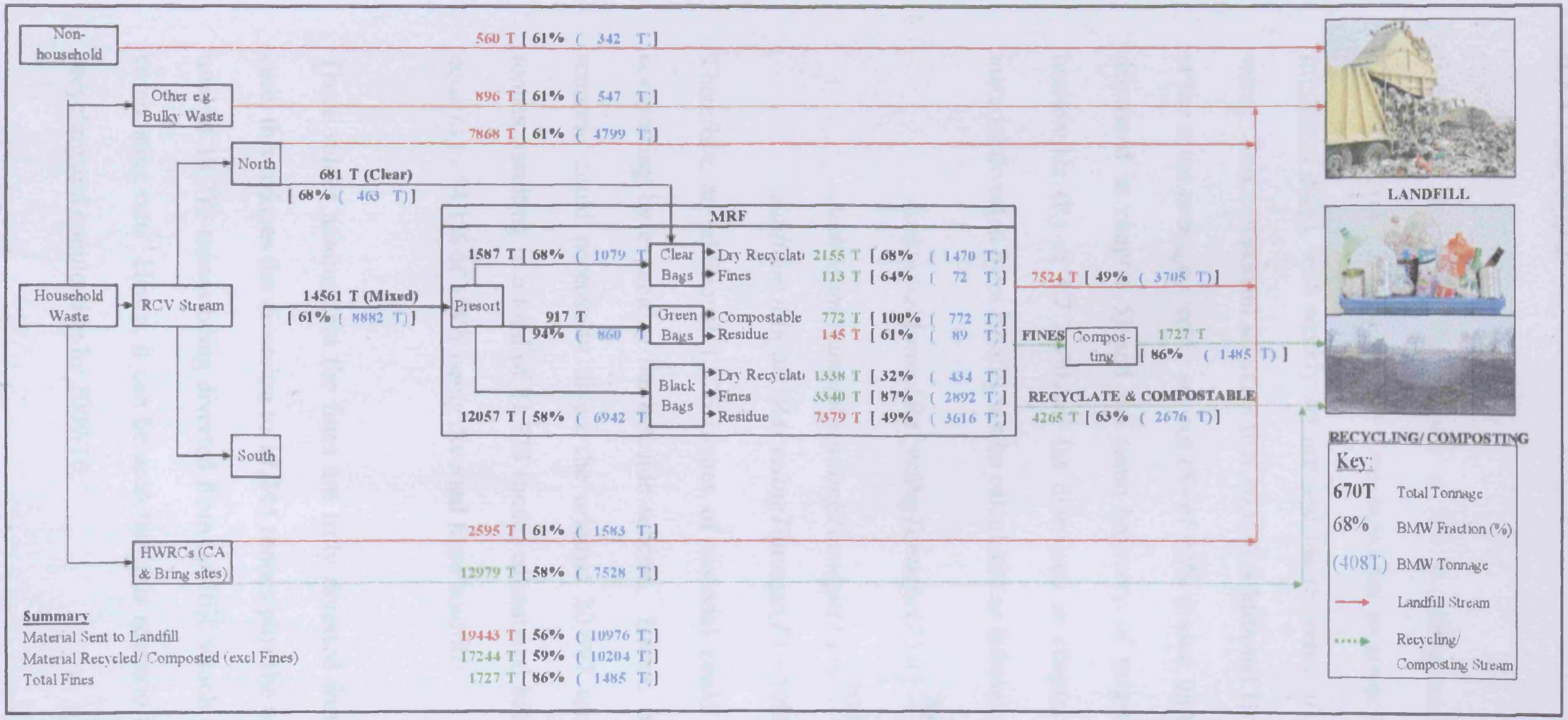


Figure 6.3: Scenario 1 – continue as per current scheme but with composting of fines

6.3.3.2 Scenario 2

Scenario 2 highlights the changes to the recycling and composting rates, and BMW diversion if the kerbside scheme were expanded to cover the whole Authority (clear bags processed only), with weekly set out and the recovery of targeted material remaining the same. This assessment assumes that 10,000 Additional Households (AH) will be covered at the same average weekly set out (S) of 42% (based on the results of the set out survey discussed in chapter 5) and the same recovery of targeted material from participating households (R) of 4.7 kg/hh/wk (as discussed in chapter 3). Therefore, the additional material diverted from landfill can be calculated as follows:

$$AdditionalAnnual\,\mathrm{Re}cyclingTonnage(T) = \left[\frac{\mathrm{AH} \times \mathrm{S} \times \mathrm{R} \times 52}{1000}\right]$$

$$AdditionalAnnual\,\mathrm{Re}cyclingTonnage(T) = \frac{10000 \times 0.42 \times 4.7 \times 52}{1000}$$

$$AdditionalAnnual\,\mathrm{Re}cyclingTonnage(T) = 1026$$

Therefore, an additional 1,026 tonnes of material could be diverted for recycling and composting by expanding the kerbside scheme. Hence, from the data in Figure 6.2 this scenario could potentially divert the original 20,697 tonnes plus the additional 1,026 tonnes, resulting in a total of 21,723 tonnes of material being diverted from landfill. This equates to 54.1% of MSW being diverted from landfill.

These values assume that the fines are truly diverted from landfill, since this is not the case, this reduces the diversion to 17,244 tonnes plus the additional 1,026 tonnes, that is a total of 18,270 tonnes being diverted from landfill, which equates to 45.6% recycling and composting rate. Hence, it can be seen that this scenario fulfills the WAG target of 40% recycling and composting by 2009/10.

In terms of BMW diversion, scenario 2 would reduce the quantity of BMW landfilled by the Case Study Authority. From the waste classification studies completed (see chapter 3), the BMW content of a clear bag was found to be 68% of the total contents. Hence, based on the fact that this scenario would result in an additional 1,026 tonnes of material being diverted, 68% of this stream would be biodegradable; hence 698 tonnes of material would be diverted from landfill. Therefore, from Figure 6.2 if the fines stream was diverted from landfill, the quantity of BMW sent to landfill would reduce from 10,976 tonnes to 9,940 tonnes of BMW per annum, and thereby would meet their LAS targets until 2012/13.

Again, due to the situation with the fines being used for landfill daily cover, the fines were effectively landfilled, hence, this increases the amount of BMW landfilled to 12,904 tonnes. Therefore, the Authority would meet their 2009/10 LAS target, but would fail to meet them in subsequent years. Further scenarios require consideration in order to provide a longer term solution.

6.3.3.3 Scenario 3

Scenario 3 highlights the changes to the recycling and composting rates, and BMW diversion if the kerbside scheme were covered the whole Authority (clear bags processed only), with weekly set out increased to 60% (that is a change in weekly set out (ΔS) of 18% from that in scenario 2) and the recovery of targeted material (R) remaining the same at 4.7 kg/hh/wk. From the 2001 census, the number of households (H) within the case study boundary is 32,000, therefore, the additional material diverted from landfill can be calculated as follows:

$$AdditionalAnnual\,\mathrm{Re}\,cyclingTonnage(T) = \left[\frac{\mathrm{H} \times \Delta\mathrm{S} \times \mathrm{R} \times 52}{1000}\right]$$

$$AdditionalAnnual\,\mathrm{Re}\,cyclingTonnage(T) = \frac{32000 \times 0.18 \times 4.7 \times 52}{1000}$$

$$AdditionalAnnual\,\mathrm{Re}\,cyclingTonnage(T) = 1408$$

Therefore, an additional 1,408 tonnes of material could be diverted for recycling and composting by having a kerbside scheme which operated throughout the region. Hence, from the data for Scenario 2, this scenario could result in 23,131 tonnes (21,723T + 1408T) being diverted from landfill, equating to 57.6% of MSW being diverted from landfill.

This assumes that the fines are truly diverted from landfill, since this is not the case, this reduces the diversion to 20,167 tonnes (18,759T + 1,408T), which equates to a 50.2% recycling and composting rate. Hence, it can be seen that this scenario comfortably fulfills the WAG target of 40% by 2009/10, but would fail to meet the WAG target of 52% by 2012/13 (as discussed in section 1.3).

In terms of BMW diversion, based on the fact that this scenario would result in an additional 1,408 tonnes of material being diverted compared to that in Scenario 2, 68% of this stream would be biodegradable; hence an additional 957 tonnes of material would be diverted.

Therefore, if the fines stream was diverted from landfill, the quantity of BMW sent to landfill would reduce from 9,940 tonnes (as in scenario 2) to 8,983 tonnes of BMW per annum (9,940T – 957T), and thereby the Authority would meet their 2009/10 landfill allowance target of 13,987 tonnes and also their 2012/13 landfill allowance target of 10,540 tonnes.

Again, due to the situation with the fines being used for landfill daily cover, the fines were effectively landfilled, thus, this increases the amount of BMW landfilled to 11,947 tonnes (12,904T – 957T). Therefore, the Authority would meet their LAS target in 2009/10 but would fail to meet their 2011/12 target of 11,583 tonnes.

6.3.3.4 Scenario 4

Scenario 4 indicates the changes to the recycling and composting rates, and BMW diversion if the kerbside scheme covered the whole Authority, with weekly set out increasing to 80% (that is a change in weekly set out (ΔS) of 38% from that in scenario 2) and the recovery of targeted material in the clear bag (R_c) remained the same at 4.7kg/hh/wk. This scenario also adds a kitchen waste collection to the kerbside recycling scheme, and assumes a kitchen waste recovery (R_k) of 2kg/hh/wk at the kerbside, and again that weekly set out (S) in the kitchen waste collection scheme would be 80%. Hence, this scenario builds on that described in scenario 2, and the additional material diverted from landfill can be calculated as follows:

$$AdditionalAnnualTonnage(T) = \left[\frac{\mathrm{H}\times\Delta\mathrm{S}\times\mathrm{R_c}\times 52}{1000}\right] + \left[\frac{H\times S\times R_k\times 52}{1000}\right]$$

$$AdditionalAnnualTonnage(T) = \frac{32000\times 0.38\times 4.7\times 52}{1000} + \frac{32000\times 0.8\times 2\times 52}{1000}$$

$$AdditionalAnnualTonnage(T) = 2972 + 2662$$

$$AdditionalAnnualTonnage(T) = 5634$$

Therefore, an extra 5,634 tonnes of material could be diverted for recycling and composting via this scenario than that assessed in Scenario 2. Hence, from the data for Scenario 2, this scenario could result in 27,357 tonnes (21,723T + 5,634T), or 68.2% of MSW being diverted from landfill.

The above assumes that the fines are truly diverted from landfill, since this is not the case, this reduces the diversion to 24,393 tonnes (18,759T + 5,634T), which equates to a 60.8% recycling and composting rate. Hence, it can be seen that this scenario far exceeds the WAG target of 40% by 2009/10, and will meet the proposed recycling and composting targets of 52% by 2012/13 and 58% by 2015/16 if there is no increase in waste arisings and no change to waste composition.

In terms of BMW diversion, scenario 4 would further reduce the quantity of BMW landfilled by the Case Study Authority. As discussed previously, the BMW content of a clear bag (B_c) was found to be 68%, and the BMW content of kitchen waste (B_k) would be 100%. Therefore, the additional BMW diversion potential if this scenario was implemented can be calculated as follows:

$$AdditionalAnnualBMWTonnage(T) = \left[\frac{\mathrm{H} \times \Delta\mathrm{S} \times \mathrm{R_c} \times 52 \times \mathrm{B_c}}{1000}\right] + \left[\frac{H \times S \times R_k \times 52 \times B_k}{1000}\right]$$

$$AdditionalAnnualBMWTonnage(T) = \frac{32000 \times 0.38 \times 4.7 \times 52 \times 0.68}{1000} + \frac{32000 \times 0.8 \times 2 \times 52 \times 1.0}{1000}$$

$$AdditionalAnnualBMWTonnage(T) = 2021 + 2662$$

$$AdditionalAnnualBMWTonnage(T) = 4683$$

Therefore, from the data for Scenario 2 if the fines stream was diverted from landfill, the quantity of BMW sent to landfill would reduce from 9,940 tonnes to 5,257 tonnes of BMW per annum, and thereby the Authority would meet their 2009/10, 2012/13 and 2019/20 landfill allowance target of 13987, 10,540 and 5,446 tonnes.

Again, due to the situation with the fines being used for landfill daily cover, the fines were effectively landfilled, hence, this increases the amount of BMW landfilled to 8,221 tonnes (12,904T – 4,683T). Hence, the Authority would meet their 2009/10 and 2012/13 landfill allowance targets of 13,987 and 10,450 tonnes.

Scenario 4 can potentially allow the Case Study Authority to comfortably meet the WAG targets for 2009/10 and 2012/13, and could potentially provide a more long term answer if a solution is found for the fines stream.

6.3.3.5 Scenario 5

Scenario 5 builds on scenario 4 and assumes that a kitchen waste collection would recover 4 kg/hh/wk instead of the figure of 2 kg/hh/wk used in scenario 4. This figure was used in this scenario as a kitchen waste collection in RCT was recovering between 4 and 6 kg per household per week (Lewis, 2008). Hence, this scenario builds on that described in scenario 4, and assumes that the weekly set out (S) remains at 80%, but an additional kitchen waste recovery (R_k) of 2kg/hh/wk at the kerbside from participating households would be collected. Thus, the additional material diverted from landfill can be calculated as follows:

$$AdditionalAnnualTonnage(T) = \left[\frac{H \times S \times R_k \times 52}{1000}\right]$$

$$AdditionalAnnualTonnage(T) = \frac{32000 \times 0.8 \times 2 \times 52}{1000}$$

$$AdditionalAnnualTonnage(T) = 2662$$

Therefore, an extra 2,662 tonnes of material could be diverted for recycling and composting via this scenario than that assessed in Scenario 4. Hence, from the data for Scenario 4, this scenario could result in 30,019 tonnes (27,357T + 2,662T), or 74.7% of MSW being diverted from landfill.

The above assumes that the fines are truly diverted from landfill, since this is not the case, this reduces the diversion to 27,055 tonnes (24,393T + 2,662T), which equates to a 67.4% recycling and composting rate. Hence, it can be seen that this scenario far exceeds the WAG target of 40% by 2009/10, and will meet the proposed recycling and composting targets of 52% by 2012/13, 58% by 2015/16 and 64% by 2019/20 if there is no increase in waste arisings and no change to waste composition.

In terms of BMW diversion, scenario 5 would further reduce the quantity of BMW landfilled by the case study authority. As discussed previously, the BMW content of kitchen waste (B_k) would be 100%. Therefore, the additional BMW diversion potential would again be 2,662 tonnes. Therefore, from the data for Scenario 4 if the fines stream was diverted from landfill, the quantity of BMW sent to landfill would reduce from 5,257 tonnes to 2,595 tonnes of BMW per annum, and thereby the Authority would comfortably meet their 2019/20 landfill allowance target of 5,446 tonnes.

Again, due to the situation with the fines being used for landfill daily cover, the fines were effectively landfilled, hence, this increases the amount of BMW landfilled to 5,559 tonnes (8,221T – 2,662T). Hence, the Authority would meet their LAS targets until 2018/19.

Scenario 5 can potentially allow the case study authority to comfortably meet both the WAG and LAS targets until 2018/19. However, this scenario would be difficult to achieve through the use of a voluntary scheme.

6.3.3.6 Scenario 6

Figure 6.4 highlights an alternative scenario whereby all of the region's collected household waste (RCV fraction) is processed in the MRF. This Figure highlights that 12,979 tonnes continue to be diverted from landfill from household waste recycling centres (HWRC), and the MRF could divert 5,138 tonnes in the form of dry recyclable and source segregated organics, and a further 5,632 tonnes of mechanically separated fine organic material. This represents a total diversion of 23,479 tonnes of MSW from landfill, which represents a diversion of 59.2% (recycling and composting rate of 44.5% as fines fraction cannot be included as the material is not source segregated).

In terms of BMW sent to landfill, based on MSW being defined as 61% biodegradable, 342 tonnes would be landfilled from non-household waste, 547 tonnes from other household waste, and 1,583 tonnes from HWRCs. As well as these, the total MRF residue sent to landfill amounts to 12,339 tonnes, with a BMW tonnage of 6,334 tonnes. Thus, this scenario would result in the region landfilling 8,806 tonnes of BMW for the year. Consequently, if waste arisings did not change and assuming that the fines are diverted from landfill in accordance with the Environment Agency and Welsh Assembly requirements, the case study authority would meet their LAS targets until 2013/14.

However, if the fines are included within the fraction of BMW landfilled, this figure increases to 13,658 tonnes. Hence, the authority would just meet their LAS target for 2009/10.

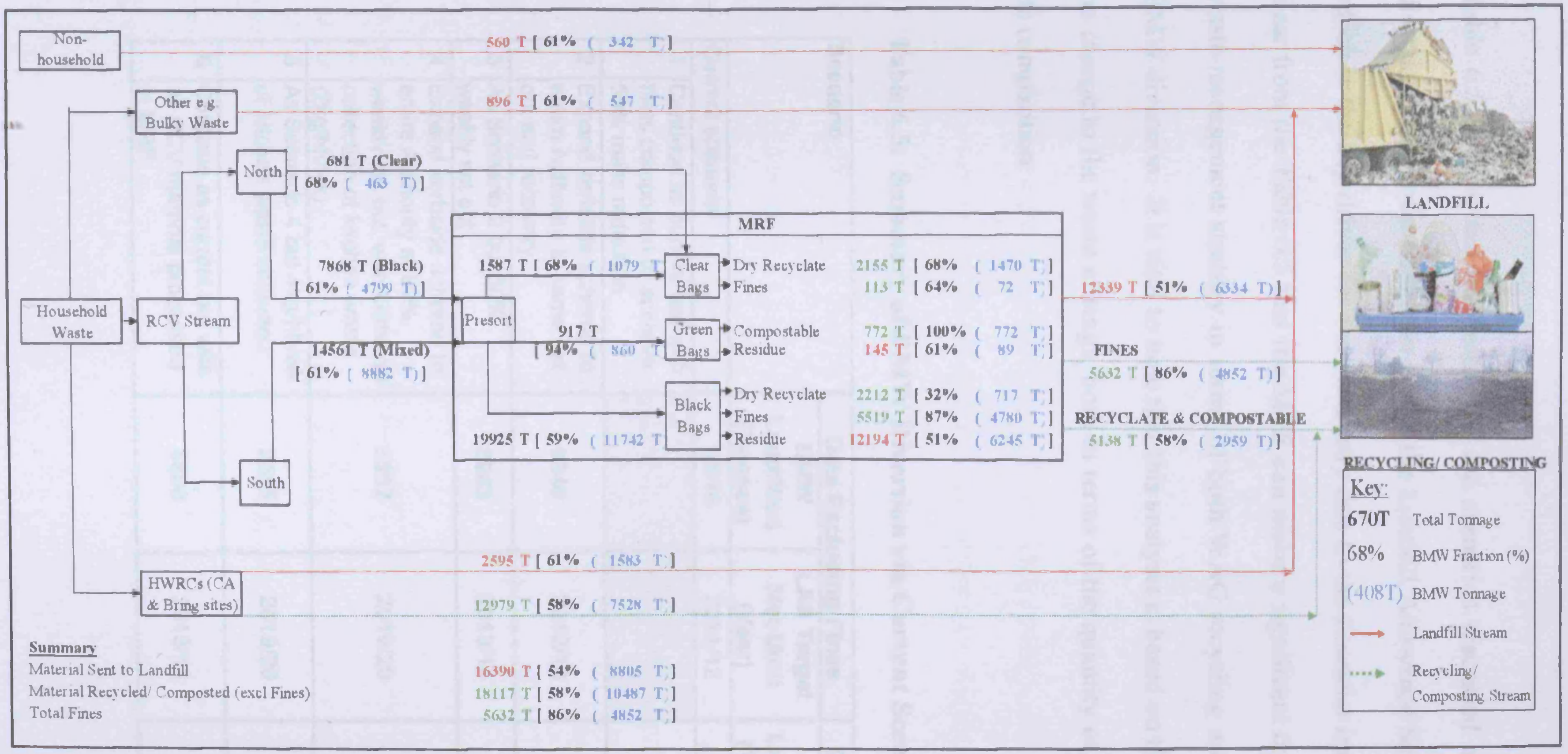


Figure 6.4: Scenario 6 – Continue as per Current Scheme but with all RCV material processed in the MRF

6.4 SUMMARY

Table 6.5 summarises the results of the scenarios discussed above in terms of BMW diversion and the timeframe in which the Landfill Allowance Scheme targets will be met, which is the key driver for the Authority due to the financial implications involved. It is clear from the Table 6.5 that the MRF can make a significant contribution to the region's waste management strategy in terms of both WAG recycling and composting targets and BMW diversion. It is vital to note that this analysis is based on the assumption that there is no change to the waste arisings, both in terms of the quantity of waste produced, and also its composition.

Table 6.5: Summary of BMW Diversion via Current Scenario & Scenarios 1-6

Scenario		Data Excluding Fines		Data Including Fines	
		BMW Landfilled (Tonnes)	LAS Target Met Until (Year)	BMW Landfilled (Tonnes)	LAS Target Met Until (Year)
Current scenario		10976	2011/12	13940	2009/10
1	Continue as current but with fines composted to achieve 50% mass reduction			11689	2010/11
2	Expand kerbside scheme to entire Authority at same set out and recovery	9940	2012/13	12904	2009/10
3	As Scenario 2 but 60% weekly set out	8983	2013/14	11947	2010/11
4	Expand kerbside scheme to entire Authority at 80% weekly set out, with kerbside collection of kitchen waste (2kg/hh/wk)	5257	2019/20	8221	2014/15
5	As Scenario 4 but 4kg/hh/wk of kitchen waste collected	2595	2019/20	5559	2018/19
6	Continue as current but with all RCV material processed in MRF	8806	2013/14	13658	2009/10

Table 6.5 highlights that the MRF can have a significant impact on whether the region will meet its annual LAS targets, regardless of whether the fines are subject to some form of treatment in order to be diverted from landfill. However, if this material is treated it provides a significant cushion by which the region can meet its targets. Currently, this material is composted in a manner which is not compliant with the Animal By-Products Regulations (ABPR) and is used as an engineering material in landfill, namely as daily landfill cover. Hence, this material currently still counts towards the region's landfill allowance figures (DEFRA, 2006a; and Environment Agency, 2005).

If the material was composted in compliance with ABPR and used in the same manner, it would still contribute to Ceredigion's landfill allowance figure; however, the reduction in biodegradability of the material would have to be taken into account. That is, if 100 tonnes of fines at 100% biodegradability were sent to landfill, all 100 tonnes would count towards Ceredigion's BMW landfill allowance limit. However, if 100 tonnes of fines at 50% biodegradability were sent to landfill, only 50 tonnes would count towards Ceredigion's BMW landfill allowance limit. This is a more attractive scenario for Ceredigion than what was occurring at the time of the study; however long term a more viable solution is needed (DEFRA, 2006a; and Environment Agency, 2005).

Scenarios 4 and 5 which both consider a kitchen waste collection offered to householders, are the scenarios which meet the LAS targets most comfortably, and therefore the region must consider this for future plans. Indeed, the targets proposed by WAG post 2010, include a target for source-segregated kitchen waste, although it is not yet clear whether these targets will be statutory or non-statutory (Welsh Assembly Government, 2007).

However, both of these scenarios consider a very high set out rate of 80%, which in reality would be extremely difficult to achieve with a voluntary system.

There may be political changes that take place which would force the general public to participate in kerbside recycling schemes, for example 'pay as you throw' schemes, or compulsory participation (e.g. fines for 'non-recyclers'). Indeed at a recent conference, it was stated by the Minister for the Environment and Sustainability and the head of waste strategy at the Welsh Assembly Government that it may become a statutory duty for the householder to recycle (Davidson 2008, and Rees 2008). Many other countries operate such systems and their recycling and composting performance is significantly better than that observed within the UK, numerous studies have found that in such schemes higher levels of both set out and material diversion are found (Folz and Hazlett 1991; Platt *et al.* 1991; Everett and Pierce 1993; Noehammer and Byer, 1997; WARMER Bulletin 2002; CIWM 2003).

Alternative Weekly Collection (AWC) schemes have attracted a significant amount of interest in recent years. These schemes may be defined as where one type of material is collected on one week (week 1) and a different type of material the following week (week 2). Where AWC schemes have been implemented where there is an alternate collection of residual waste and recyclable material, data have shown that significant increases in diversion are observed. For example the Vale Royal Borough Council in England increased their household waste recycling rate from 15% in 2003/04 to 40% in 2004/05 due to the implementation of an AWC scheme (WRAP, 2005).

The priority for the region must be compliance with the LAS targets as these are statutory targets and there are potential significant financial penalties involved. Currently WAG recycling and composting targets are non-statutory, although it is important that the Authority do not dismiss these targets, as they could become statutory targets in the future.

It is clear that without changes to legislation or the political will to introduce an AWC scheme for example, it will be very difficult for the Authority to comply with the requirements of the LAS scheme. This scheme is essentially a penalty for landfilling BMW, therefore a guaranteed solution which does not depend on public participation would be some other form of disposal route, namely a thermal process. Thus, if the Authority were to send the residual MSW for thermal processing as opposed to the material being landfilled, this would enable it to safely meet the requirements of the LAS scheme. Current thinking within the Authority is to consider thermal processing of MSW, however, no decision has been made in terms of the type of thermal process to be utilised or whether the Authority will procure its own thermal process or enter a contract with a waste management contractor with a suitable facility. It is imperative that these important decisions are taken as soon as possible, as time is a significant factor in relation to the planning, installation and commissioning of thermal waste treatment plants.

It must be noted that the results in this chapter only consider the mass balances for the various scenarios based on the results obtained in the waste classification study (see chapter 3), and the MRF efficiency study (see Chapter 5). However, a number of other factors must be considered by the Authority prior to determining what changes are needed to their waste management strategy. These are:

- cost – that is the cost of funding the proposed changes;
- life cycle assessment – i.e. is their a net environmental benefit to collecting the stream;
- health and safety – i.e. do the proposed changes affect the working conditions that operatives are exposed to, e.g. bioaerosols, weight of containers; and
- ease of use of the proposed changes to the general public.

However, such decisions are down to the Authority to determine which direction their waste management strategy will take, in order to meet the stringent Landfill Allowance Scheme targets and also the non-statutory Welsh Assembly Government recycling and composting targets.

CHAPTER 7: Conclusions & Recommendations

7.1 CONCLUSIONS

The significant changes that have taken place in terms of waste management legislation in recent times are mainly as a result of changes at an EU level, and as a result the waste management industry is undergoing a period of significant change within the UK. The UK has traditionally been heavily reliant on landfill as a means of dealing with its ever increasing levels of municipal solid waste (MSW); however, as a result of EU drivers alternative means of dealing with MSW such as kerbside recycling, composting and thermal processes are increasing in popularity within the UK.

Local authorities have a significant role to play as essentially they have the power to deliver these statutory and non-statutory targets on a local level. Traditionally waste management strategies have included the provision of Household Waste Recycling Centres (HWRCs) and kerbside recycling schemes for the segregation of recyclable and compostable materials away from the general waste stream.

This thesis has examined how a materials recovery facility (MRF) could assist a local authority to meet the required statutory and non-statutory targets. The Case Study Authority operated a kerbside recycling scheme which utilised survival bags for the collection of dry recyclable and garden waste, these survival bags were collected at the same time and in the same vehicle as the residual waste (black bag) stream. The rationale for this type of scheme, being that as the Case Study Authority was rural in nature, the transportation costs involved in operating a separate collection was deemed prohibitive. Along with this survival bag scheme, the Authority had a network of five HWRCs which traditionally had been very well used by householders, and made a significant contribution to the Authority's recycling and composting targets.

The household waste stream within the Authority was analysed in order to determine the composition of the waste stream, and also the quantities of waste generated by householders. This analysis was conducted in an area where the survival bags were in operation, and as a result data was obtained on the dry recyclable, organic and residual waste streams. This analysis determined that the average household waste generation within the region was 14.9 kg/hh/wk, which ranged from 13.4 kg/hh/wk in the Winter to 16.5 kg/hh/wk in the Summer. These figures are lower than the Welsh average figure of 17 kg/hh/wk (National Assembly for Wales, 2003). Participating households typically generated 4.7 kg/hh/wk and 3.0 kg/hh/wk of segregated dry recyclable and organic material respectively.

The compositional analysis of the household waste stream established that the average BMW content was 72%, which was significantly higher than the 61% used to define MSW for the Landfill Allowance Scheme (LAS) figures for Wales. Hence, the region has a larger pool of BMW to target in order to comply with the stringent LAS targets. However, the performance at the time of the compositional analysis highlighted that much of this biodegradable material remained in the residual waste (black bag) stream, it was not diverted via the dry recyclable or organic collection schemes available to householders. Thus, this emphasises the need for Authority to increase the amount of biodegradable material segregated by householders, which could be achieved by targeted education and awareness. However, during the study there was a shift in the policy of the region, and a charge was implemented for the organic waste collection scheme, which had the effect of reducing the quantity of BMW diverted via the kerbside recycling scheme. The rational behind this being that by collecting this material, garden waste which previously had not entered the waste stream was being collected, which resulted in a substantial increase of approximately 3000 tonnes of annual MSW arisings. An alternative means of recovering this BMW would be to process the residual waste, as such a scheme would not be bound by the participation of householders.

A number of MRFs were visited both in the UK and overseas, which consisted of both clean and dirty MRFs, and a review of each process enabled best practice ideas to be developed, which coupled with the waste composition and generation data for the region enabled a MRF conceptual design to be developed. It was clear from the MRF process reviews undertaken that process flexibility was the key factor to consider in any MRF design, as it would enable the MRF to adapt to changes in the market, and also to be able to process different material streams. The design which was developed was flexible in that it was able to process both dry recyclable and residual waste (black bag stream), and thereby enable the region to segregate BMW via both the kerbside recycling scheme and the residual waste stream. This conceptual design was adapted to allow for a phased implementation of the MRF so as to minimise the financial outlay for the waste management contractor.

An efficiency study carried out on the first phase of the MRF implementation highlighted that when processing a residual waste (black bag) stream, the recovery of dry recyclable increased from 8.7% for the pilot MRF to 11.2% for the phase 1 MRF, but as well as an increase in the proportion of dry recyclable collected, the throughput through the plant increased five fold. As well as the dry recyclable stream, the MRF also segregated a mechanically segregated fine organic stream (less than 50mm fraction), which accounted for 27.7% of input material with a BMW content of 86.6%. This stream had the benefit of improving the quality of the dry recyclable streams, and also a health and safety benefit as much of the biologically active material was segregated before picking operatives came into contact with the waste stream. The segregation of this material also enabled research to be carried out on some form of waste process to be carried out on this material in order to divert this material away from landfill; however, that activity was outside the scope of this study.

The efficiency study highlighted that the MRF was recovering 56% of the available dry recyclable within the residual waste stream, with the manual picking operations generally achieving a higher recovery rate, compared with the automated processes used for aluminium and steel. This was as a result of poor presentation, as a result of plastic film, paper and card covering much of the conveyor at the automated sorting stations.

When processing a dry recyclable stream, the efficiency study identified that 95% of the material was recovered for recycling; however, two-thirds of this was in the form of a low grade paper product, which was essentially the residual material within the MRF when processing this material. In terms of positive sorting activity, 41% of material was recovered, and in contrast to the residual waste efficiency results the automated processes outperformed the manual picking operations.

It was evident from the efficiency study on both residual and dry recyclable streams, that anther form of segregation was needed in the MRF in order to make the process more efficient. This will be delivered via the next phase of the MRF development with the installation of a ballistic separator, which will enable the two dimensional and light material such as paper, card and plastic film, to be separated from the three dimensional and heavy objects such as cans and bottles. This will enable the sorting operations to be more effective and efficient.

The data obtained in the MRF efficiency study enabled a modelling activity to be carried out on the Case Study Authority's annual MSW data. This thesis has found a MRF of this type can have a significant impact upon the performance of the region in terms of both LAS and WAG targets. Current thinking within the region is the investigation into thermal processes for the treatment of waste streams destined for landfill; however, it is vital that the region give consideration to the WAG targets post 2010, as it has been announced that a target of 70% recycling and composting by 2024/25 will be implemented, and it is not yet clear whether these will become statutory targets.

An integrated approach will be needed to meet both LAS and WAG targets, and the MRF can play a significant role in that approach. Changes will be needed to the waste management approach in the region, and it may be that approaches such as alternative weekly collection (for example Vale Royal Borough Council), a strict no side waste policy etc. are introduced in order force householders to participate in the kerbside recycling scheme. However, it must be remembered that with such schemes, strict enforcement is required in order to avoid contamination problems in the dry recyclable and organic waste collection schemes.

This thesis has a made a contribution to research in this field, particularly in relation to the efficiencies and operating conditions of MRFs, as such detailed information is unique and rarely made public by waste management companies for commercial purposes. As a result, the impact of MRFs can be more accurately modelled on local authority waste arisings, to assess options for landfill diversion.

7.2 RECOMMENDATIONS FOR FUTURE WORK

It is recommended that future research be conducted into the following areas:

- an efficiency study into the second phase of the MRF development, in order to ascertain the impact of the additional equipment on the performance of the MRF, and also the MRFs impact on the region's LAS and WAG targets;
- further development of benchmarking tools in order to enable comparisons to be made between MRFs, consideration needs to be given to contamination levels within the feedstock material;
- a study on the costs of separate collection versus survival bag collection within the region;
- an examination of the impact of Alternate Weekly Collections on waste composition and arisings; and,
- an assessment of the BMW content of the Welsh municipal waste stream, as this thesis clearly finds that the BMW content of the waste stream within the case study authority is significantly higher than the 61% used throughout Wales.

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