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Material change for
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Final Report

Good practice in construction and demolition materials recovery facilities

A review of UK MRFs to identify, and to encourage MRF operators to adopt, good practice in the recovery of non-inert C&D waste materials.

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WRAP helps individuals, businesses and local authorities to reduce waste and recycle more, making better use of resources and helping to tackle climate change.

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Front cover photography: Mechanical grab pre-sorting construction and demolition waste.

Executive summary

WRAP (Waste & Resources Action Programme) is leading a drive to halve the amount of construction, demolition and excavation (CD&E) waste sent to landfill by 2012. Many construction contractors, demolition and excavation companies and their major clients and waste managers are signing up to The Construction Commitments: Halving Waste to Landfill which commits them to playing their part in halving the amount of construction, demolition and excavation waste going to landfill by 2012[1]. In order to achieve this, the construction industry is encouraged to work closely with waste management companies (WMCs) to identify and implement good practice across the waste supply chain. From the point of waste arising on C&D project sites through to the delivery of quality materials at the re-processing facilities, the successful retrieval from these waste streams of materials for re-processing is a vital element in achieving the stated aims. Methods for recovering and recycling inert wastes, such as aggregates, soils and concrete, are well-established in the UK. However, despite the introduction of various regulatory and fiscal measures, the volume of non-inert wastes disposed to landfill remains high. Such materials include cardboard and plastic packaging, plastic products, wood, insulation, some ferrous and non-ferrous metals, ceramic materials and bio-organics.

This report describes the findings of a review which focused on a key element of the waste supply chain, namely the contribution made by Materials Recovery Facilities (MRFs). The review sought to identify, and to encourage MRF operators to adopt, good practice in the recovery of non-inert C&D waste materials.

The working method for the review included visiting 15 UK sites thought likely to demonstrate good practice in part or all of their operations. To gain a wider European perspective, visits were also made to three C&D MRFs in the Netherlands - a country considered advanced in its treatment of C&D waste. Additional insights were gathered through telephone interviews with three further MRF operators, discussions with sorting technology manufacturers and suppliers, and at two workshops with waste management and construction companies organised by WRAP.

The definition of 'good practice' is subjective, and opinions within the industry differ as to whether or not a particular practice is 'good'. This report describes good practice where this is undisputed by all stakeholders and, for those elements of MRF operations where processes or management systems are disputed, the report reviews the arguments for and against such practices.

While certain elements of good practice were exhibited by all the sites visited, none were considered exemplars in all aspects. Thus the current report does not focus on any specific sites but rather highlights elements of good practice identified from all the MRFs visited or interviewed. In effect it describes an exemplar MRF in which key elements of the processes associated with the recovery of quality non-inert C&D waste recyclates are identified.

It was not possible to visit all of the UK's C&D MRFs during the review, and we accept that examples of good practice will also exist in many sites not covered by the review.

[1] *More information on The Construction Commitments: Halving Waste to Landfill is available at www.wrap.org.uk/construction*

Contents

Abbreviations

C&D	construction and demolition
C&I	commercial and industrial
CCTV	closed circuit television
CHP	combined heat and power
Defra	Department for the Environment, Food and Rural Affairs
EA	Environment Agency
EfW	energy from waste
EWC Code	European Waste Catalogue Code
ESA	Environmental Services Association
H&S	health and safety
HDPE	high density polyethylene
ISO	International Organization for Standardization
KPI	key performance indicator
LAP	National Waste Management Plan (Netherlands)
LDPE	low density polyethylene
LOW	List of Waste (replaced EWC codes)
LSU	lights separation unit
MDF	medium-density fibreboard
MRF	materials recovery facility
NIEA	Northern Ireland Environment Agency
OHSAS	Occupational Health and Safety Management Systems
PET	polyethylene terephthalate
PP	polypropylene
RDF	refuse-derived fuel
RORO	roll-on-roll-off skip
RRS	Recyclers Registration Service
SEPA	Scottish Environment Protection Agency
SSWAT	Site Specific Waste Assessment Tool
SWMP	Site Waste Management Plan
uPVC	unplasticized polyvinyl chloride
WEEE	waste electrical and electronic equipment
WTS	waste transfer station

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1.0 Introduction and working method

1.1 Introduction to this report

Halving waste to landfill is a construction sector goal which supports the Strategy for Sustainable Construction in England, the Scottish Government's Zero Waste policy and the Welsh Government's policy on Zero Waste. In consultation with industry, WRAP has developed a voluntary agreement which demonstrates corporate contributions to the Construction Commitments: Halving Waste to Landfill, by 2012, with actions to halve the amount of construction and demolition (C&D) waste that is currently being sent to landfill. Individual companies are not expected to halve their own waste going to landfill, but rather to prove year-on-year reductions in tonnages of waste landfilled. More information on The Construction Commitments: Halving Waste to Landfill is available on the following website: www.wrap.org.uk/construction.

The successful recovery and processing of C&D waste by operators of Material Recovery Facilities (MRFs) is key to achieving the Having Waste to Landfill targets. The construction industry, waste management companies and material re-processors are encouraged to work together to identify and implement good practice across the waste supply chain, from the point of waste arising on project sites through to the delivery of quality materials at the re-processing facilities.

Methods for recovering and recycling inert wastes (such as aggregates, soils and concrete) are well-established in the UK. However, despite the introduction of various regulatory and fiscal measures, the volume of non-inert[2] waste (such as cardboard and plastic packaging, plastic products, wood, insulation, ferrous and non-ferrous metals, ceramic materials and bio-organics) disposed to landfill remains high.

This report describes the findings of a review which focused on a key element of the supply chain – namely the contribution made by MRFs[3]. With its sophisticated manual and automated segregation systems, the MRF is a recent arrival on the waste management scene. In the past, beyond some limited recovery of aggregate and metal, waste management companies serving C&D customers would simply consolidate waste at a site prior to disposal to landfill. Today, the high cost of landfill and increased markets for recyclates have incentivised the recovery of a wider volume and variety of materials. The Construction Commitments: Halving Waste to Landfill initiative will further drive improvement in the MRF process.

Carried out by consultants Oakdene Hollins Ltd, the review sought to identify - and to encourage MRF operators to adopt - good practice in the recovery, handling and sorting of non-inert C&D waste materials.

1.2 Structure of the report

After an outline of the methods used in the study (Section 1.3), and an introduction to the C&D MRF process (Section 2.0), this report highlights good practice in the way MRF operators work with their waste suppliers (Section 3.0), and move the material through their plant (Section 4.0). Sections 5.0 and 6.0 describe approaches to getting the best out of people and automated sorting systems, while Section 7.7.0 covers the management and onward movement of material outputs from the facility. The report concludes with ways to reduce environmental impacts and health and safety risks at a C&D MRF (Section 8.0).

Four stand-alone case studies are included which describe:

- the findings of an industry stakeholder workshop run by WRAP;
- ways to motivate staff;
- a MRF which is investing heavily in automation; and
- good practice in the Netherlands.

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[2] *The term 'active waste' is also used to describe non-inert arisings since they decay in landfills or contaminate land.*

[3] *Not all the companies visited classified themselves as 'MRFs'. Some felt the term was more appropriately used to describe a facility designed for processing a limited range of household recyclables rather than all types of waste arising at C&D sites. However, this opinion was held by a minority of informants and this report uses the word MRF in the latter sense. Note, that many of the findings here apply also to waste transfer stations, since the distinction between these and MRFs is increasingly blurred. In the past, WTSs were used solely to consolidate waste material prior to onward movement (originally to landfill), but today many of the recovery processes occurring at MRFs are also performed by WTSs. Similarly, several MRFs visited for this study also included areas where additional waste was bulked-up, baled and moved on without specific material recovery.*

1.3 Methodology and scope

In carrying out the review, an initial database of over 600 UK MRFs and waste transfer stations (WTSs) was compiled using information supplied by the countries' regulatory authorities (EA, SEPA and NIEA). The database obtained was a listing of all MRFs taking municipal, commercial/industrial (C&I), and construction/demolition (C&D) waste. In the C&D sector, it did not distinguish sites processing exclusively non-inert C&D waste from those handling only the inert fractions of construction waste. Nevertheless, from the database and from supplementary information obtained from Oakdene Hollins' and WRAP's industry contacts, a list was drawn up of 18 UK sites thought likely to demonstrate good practice in part or all of their operations. This list is designed to reflect conditions in different regions of the country with varying local waste arisings, disposal routes and other factors. MRFs in both urban and rural settings were selected since operations and profitability are affected by the proximity and cost of landfill. It was not possible to visit all C&D MRFs in the UK during our study, and we recognise that good practice in C&D MRF operations will also exist in many sites we were unable to visit.

Between November 2008 and March 2009, fifteen of the shortlisted UK MRFs were visited, and phone interviews conducted with a further three. To gain a wider European perspective, visits were also made to three C&D MRFs in the Netherlands - a country considered advanced in its treatment of C&D waste.

Information was also gathered through telephone interviews with technology manufacturers or suppliers including Komptech UK Ltd, General Kinematics, FTL Engineering Systems Ltd and Lindner-Recyclingtech GmbH. Information on regional differences in waste management regulation was provided by contacts at the Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment Agency (NIEA). Information on the requirements for refuse-derived fuel (RDF) was supplied by Fibre Fuel Ltd and ITI Energy Ltd.

Additional insights were gained from two workshops organised by WRAP attended by representatives of the waste management and construction industries.

All elements of good practice in the MRF operation were considered. These ranged from contractual and logistical relationships with both the MRF feedstock suppliers (i.e. construction and demolition contractors and their clients) and material re-processing customers (e.g. paper mills, scrap metal and plastics recyclers), to the operational elements of receiving, storage, processing and delivering quality recyclates to the re-processors. The use of management systems, advanced technology, automatic versus manual sorting, and human resources policies were also reviewed.

Clearly, what constitutes 'good practice' is subjective; opinions within industry differ as to whether a particular practice is good or not. Examples of the latter, where divergent views were offered during our study, are the pre-sorting of waste at construction sites and the use of automation in preference to manual picking. For the purpose of this report we focussed on those practices that appeared, directly or indirectly, to deliver recovery of greater ratios or higher value of recyclates to the re-processors, or which achieve improved social responsibility (particularly environmental impacts and health and safety benefits) in their operations. Where opinions of operators on any specific practice seemed polarised, the report sets out both arguments for and against adopting that practice.

While certain elements of good practice were exhibited by all the sites visited, none were thought to be exemplars in all aspects. For this reason the current report does not focus on any specific sites but rather highlights elements of good practice identified from all the MRFs visited.

1.4 Site visits and interviews

As noted above, from the target list of C&D MRFs drawn up, visits were conducted to 15 sites in the UK:

- **Ahern Waste Management Services**, West Thurrock, Essex;
- **Commercial Recycling**, Wimborne, Dorset;
- **Eastern Waste Disposal**, Brightlingsea, Essex;
- **Ethos Recycling**, Uxbridge, Middlesex;
- **JBT Waste Services,** Bedlington, Northumberland;
- **M & M**, Oxford;
- **Malcolm Construction Services,** Glasgow;
- **McGraths**, London;
- **Nick Brookes**, Wardle, Cheshire;

- **Pearsons**, Thetford, Norfolk;
- **Powerday**, London;
- **Premier Waste**, Birmingham;
- **Shanks,** Kettering, Northamptonshire;
- **Smiths**, Gloucester; and
- **William Tracey**, Glasgow.

Phone interviews were conducted with:

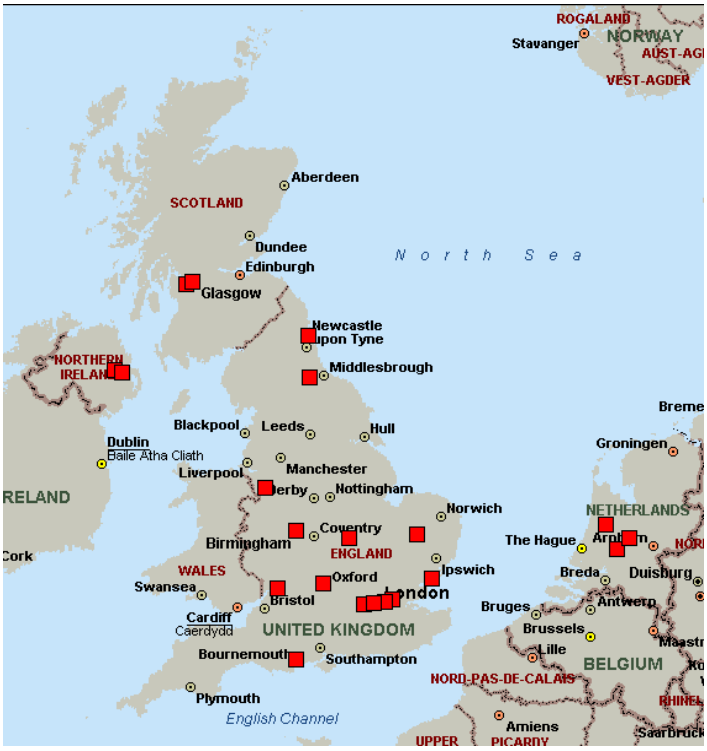
- **John Wade Group,** Darlington, Co. Durham;
- **Irish Recycling Services**, Belfast;
- **McKinstry Skip Hire**, Crumlin, Co Antrim.

Three further sites in the Netherlands run by Shanks Waste Management Group were visited, providing a Continental perspective:

- **Icova B.V.,** Amsterdam;
- **Smink Groep**, Amersfoort; and
- **Van Vliet Groep**, Nieuwegein.

Appendix 1 lists contact details for all MRFs visited, whose locations are illustrated in Figure 1.

Figure 1 Distribution of C&D MRFs visited or interviewed for this study



These sites represented a cross-section of the industry. Where data were available, annual waste volumes processed ranged from 30,000 to 500,000 tonnes; recovery rates from 75% to 98%; numbers of manual pickers from 7 to 22; and sorting speeds from 20 to 67 tonnes per hour. The smallest MRF visited had an estimated floor space of just 5,500m^2, the largest covered 22,000m^2. Plants were located in both cities and rural areas, and the radius served varied between 24 and 120km. Some facilities processed waste around the clock, all year, while others operated for only 53 hours per week.

Each site visit consisted of a semi-structured interview (see Appendix 2 for a list of topics covered), followed by a tour of the facility, preferably while in operation. Photographs were taken with permission.

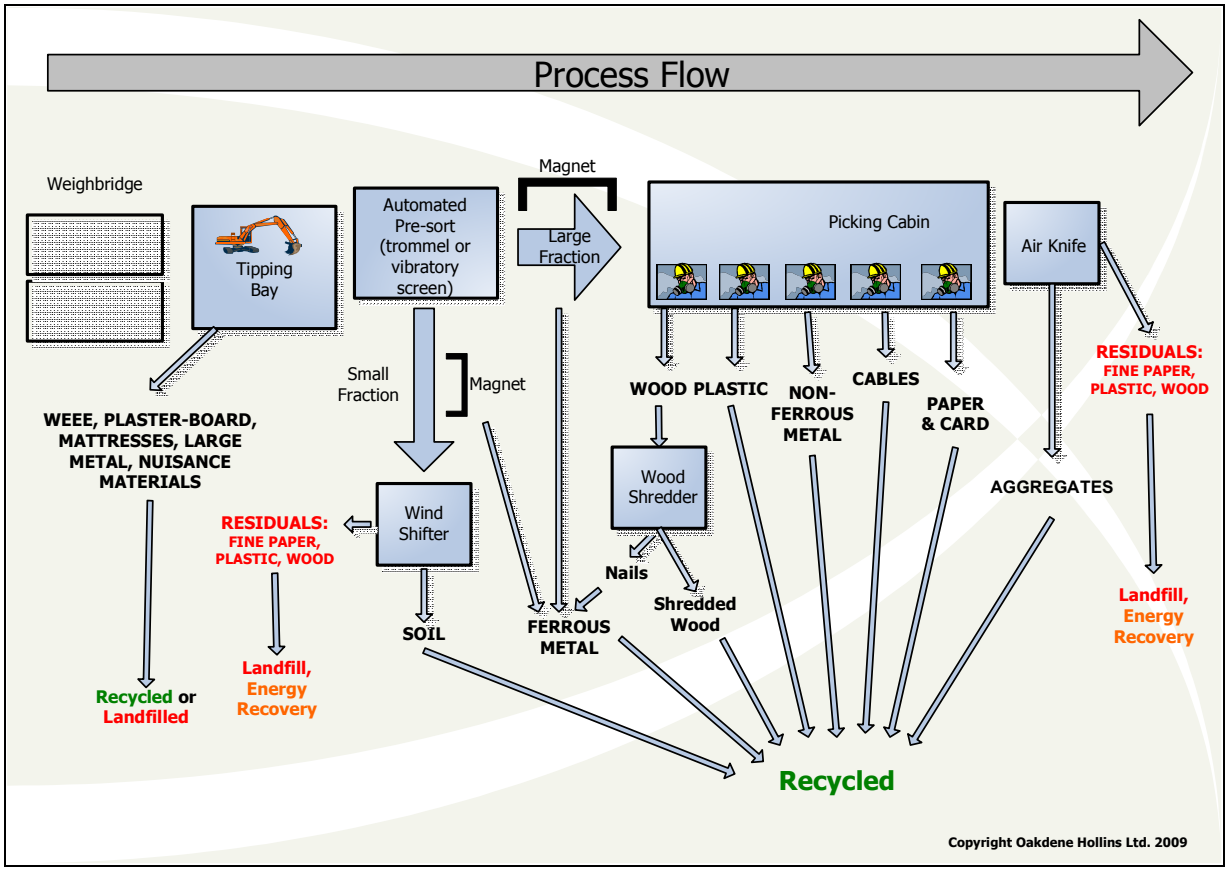
2.0 Introduction to the C&D MRF process

2.1 The typical MRF

This section outlines the typical methods by which construction and demolition wastes are accepted and processed, and recovered materials moved on, by Materials Recovery Facilities.

Every C&D MRF differs in its particular layout and combination of manual and automated sorting processes. However, Figure 2 illustrates the typical sequence in which output materials are recovered.

Figure 2 The typical C&D MRF process



2.2 Acceptance of C&D waste onto the MRF site

Waste from construction and demolition sites is usually transported by road to the MRF. Some operators accept waste by rail, canal, or both (Figure 3). One site estimates for the period of one job, its rail-link to a reprocessor site every day saved some 80 truck journeys of 67 miles.

Figure 3 Canal and rail links at a MRF

For convenience, we refer to skips only from this point, although MRF operators will hire out a range of other waste containers including domestic-sized wheelie-bins, eurobins, roll-on-roll-off skips (ROROs), grab bags, sacks, grab lorries, and bulker lorries.

At the weighbridge (Figure 4) the gross weight of the skip-truck is measured. The skip-truck driver also hands over a Duty of Care note to the weighbridge office detailing the type of waste using a 6-digit code from the List of Waste, a categorisation system which has replaced the European Waste Catalogue (EWC). Duty of Care notes require both the waste producer and receiver to demonstrate awareness of the quantity and type of waste being transported and transferred[4]. This information is communicated by two-way radio to staff in the tipping area, for verification. The skip is emptied and the truck exits the site, again via the weighbridge in order to calculate the net weight of material tipped. The driver is also given a ticket stating this figure. Data on weight and LOW code are used to generate invoices.

Figure 4 A weighbridge

[4]Defra is planning to lead a full review of the code of practice governing Duty of Care in England and Wales for Waste Carriers and Brokers in 2009. Any updates to the rules will be published first on the Defra website: www.defra.gov.uk/environment/waste/legislation/duty.htm. Further information on compliance is available at: http:// www.netregs.gov.uk/netregs/63197.aspx

2.3 Initial waste inspection and preparation

Waste pre-sorted at the construction site can bypass the MRF's normal processes and be directly tipped into the appropriate bulk storage bay ready for transfer to a bulk container for onward shipment to the re-processor, provided it is of suitable quality and is in a collection container that facilitates efficient handling.

Mixed wastes will be tipped into an area for subsequent loading into the processing line (Figure 5). In this tipping area, any materials unsuitable for the general MRF process are removed for separate management. These include hazardous materials such as asbestos, oils, contaminated soils, chemicals, waste electrical and electronic equipment (WEEE), batteries, and treated wood, as well as gypsum-containing materials, and awkward items such as doors and mattresses (Figure 6).

Figure 5 A recently tipped skip

By law, the MRF operator should be made aware of any hazardous waste coming to the plant before it leaves the C&D site. The relevant environmental licensing authority (i.e. EA in England & Wales, SEPA in Scotland, NIEA in Northern Ireland) should be informed that the MRF operator will be placing a skip for hazardous waste on the C&D site – and the MRF operator must allow sufficient time for the regulatory body to process the paperwork before collecting and processing the waste. If the hazardous waste arrives unexpectedly onto the MRF site and the operator does not have a licence for dealing with this, then it should be returned directly to the customer unless there is a suspicion that the waste may be disposed of illegally. If the MRF accepts the material, it must store it appropriately in a quarantine area, inform the regulatory body as above and may need to charge the customer accordingly. Any onward movement will again require paperwork. Further information can be obtained by phoning, or consulting the website of, the appropriate regulatory authority (i.e. EA, SEPA or NIEA).

Figure 6 Hazardous and awkward wastes recovered from tipping areas not put entered into the MRF

L to R: WEEE, hazardous treated wood, mixed 'awkward' material

Polythene film tends to jam rotating machinery or wrap around waste and is best removed here too, as are pieces of ferrous metal too large to be recovered by magnets. Materials which in combination with others may be difficult to separate later (for example, metal often sticks into cardboard) are also recovered during the pre-sort.

In highly automated facilities, mixed waste may be crushed or shredded to facilitate the work of recovery equipment. However, shredding will cross-contaminate materials and also reduces the efficiency of hand-picking so is generally avoided in less automated plants.

In order to reduce cross-contamination, one MRF visited had been split into two separate lines: one half designed for processing lighter materials such as paper and plastic, and the other heavy materials such as soil and hardcore. This was argued to be the single most effective way of ensuring quality of output materials.

2.4 Up-front automated screening process

After the initial sort, a mechanical grab operator loads the waste either directly or via a conveyor belt into an up-front screening machine. The trommel is the most commonly used screening technology (Figure 7), although vibratory screens or disk screens may be used instead of, or in conjunction with, trommels.

Figure 7 Trommels are commonly used as pre-sort equipment at C&D MRFs

The initial automated pre-sort recovers soil and other fine material which account for a large proportion of the input stream's weight. The waste, which will have been compacted in the skips and other containers during delivery, is also loosened up and aerated in the screening process. Two or more fractions are separated on the basis of particle size, shape or weight. Fine waste, sometimes known as the 'unders' stream, falls through (Figure 8), while oversized waste continues on the line. Both material streams may be first introduced onto a hopper spreading the material on the conveyor belt, thereby facilitating subsequent sorting processes.

Figure 8 The unders fraction from a trommel

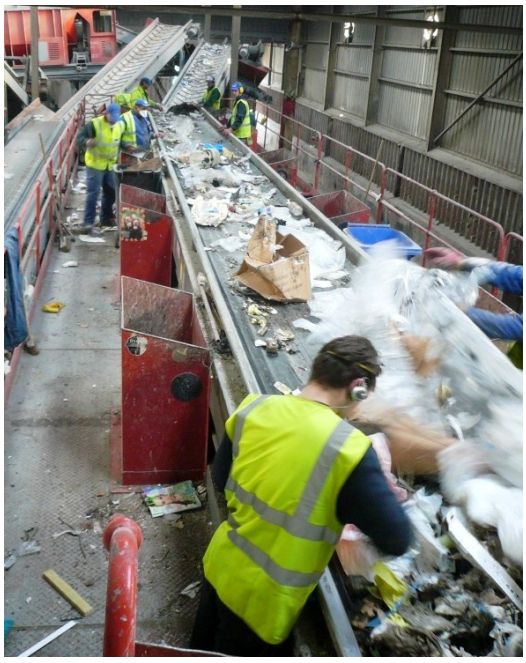
2.5 Material recovery from the undersized fraction

The unders stream sometimes enters a picking cabin (see Section 2.6), but more often undergoes additional automated processes: magnets remove small pieces of metal, while wind-shifters or density-separators (sometimes called lights separation units or LSUs) blow or suck to recover small pieces of paper, plastic film and wood. Until recently, this material - known as fluff or flock - was simply landfilled, but MRF operators now send it for composting or convert it to RDF (refuse-derived fuel) (see Section 7.5). The cleaned-up soil and fine aggregate remaining may undergo further processing. This material is typically used for land restoration purposes.

2.6 The picking cabin

The large fraction emerging from the pre-sort screen often passes under an overband magnet, which pulls off small pieces of ferrous metal, and then approaches the picking cabin (Figure 9). Most plants still rely on manual labour for recovering non-inert recyclates. Pickers pull off various types of rigid and film plastic (e.g. HDPE, LDPE, PP, PET, and uPVC), non-ferrous metal (e.g. copper, lead, brass and aluminium), cables and wires, paper, card and wood. The latter is frequently divided into A and B grades. Ferrous metal not removed by previous magnets is also picked off. Each recovered material is dropped down chutes into separate bays located below the picking shed, for onward movement. Any oversized objects or non-recyclables such as insulation foam, polythene sheets, batteries and WEEE missed in the tipping area are also removed in the picking cabin. Glass and textiles are sometimes also removed here. Most picking cabins have a 'waste' chute for material whose recycling is uneconomic, such as polystyrene or contaminated items.

Figure 9 Picking station



Most of the material passing untouched through the picking cabin is aggregate – although in some facilities manual pickers may even take off this material. An air-knife removes fine pieces of paper, plastic and wood from the aggregate as the latter drops off the line. This flock, typically blown into a cage, was once landfilled but, as described above, MRFs may now send it for composting or energy recovery at incinerators and combined heat and power plants. The aggregate itself is crushed (perhaps using an 'in-line jaw crusher'), sieved and washed before being sold on for road-building and other uses.

2.7 Onward destinations for non-inert material recovered by MRFs

Little further processing is performed at the MRF on the recovered materials, although wood is normally shredded for ease of storage and transport. Any ferrous nails and screws embedded in the wood are recovered using magnets incorporated in the shredder and are sold on for recycling.

Today almost all non-inert outputs from a C&D MRF can be recycled or reused in some way. Depending on the material, the operator will either be paid or incur a cost for onward movement. All forms of ferrous and non-ferrous metal can be entered into closed-loop recycling, as can paper, cardboard and a growing range of plastic polymers. Recycling uPVC (often in the form of door and window frames) has traditionally been a problem, but a number of take-back schemes are now in operation, and the material can now be closed-loop recycled.

High quality timber (often in the form of old wooden pallets) is variously known by MRF operators as 'A grade wood', 'clean wood' or 'white wood' and commands a good price from re-processors who convert it to animal bedding, panelboard, or burn it as a biomass fuel. Which of these outlets is used depends on the location of the MRF; few panelboard makers operate in the south of England, so facilities based here tend not to use this option. 'B wood' such as treated or painted timber, chipboard and MDF is worth less but still has a value, again in biomass burning. Lower grade wood may also be composted along with green waste (i.e. leaves, branches and other vegetation) or used as a landfill cover if exemptions are applicable. One MRF is working with a waste management company trialling the use of lower quality wood as a road surfacing matting on landfill sites, as aggregates tend to sink into the waste. Whether this qualifies as recycling is debatable. A new process using microwave technology to recycle MDF waste into new MDF is currently being trialled[5]. However whether this would be suitable for re-processing treated, post-consumer MDF rather than factory offcuts is as yet unclear. In most - if not all - cases the wood will be shredded prior to onward movement to reduce transport costs.

Recycling low grade plastic and paper is a problem for C&D MRFs as they tend to be contaminated with cement and other building materials (Figure 10), particularly when collected with a mixed load.

Figure 10 Rigid plastic contaminated with cement

Sometimes the plastic can be sent to washing plants but this is unlikely to be cost-effective, thus materials such as these are normally sent to landfill. However, as discussed in Section 7.5, the emergence of a network of energy recovery facilities is providing a new outlet for low grade paper, wood and plastic: material previously landfilled. Depending on where in the country the MRF is located – and hence the local landfill rates – the use of energy from waste (EfW) facilities may be a more economic option, particularly as the cost of landfilling is rising with the Landfill Tax escalator. In Scotland and parts of northern England, however, landfill gate fees are still very low even with the rising tax, so the financial incentive to recycle low value materials or even to send them more than a certain distance for energy recovery may not yet exist here. One MRF company suggested that the cost of landfill in Scotland was lower because less waste was available and landfill operators were "fighting for tonnage".

Several companies are able to recycle plasterboard and gypsum-containing materials, and the sector is likely to grow now that that material will be banned from non-hazardous landfills in England, Wales and Northern Ireland (Section 3.8). The situation in Scotland is less clear as some MRF operators inform us that outlets are scarce in Scotland, and transport costs to re-processors south of the border are prohibitive.

[5] *This process was patented in 2004 by Microrelease Ltd, a subsidiary of Nviro Cleantech. More information is available at: http://www.nvirocleantech.com/our-portfolio/mdf-medium-density-fiber-recycling/*

Glass is a less common output from C&D MRFs, but where cullet is recovered the material tends to be used in aggregate applications, because closed-loop recycling requires colour separation of larger pieces of glass. As discussed in Section 3.8, ceramic material from tiles presents a problem for MRFs in that this can contain hazardous material, but some MRFs questioned revealed that this material was typically processed for use as an aggregate in the same way as glass.

Figure 11 Some non-inert C&D WASTE materials recovered by MRFs

Top L to R: plastic film, rigid plastic.
Middle L to R: cardboard, ferrous metals and copper.
Bottom L to R: A grade wood, B grade wood.

CASE STUDY: MRF operators workshop

At a meeting in December 2008, organised by WRAP, a number of MRF operators were invited to identify what they thought was 'good practice' in construction waste recovery. The following is a summary of the outcomes.

■ Advise the customer – the earlier the better

All delegates agreed that it is important to advise the customer about site waste practices at the beginning of a C&D project. The earlier this can be discussed, the better for both parties. One delegate kept an eye on planning applications in the area, even to the extent of writing to the architect and offering help with the planning application. This opens up opportunities to offer a greater range of services and to have a greater influence on site waste management arrangements if successful, thus ensuring a better quality of input material.

This early involvement is still rare, however. Waste operators rarely get called in at the design stage of a project and the introduction of Site Waste Management Plans (SWMPs) in April 2008 has had limited impact on this situation.

Methods of advising the customer included:

- A DVD of waste and recycling services offered;
- Visits to the MRF;
- Offers to assist with SWMP;
- Offers of on-site waste management staff (only practical on larger projects or with the larger blue chip companies). It was noted amongst the delegates that there had been little uptake of this offer, possibly due to the historic lack of trust in the waste management industry. As waste service suppliers become more professional, however, the general trust of the industry is growing. Membership of the Environmental Services Association's Recycling Registration Service (RRS) was seen as an additional important step in this direction, although the scheme is principally aimed at waste management companies handling and processing municipal recyclables for export to overseas re-processors; and
- Pre-project meeting to assist in waste management planning.

Services offered to the customer must adapt to the changing waste composition as a project moves from demolition through excavation, footings, build and fit-out.

■ Data reporting

Customer-specific, project-specific and material-specific recovery figures are increasingly requested by C&D customers. In practical terms these are only achievable by visually checking every load and recording the approximate mix of materials. An added benefit of this practice is the ability to alert customers to non-compliance issues as soon as they occur. It is possible, with large contracts, to stockpile waste from one source, empty the line, then run the line from the stockpile, although storage of material prior to processing can be an issue. This would give a complete data set which is specific to one project, if only on a sampling basis. All data should be weight-based (tonnes) rather than volumetric, such as the number of lifts of containers of specific volumes. The weight of each load is then taken from the weighbridge records at the receiving MRF or transfer station.

It was agreed amongst delegates that there should be no need to hide MRF performance data from the customers, as has been widespread in the past, since good MRF results have a positive public relations value and discourage the use of less responsible waste operators. Proactive companies which respond quickly to clients needs have a competitive advantage.

■ Requests to supply on-site mobile plant

Mobile compaction plant is sometimes requested in order to minimise space requirements for waste containers on site. It was agreed that this should be carefully considered because of the risk of misuse, particularly by filling with heavy or unsuitable material, which may be hidden at the point of collection and which can damage the MRF plant, and subsequent potential health and safety risks that may be present to MRF operatives. However, for larger projects, on-site treatment plant (such as shredders, crushers and trommels) is sometimes requested and this is provided.

Control of feedstock and avoidance of unsuitable wastes

The use of the waste contractor's own fleet was preferred since this provides better control of the quality of feedstock. Also it was felt that, if third party transport is used, the waste may be 'skimmed' of valuable recyclates prior to delivery to the MRF. It was agreed that it is important to develop a good working relationship with clients to encourage better communications and result in better control of the waste material.

MRF size

Although the larger the MRF, the greater is the opportunity for investment in processing equipment, MRF size is largely controlled by the site location and the type of wastes available. The availability of land is an issue – MRF operators always want more space, especially when stockpiling of recyclates is necessary.

Processing and technology

The general consensus amongst the delegates was that there needs to be a mixture of automation and manual sorting in any process layout. One operator argued that "you cannot do away with the picking cabin manual sorting process if you wish to obtain a high quality material output".

Pre-sorting or 'quality picking' is vital at the tipping stage, to remove problem items such as mattresses, canisters, and large plastic film, and to minimise the contamination of sensitive materials. Separate collection may be better for some of these materials. Delegates present at the workshop did not use manual pre-sorting, primarily for safety reasons, arguing that an experienced mechanical grab operator can identify and safely remove even the smallest of unsuitable items from the tipping floor.

Other comments

- The use of large balers provides the opportunity for higher per tonne sales values of material outputs.
- It is important to design the sorting plant to be flexible and to permit adaptations to handle changing waste composition. The use of purpose-built equipment to match one's own waste types may be achieved by taking off-the-shelf machines and modifying them.
- Good maintenance, both planned and preventative, is vital.
- An on-site engineer is valuable, but should be supplemented by local third party engineering service operators who are able to respond at short notice to emergencies.
- Do not attempt too much integration of recycling or re-processing facilities for non-inert materials within the MRF. "Stick with what you are good at." The exceptions to this are that consideration may be given to installing on-site thermal treatment (EfW) plant, plastic and paper segregation, and size-reduction of rigid plastics.

Look after your employees

The need to train and develop staff at all levels, in order to motivate and retain them, was universally agreed. Currently, it was felt, there is too much reliance on "transient" and agency labour at floor level. The use of financial incentive schemes, however, was not universal amongst MRF operators. One delegate paid a quarterly bonus based on the value of the scrap metal sold. The bonus is lost when the value falls. Another operator was working on a MRF-wide bonus scheme based on overall quality and throughput. Such schemes were said to stop employees taking materials of value. Some driver bonus schemes are in place which reward (or penalise) the drivers for good (or bad) control of waste collections.

Optimum flexibility of staff is achieved through training and the setting up of skills matrices so that, ideally, everyone can do every job at the site.

Clearly, good working conditions were favoured including:

- Comfortable cabin conditions for manual pickers;
- All operations being carried out under cover; and
- The use of dust suppression such as odorised misting systems.

Other 'good practice'

Develop good relations with material processors and manufacturing organisations. Evidence suggests they will maintain off-take in difficult times, if at all possible, in return for trusted quality.

Develop good relations with local residents; especially important in urban locations. This may be achieved by a combination of such activities as secure/acoustic fencing, odour control, noise control, open days, community talks and control of lorry movements.

3.0 Managing supplies

This section explores some approaches by which MRF operators can manage suppliers of waste – and thus control the waste itself.

3.1 Meeting the supplier's requirements

MRF operators should be prepared to offer C&D customers a wide range of services. Until recently, customers were merely interested in a competitive skip hire rate and compliance with environmental regulations. Today, many C&D customers - especially the larger ones - expect a more comprehensive service from their waste management contractors including project-specific and material-specific recovery rates and breakdowns of the fate of all waste processed. Indeed, some C&D contractors or their clients now audit waste management systems. This occurs both at the tendering phase, where environmental and data reporting issues may influence the award of a waste management contract, or during the construction project itself, to ensure compliance with promised performance. Whilst only top-level data are required by Site Waste Management Plans, more detailed reporting as outlined above can be inputted into resource efficiency tools such as SMARTWaste Plan (developed by BRE) and WRAP's NetWaste Tool. Many of the MRF companies visited for this study were asked by their customers to provide this level of detail – although the accuracy of the figures supplied has been called into question by some. In extreme cases, MRFs were prepared to run client's waste separately through the plant and weigh each output stream in order to gain accurate information on material-specific recovery rates. WRAP developed, trialled and launched the Site Specific Waste Assessment Tool (SSWAT) a new measurement method for MRF operators to calculate consignment-specific recovery rates. This is freely available on the WRAP website under www.wrap.org.uk/constructionmrf.

3.2 'Know your waste'

This piece of advice was frequently offered by informants to the study. Construction and demolition waste is diverse. The material varies in density, shape, stickiness, water content, chemical composition and many other properties each influencing the recovery processes. To maximise recovery, C&D MRF operators must be aware of exactly what is brought onto the site. This is straightforward where a regular business relationship exists with the constructor and where the MRF operator's own drivers are used and are fully trained in waste acceptance criteria.

Additional scrutiny of incoming waste from third-party tippers (such as independent skip hire companies) is required, as this may result in unfamiliar material entering the site. Where such waste is accepted, often from local companies with whom the MRF operator has a long business relationship, skips should be tipped immediately and contents scrutinised for non-compliance with the site licence or discrepancies with the Waste Transfer Note.

The process of getting to know waste should start early in the supply chain. MRF operators could consider scrutinising building projects at the tendering stage and even at the planning stages. New C&D sites should be visited to assess likely waste materials – and to ascertain the likely sequence in which different waste types will arise. As discussed above, various tools and methodologies, such as the NetWaste Tool and the SMARTWaste Plan have been developed to predict the type and volume of waste materials likely to arise at each phase of a building project[6].

Several MRF managers second their own staff to larger C&D sites to advise clients on waste and recycling issues, to oversee disposal into skips, and to prepare waste for optimal sorting at the MRF. Weight analyses of skips are sometimes performed at the C&D site. These services may either be offered free or along with equipment hire as part of a total waste management package.

The MRF operator should prepare for waste arisings to vary with the season. One informant estimates that levels of waste fluctuate over a 30% range through the year. Peak periods include spring and summer; C&D activity is reduced in winter and this is a good time to implement significant changes to MRF systems or equipment.

3.3 Source-segregation vs. mixing waste

Source-segregation of C&D waste prior to disposal is growing in the UK. Not only does this reduce waste disposal costs and benefit the environment, but segregation schemes often result in a more orderly site, safer working

[6] *http://www.wrap.org.uk/construction/tools_and_guidance/index.html*

conditions, and an enhanced company reputation[7]. Materials typically segregated include wood, plasterboard, brick and rubble. Skips may also be provided for mixed light recyclables such as paper, card and plastic and for rigid plastics such as uPVC window and door frames. Where material-dedicated skips are used properly the recovery process is made easier, and costs to both customer and MRF operator are accordingly reduced. For example, one MRF operator charges waste producers a flat transport fee of £65 with an additional £57 per tonne disposal cost for mixed 8-yard skips. For source-segregated skips, the disposal costs charged to customer are far lower. For higher value materials (e.g. scrap metal) the disposal cost is negative; in other words, the MRF will effectively offer the producer a rebate on the £65 per skip transport cost. The same MRF operator reports that the average weight of waste in a mixed 8-yard skip is around 4.5 tonnes, while source-segregated materials weigh on average 1.5 tonnes. Clearly, waste producers hiring skips from this company benefit enormously by avoiding the use of mixed waste skips.

Figure 12 A mixed skip in London

In urban settings or in high-rise projects, where space is limited, it may be practical only to provide one skip (Figure 12). However, one MRF operator reports that even in a one-house-build project, source segregation is still economic. In confined situations alternative container solutions such as builders' bags[8] or wheelie-bins could be considered. In this system, a simple colour coding scheme, backed up by icon labels, should be applied to optimise waste segregation and help with communication with the receiving WMC and staff at collection point.

Policing single-material skips to prevent contamination is vital because the latter leads to increased expense for C&D customers charged the higher price of a mixed skip. One MRF company informs us that if contamination of a source-segregated skip exceeds 5% they give the waste producer a verbal warning (accompanied by supporting photographic evidence). If the non-conformities continue, the higher costs are levied. The same MRF reports that of the roughly 200 containers processed daily, around six present 'quality issues'.

It is not clear whether anecdotes such as these were related from a vested interest, in that MRF operators could lose out financially if most of their customers switched to source-segregation. Several interviewees commented: "We are the waste experts so leave the sorting to us."

[7] *TRADA Technology. 2004. Research information. Saving on waste disposal – through waste segregation in construction. A timber waste management case study – Construction.*

[8] *WRAP has recently commissioned trials into the use of using builders' bags for collection of packaging waste. The bags are transported to the MRF and removed separately.*

3.4 Customer education and training

MRF operators themselves benefit when they educate and train their waste suppliers and other stakeholders in the proper way to present material. For example, the financial (and environmental) cost of not using source-segregated skips should be made clear to the C&D client. Several MRFs interviewed encourage C&D customers to visit their site in order to understand the requirements of the material recovery processes. They also hold workshops or give talks in the community, and a few have invested in on-site education centres, and training or marketing suites. In one case, the MRF operator nominates a 'green champion' on each construction site and rewards good quality waste management with a monthly box of chocolates or crate of beer. It was reported that these apparently simple measures could increase C&D site waste recovery rates by up to 25%. Unfortunately, in other cases where the 'recycling culture' is not embedded in the C&D workforce, even financial incentives may not have the desired effect. For example, an interviewee described how, despite the potential to personally gain up to £400 per week for excluding non-inert materials from aggregates-dedicated skips, one foreman was still failing to achieve this. Another MRF operator highlighted the case of a single large construction customer who failed to police source-segregated skips properly at fourteen of its fifteen sites.

3.5 Reuse and remanufacture

Strictly speaking, once something has been discarded it should be regarded and treated as waste. However, in practice, if an item can be directly reused in its current form (without re-processing) with minimal risk to human health or the environment then scope for reuse or remanufacture exists. The MRF operator should thus use common sense and still follow proper duty of care.

Where possible, opportunities for reuse and remanufacture should be assessed at the C&D site, particularly on large demolition projects. Networks are now well established[9] for many types of end-of-life products including material from C&D projects. Once waste arrives at a MRF, objects can also sometimes be recovered for reuse or salvage as long as site safety is not comprised. MRFs report salvage of items such as Belfast sinks, fireplaces, culverts and walling stone. It may sometimes be possible to donate items to charities[10]. The most appropriate stage at which to extract materials is during the pre-sort where the mechanical grab can pick out materials. For obvious reasons employees should avoid rummaging by hand through piles of tipped waste. A dedicated, covered bay for salvage should be assigned away from machinery or moving vehicles. Certain items may not be suitable for reuse or remanufacture; for example, chairs may be weak and could collapse exposing the MRF operator to litigation. Old fire-doors and other safety equipment cannot be reused as such for similar reasons.

3.6 Generating business

MRF operators suggested ways to sustain and grow business in an unstable economic climate. Although repeat business may comprise a significant proportion of a MRF's turnover - 70% in one case – MRFs are increasingly required to take a more active approach and perhaps look further afield for custom.

Interviewees discussed new ways to generate business such as employing sales people, re-branding the company image, and creating a high quality website. An increasing number of MRF operators are signing up to The Construction Commitments: Halving Waste to Landfill which sends a positive message to would-be customers that the waste company is not a 'cowboy', but is serious with regard to responsible waste recovery.

An obvious step is setting the cost of using a MRF at a level competitive with other MRFs and alternative disposal routes including landfill. This cost may simply be in the form of a gate fee, or subsumed within the skip hire price.

In return for exclusive access to waste, some MRFs in competitive environments offer their customers loyalty discounts. With the provisos outlined above, MRF operators should aim to accept as wide a range of wastes as possible under their licence, but equally be prepared to walk away from a job when necessary. At all times, the MRF has to be able to control and manage the waste effectively.

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[9] For more information visit www.remanufacturing.org.uk - the website of the Defra-funded Centre for Remanufacturing and Reuse.

[10] In England & Wales, the Environment Agency has published a list of waste exemptions for storage and handling materials due for recovery, and even where an exemption does not currently exist, the EA may sometimes apply a 'low risk ' position – for example, on furniture or clothing. More information is available at: http://www.environment-agency.gov.uk/business/topics/waste/32080.aspx.

MRF operators should seek a wide range of C&D clients, but a few reveal that business was being sustained during economic downturn thanks to relationships with a few large social housing firms. Public sector construction is perhaps more immune to poor economic conditions than is the private sector.

In rural or isolated areas of the UK where transport costs become a limiting factor, some MRF operators use drawbar trailers which can fit up to six skips on the same vehicle. This increases the geographic area that can be economically served. Similarly, drawbar trailers can increase the range that outputs can be transported for re-processing. For example, one MRF operator will use drawbar trailers when needing to move recovered wood further than 20 miles. Many waste management companies establish satellite transfer cabins to consolidate waste from a wide area before onward transport to the MRF. As a last resort, MRF operators can also use the services of fully-vetted third party skip companies to further their reach. A number of the larger MRF companies visited have expanded by acquiring skip hire companies in their region allowing them to increase coverage while remaining in control of their waste.

Transparency in the onward destination, and the sale price, of output materials can also help MRFs attract business, especially from higher profile customers such as blue-chip construction firms. If economically viable for the MRF, the output revenues may be shared with customers although this tends to be more common in municipal MRFs where the outputs are generally of a higher value. One MRF, which accepted household recyclates as well as C&D arisings, offered its Local Authority customers rebates linked to materials prices published on websites such as www.letsrecyle.com. The same company also offered a rebate based on metal sales to a nationwide retailer whose waste it processed. Openness in terms of other MRF expenses such as transport and management fees is also important.

3.7 Recovery rate measurement and reporting

All the MRFs visited provide waste producers with average site-wide material recovery rates calculated on a monthly basis. However, new customers can be attracted by offering, at little or no cost, data on the recovery rates for each skip load tipped. One MRF questioned revealed that on request, and on a sampling basis only, they would tip the contents of several skips onto the MRF floor, segregate each waste material manually, and individually weigh the fractions in order to provide a breakdown. The new SSWAT can provide consistency in measuring and reporting particularly with mixed waste consignments. Clearly this process is time-consuming but, according to the MRF, is worth doing to provide the customer with a snapshot of their waste profile. This type of service is of particular value to larger waste producers in England because for any project exceeding £300,000 in value a Site Waste Management Plan has been a legal requirement since April 2008. SWMPs are still voluntary in Wales, Scotland and Northern Ireland but may become mandatory in the near future.

For the same reason, MRF operators should look at implementing formal management systems such as ISO 9001 (quality management), ISO 14001 (environmental management) and OHSAS 18001 (health and safety). These internationally-recognised standards are increasingly called for when tendering for work with larger waste producers, particularly those in the public sector. However, putting these systems into place is time-consuming, and operators need confidence that customers will require them. Several larger MRF operators questioned nevertheless saw value in the systems for improving their own day-to-day activities, especially as their management structures became larger and more complex.

Reported recovery rates ranged from 75% to 98%. A significant barrier to maximising landfill diversion was a lack of storage space – particularly a problem during the economic downturn where many MRFs are being forced to landfill certain output materials rather than hold out for a good market price. Several operators wanted to expand the size of their facility but were facing planning constraints. Another barrier to 100% diversion cited by informants was the lack of nearby EfW plants to accept the residual waste, and even when the latter were available, MRFs struggled to provide fuel of sufficiently acceptable quality. A lack of funds for capital expenditure on new equipment – especially in an economic downturn - was also cited as a barrier to maximising recovery rates. Even with its rising cost, many MRF operators still feel forced to dispose of significant volumes of material to landfill.

3.8 Problem materials

Certain materials arising from C&D activity pose particular difficulties for MRF operators, and justify careful visual inspection of every incoming load, regardless of origin. Special processes and licences are required for managing hazardous materials including WEEE, asbestos, gas bottles, clinical waste, and incineration residues (Figure 13).

Figure 13 Storage area for hazardous waste

Plasterboard and other gypsum-containing material frequently arise from C&D projects and, although not classed as hazardous (unless contaminated with hazardous material), are a particular issue for the MRF operator. Proper disposal has in recent years caused some confusion in England and Wales. With the April 2009 revision to the Environment Agency position on waste plasterboard management, waste managers will now be required to recycle all gypsum materials or send it to dedicated mono-cells at landfills where it cannot mix with biodegradable waste. Up until the April 2009 revision, small concentrations of the material were permitted to be disposed in ordinary landfills – the '10% rule'. Any gypsum-containing material delivered at the MRF must now be kept separate from other waste materials to prevent incorrect disposal, and it is in the interest of the MRF operator to require suppliers to collect gypsum waste separately on site. In England, several companies will recycle gypsum-based products, and plasterboard take-back schemes are operated UK-wide by manufacturers British Gypsum, Knauf Drywall and Lafarge Plasterboard. The '10% rule' still applies in Scotland, possibly due to a lack of outlets for plasterboard as reported by one Scottish MRF operator. MRFs in Northern Ireland apparently have more options since, according to one interviewee, a gypsum recycling company is present in the Province and several more are located south of the border in the Republic of Ireland. As in England and Wales, Northern Ireland has banned disposal of gypsum to non-hazardous landfill as of April 2009. Appendix 3 has further information on waste gypsum management. Apart from these regulatory issues, plasterboard is in itself an awkward material in that it easily breaks up releasing dust in the air and, in wet weather, forming a messy 'glue'.

Where doubt exists as to the nature of a material, MRF operators should err on the side of caution as they will need to prove to regulatory authorities that they are compliant with the stipulations of their site licence. If any non-conforming material does enter the MRF then the process must immediately be halted and the offending waste items removed, securely stored and passed on for appropriate processing. A record of the incident should be kept.

As discussed in Section 2.3, various non-hazardous materials also disrupt the smooth operation of a C&D MRF. Mattresses are a particular problem as their wiring can jam up machinery, as does polythene shrink-wrap, loose baling wire, and unravelling video cassette tape (Figure 14). These materials also wrap around recyclables obstructing effective manual or automatic recovery. When such articles enter the MRF, operators are forced to stop the line and resort to wire cutters and utility knives to remove the blockages - itself a hazardous process.

Figure 14 Video tape wrapped around trommel

Most, if not all, of the MRFs visited accept a proportion of commercial and industrial (C&I) waste such as office canteen waste and old packaging. In rural areas, plastic film associated with the food growing and processing industries can be a common waste stream and causes problems since packaging contaminated with food, especially meat products, needs to be treated separately under animal by-products regulations. The presence of biodegradable polymers in mixed plastic bales was also mentioned as a problem because the latter fall apart if stored for too long. Other problem materials include ceramic tiles (particularly fire-resistant ones which may contain hazardous ingredients), wet plaster bags and insulation (polystyrene and phenolic foams).

Of course, any material (e.g. low grade mixed plastic or mixed paper) whose recovery is not economic is also by definition a problem for MRFs, especially if no EfW plants are close by. Such materials are still being sent to landfill in substantial quantities.

4.0 Material flows

This section examines how at every stage MRF operators can process C&D waste to optimise material recovery and diversion from landfill.

4.1 At the C&D site

As discussed in Section 3.2, MRF operators should work closely with waste producers and where possible visit C&D projects in advance. Once the waste begins to arise, a series of checks should be performed verifying that material placed by waste producers into skips (or other containers) conforms to details entered on documentation. For example, consignments handled by one MRF are checked three times: first by the C&D customer, then by the skip-truck driver, and finally by personnel at the MRF itself. Any non-conformities can quickly be identified and information fed back to the customer for corrective action.

4.2 At the weighbridge

Although Duty of Care rules require both the waste producer and receiver to understand the type and quantity of material being transported, in practice the weighbridge is often the first opportunity the operator has to gain a full understanding of the material arriving on the site (Figure 15). This is because waste producers from C&D sites frequently mark the consignment as 'general waste' – EWC code 17.09.04. In many MRFs, site managers work in the same location as the weighbridge operator to have a direct overview of all incoming material. Regular communication, typically with two-way radios, between the weighbridge and personnel working in the MRF itself is crucial. Two-way radios should be provided to all vehicle operators for safety and general communication. Weighbridge staff who are given Waste Transfer Notes by skip drivers can inform colleagues in the waste receiving bay about incoming waste, and in return can be quickly alerted should non-conforming waste be tipped.

Figure 15 Skip-truck drives onto a MRF weighbridge

4.3 Initial management of waste

Before any skip-load is tipped, the MRF operator should assess whether or not the waste actually needs to pass through the MRF sorting line. Well-managed single material consignments from trusted sources, for example skips of wood or rubble, can be directly off-loaded in areas of the MRF where recovered material of this type is stored for further processing. Several MRFs visited had designated zones for 'white van waste', i.e. arisings from local builders which can be directly hand-sorted, thus by-passing the MRF. One plant directed any skip weighing more than 6 tonnes to a hardcore tipping area.

The mechanical grab operator is critical in ensuring a steady, manageable flow of waste into the MRF; the grab also breaks apart any bags containing waste. Once a skip or other container is tipped, the contents should be examined and pre-sorted, and if necessary any bulky objects which can cause blockages later on should be removed (Figure 16). Personnel should not work on the bay floor in front of the grab as this is dangerous. However, in one MRF visited, a safety protocol was strictly adhered to whereby a pre-sort operator was able to

safely remove, or identify for mechanical removal, unsuitable items in one tipping bay while the mechanical grab was loading waste from another bay onto the sorting line.

Figure 16 Mechanical grab driver pre-sorts C&D waste

Any non-conformities or hazardous contaminants of the type discussed in Section 3.8 should be immediately reported to the weighbridge and extra charges added to invoices when appropriate. Digital photographs should be taken, and if possible sites should operate CCTV, to gather corroborating evidence (Figure 17).

Figure 17 CCTV cameras over MRF weighbridge

Gypsum-containing materials and hazardous waste for which the operator has a licence but which is not suitable for recovery in the MRF process line (e.g. WEEE, batteries and used oil) should also be removed. As well as spotting non-compliance, the pre-sort facilitates the automatic and manual sorting processes which follow, and maximises the quality of outputs. Materials likely to cause hold-ups - such as polythene shrink-wrap and wires - should be removed here, as should doors and other items too cumbersome to recover by hand on the picking line.

In MRFs designed around manual sorting systems, initial size reduction of input materials using shredders or crushers was avoided as this would create more work for people in the picking cabin further down the line. One MRF decided to remove its shredder as it created fines which had then to be tested on a daily basis before being sent to landfill. By contrast, those operating highly automated processes less reliant on manual picking should consider coarse shredding or crushing, because sorting and recovery technologies typically perform better on a size-reduced waste stream. However, waste should not be crushed too finely as this can lead to cross-contamination of material. One technology provider recommends tearing or crushing material to about 300-400mm – a material size suitable for either manual or automatic processing.

4.4 Introducing material into the MRF process

On start-up of the MRF, the process should be switched on in reverse. In other words, automated or manual elements located at the end of the line should come on first, then the preceding stage and so on, until the point at which waste is loaded onto the line. This ensures that each stage of the MRF is ready to deal with the material as it starts flowing through the MRF. Some MRFs visited operate a traffic light system by which those working in the picking cabin communicate to the mechanical grab driver their readiness to receive material.

Double-handling of waste costs time and money, and should be avoided. For example, when loading waste into the first stage of the MRF, be it a trommel or vibratory screen, care must be taken to reduce spillage; in addition, conveyor belts should be bordered by walls or sheeting to prevent material dropping off the side.

Figure 18 Oversize and fines waste fractions sorted by a finger screen

4.5 Monitoring and optimising MRF performance

Bottle-necks in the MRF can be identified visually but, budget allowing, weight-sensing equipment should be installed at strategic points to provide a sophisticated analysis of bottle-necks. The data collected can track the performance of each stage of the MRF and of the process as a whole. The sensors should be sufficiently spaced to avoid false readings caused by long items such as planks triggering more than one. Most advanced facilities have control panels indicating where any blockages or machine shut downs have occurred. One MRF visited was using a computer-based management tool developed in the car industry to streamline its production process.

MRFs consume large amounts of energy. For example, some new plant being installed at one site visited will consume 240kVA[11]. For this reason, operators could try to cultivate good relationships with local producers and

[11] *Approximately the same rate of energy consumption as four family saloon cars*

where possible seek supply deals, especially with local EfW plants. Several MRF operators are planning their own on-site power generation systems, such as gasification, as a way of treating non-recyclable waste and saving on energy bills. Power factor correction is also worth considering. Capacitors convert out-of-phase electricity consumption into single phase reducing the effort required to drive the electricity around the plant. The choice of equipment determines energy use: for example, conveyor belts are a more energy-efficient way to transport material than compressed air systems.

5.0 People

Never underestimate the human factor. Even highly-automated facilities need a manual element to optimise the quality of outputs. This section suggests how to get the best out of site-based employees.

5.1 Hiring staff

Most MRFs visited emphasised the importance of hand-sorting in ensuring quality of the final product. Although machines are now able to distinguish between most types of material, humans are still more effective at extracting most objects from the waste flow. Even highly automated MRFs rely on manual picking for the recovery of awkward materials, such as larger metal objects or non-ferrous items like copper wire.

The use of agency staff or short term contracts was common, offering flexibility to the operator as material flow fluctuates. As discussed in Section 3.2, waste volumes can drop by 30% or more during winter. However, MRF operators should retain core staff to train and motivate temporary workers. These permanent employees should be trained to operate all equipment in the MRF in case of staff absence. Most MRF operators implemented a relatively flat management structure to maintain close control of the flows of material in the plant. It is recommended that each member of staff is trained to operate all machinery to offer flexibility and cover employee absences.

When recruiting senior staff, MRF operators should consider looking outside the waste industry. MRFs resemble production lines, so a manufacturing expert might get more out of staff and equipment than could someone from a waste background. The net should also be cast wide when seeking experts in health and safety. One MRF operator had hired someone unfamiliar to the waste management industry in order to bring a fresh perspective to potential hazards.

Figure 19 Loading shovel in action at a C&D MRF

5.2 Motivating and training staff

Keeping picking staff motivated in what can be a mundane job is vital for maximising material recovery. MRF operators should take trouble to ensure the working environment is well-lit, comfortable and safe (Figure 20). The installation of dust extractors, and air conditioning and heating units is recommended. Many MRFs had sound systems to keep workers entertained, and a few provide excellent quality canteens and changing rooms. Regular breaks are also important, and where appropriate staff should be rotated between tasks.

Although exceptions to the rule, several MRF operators visited for the study used financial incentives to motivate picking staff and other employees such as drivers and maintenance workers. One plant offered pickers a £4 bonus for every tonne of wood recovered, while another linked the bonuses of all employees to the total value of recovered output materials. One site paid workers a small Christmas bonus based on the annual recovery of non-

ferrous metals. Some sites penalise drivers who accept non-conforming waste consignments from C&D sites. The schemes should be designed so that recent recruits cannot earn more than more established employees as this can be divisive. One approach may be to reward loyalty in the picking cabin by moving pickers from lower to higher value output materials, linking pay to the respective output revenues. The schemes should also be managed so that employees do not simply 'chase their bonus' to the detriment of fulfilling other key aspects of their job such as equipment maintenance. It was suggested that materials-related bonus schemes could be unfair since prices for, and tonnages of, certain materials could not be guaranteed.

Many MRF operators report good results from investing in staff training; one received funding from the local Learning and Skills Council. Another stressed how import it is that all staff are aware of the financial implications of making mistakes with waste, and ran 'toolbox talks' on new equipment and output quality control.

Figure 20 A picking cabin

5.3 Monitoring staff performance

The other side of the coin is ensuring pickers - and other employees - are working efficiently and safely, since labour is normally the largest running cost for a MRF. CCTV systems in picking cabins and in-vehicle tracking devices are widely installed to monitor staff activity. These trackers have sometimes enabled the recovery of stolen trucks. Practice shows that although initially unhappy to accept these measures, skip-truck drivers tend to get used to them. As mentioned elsewhere, managers must discourage employees from picking items out of the waste flow for personal use. This activity, known as totting, can be dangerous and reduces process efficiency; workers will also miss recoverable materials.

CASE STUDY: Staff motivation via incentive schemes

Regardless of the degree of automation in the materials sorting process, the MRF managers interviewed in the study were unanimous on the need to maintain the highest levels of skills and motivation amongst the employees on the line.

Figure 21 The picking staff at Ahern Waste Management benefit from a performance-related bonus scheme

Maintaining high morale is particularly challenging in the C&D MRF environment where much of the work is repetitive and can also be both noisy and dirty. Some companies run bonus-related incentive schemes for some or all of their employees on the site and including the drivers. Successful schemes need to be related to the quality of the work carried out (assuming satisfactory throughput rates are achieved), should be targeted at individuals or small groups and be paid as near as is practical to the day or week in which the performance occurred.

Within our study, however, the use of financial incentives for employees was the exception rather than the rule, and, where such schemes were in place, they were not site-wide. An example of the latter is Ahern Waste Management in West Thurrock, Essex (Figure 21) where a bonus is paid to staff engaged in manual picking and sorting operations only. Here, a bonus is paid based on the overall recycling percentage of the MRF.

The majority of operators, however, insisted that good basic pay levels and the provision of optimum working conditions, backed up by close supervision and strong management, was the best formula for motivating and retaining skilled staff.

The following sets out some specific examples, other than Ahern, where bonus-related incentive schemes were applied:

- Any employee's basic wage might be increased on the basis of length of service in their first five years of employment with the company, or against a skills matrix which would reward their proven adoption of additional skills and expertise. This system has the advantage of increasing the flexibility of the workforce to cater for changes in the quantities or mix of materials received and to maintain throughput during times of sickness and holidays.

- Drivers of waste collection vehicles might get a bonus for each day in which they bring in an agreed number of well managed loads to the site, but would get that bonus reduced for the day if they allow one skip to enter carrying undesirable or non-contracted materials or if they are found to have picked up contaminated waste which is meant to be site-segregated. Errors such as this will be recorded either by cameras at the receiving weighbridge or by the pre-sorting operator at the point at which the waste is tipped.

- Manual picking operators were mostly found to be on the minimum wage. However, their work is often vital to achieving the quality and quantity of recovered materials which are critical to the commercial success of

the site. Regular inspections by the picking supervisor of the quality of materials sorted into each bay could be the basis of such a scheme and a bonus paid to the whole picking team. If poor quality of sorting happens then the bonus is reduced. Team-work may be encouraged by such group bonuses, with peer pressure likely to be applied to poor performing members. In this case, as indeed with all such schemes, close supervision is vital to ensure that it does not have a negative effect on motivation due to circumstances which may be outside the team's control.

- A site-wide scheme based on a 'balanced scorecard' approach was also raised. Such a scheme is designed to reward all employees on a team basis in which everyone works together to increase a bonus pot. The scheme involves allocating points to each key performance indicator (KPI) for the site, such as tonnage processed, overall efficiency, percentage recovered, segregated and cleaned waste, and plant downtime. Each KPI point score is then weighted according to its influence on the commercial success of the site to arrive at a targeted points level, and a bonus is paid if the target is surpassed.

- Site-wide, the importance of regular management and sales meetings was evident, with all performance statistics for the site openly displayed, and with everyone knowing what level of performance is needed for the site to break even. Indeed, any individual schemes might be over-written by either a 'top-up' bonus in any week in which the site meets or exceeds its target, or by a minimum performance level below which no bonuses are paid.

6.0 Equipment and technology

Installing the right equipment at a C&D MRF is crucial. This section outlines issues to consider when choosing technologies, and assesses the relative merits of some important pieces of kit.

6.1 Limits to automation

The level of automation in the MRFs visited varied markedly. In one case, handpicking had been reduced to an absolute minimum in favour of machines recovering specific materials. The main advantage of automation is that it can substantially boost a MRF's sorting capacity and recovery rate. For example, after investing in a new vibratory screen, one site's average recovery rate increased from 70% to 85%. Machines also offer savings in terms of labour cost and can reduce the risk of accidents inherent in manual sorting.

One MRF operator reported that many larger customers are becoming more interested in, and knowledgeable about, the waste they are producing, and particularly its value. For this reason, the character of the waste coming into MRFs is starting to change with easy-to-recycle valuable items such as metal often already recovered, while harder to separate or lower value materials make up an increasing proportion of the skip's contents (Figure 22). MRF operators must be able to adapt their processes accordingly.

Figure 22 A typical load of mixed C&D waste

Various sorting equipment is now available recovering material on the basis of size, mass and other physical and chemical properties. As one contributor says, "MRF operators must keep abreast of new technology developments – continual improvement is vital to stay profitable." Senior managers are well-advised to monitor innovations in this fast-moving sector both in the UK and abroad. Modularity is important; MRF operators should be able to 'bolt on' equipment as necessary – for example, when the market value of a specific output material justifies it.

Automation is never perfect due to the sheer variability of waste, and the unpredictable way in which it responds to sorting techniques. For example, the orientation of an item with respect to a jet of air in a wind-shifter may determine whether or not it is recovered. As stressed above, some form of manual intervention is always required to optimise output quality. Buying, installing and maintaining machinery is expensive; for example, a vibratory screen can cost around £300,000, almost twice the price of a trommel with a similar throughput capacity. Improvements in recovery efficiencies are also ever more difficult to achieve. One technology provider reports that equipment with sorting accuracies of, say, 80% may cost four times more than equipment with 70% accuracy.

MRF operators considering upgrading equipment must be confident of a rapid return of their investment. The market for a particular output must justify the investment. The manager of one MRF visited was relieved not to have installed an eddy current separator for recovering aluminium when the price for this metal slumped recently. Another MRF had recently put in equipment for extracting plastic film from the waste stream and benefited both

from increased revenue from material sales and from reduced landfill costs. A third MRF considered spending £250,000 in a machine to convert expanded polystyrene into condensed briquettes, but found that the high transport costs for polystyrene foam would outweigh any revenues from the investment.

Where practical, sorting equipment should be kept mobile in case the plant layout needs reconfiguring. MRF operators should aim to buy kit purpose-built for the specific facility and the type of waste likely to arise. Alternatively they should be prepared to modify off-the-shelf machines.

Many of the more advanced technologies are more effective with size-reduced waste. For example, one highly automated facility starts by crushing all C&D waste to 50mm maximum size. Shredding material more finely than this should be avoided because (as discussed in Section 2.3) size-reduction hampers any handpicking – and leads to unnecessary cross-contamination of waste.

6.2 Initial screening equipment

Even basic MRFs usually invest in up-front pre-sort equipment. The choice of technology is vital. Up-front screening of waste serves several purposes: soils and other fines not easily sorted by hand are removed mechanically, the weight of material is reduced, and compacted waste is loosened up and aerated. A range of equipment is available to perform these tasks.

6.2.1 Trommels

Trommels of varying sizes are perhaps the most commonly used. They consist of a rotating cylinder set at an angle with holes of a fixed diameter (Figure). Small matter falls through the holes, while larger fraction continues onto an onward conveyor belt. Some trommels have split screens – i.e. two sets of holes with different diameters - so that more than one unders fraction can be sieved out. Trommels are tried and tested, space-efficient with a relatively large screening area, simple to use, and have a high throughput and hence process waste quickly. However, the fast process rate can cause problems for manual sorters further down the line; as always, a trade-off exists between speed and accuracy of processing.

Figure 23 Under a trommel

One problem with trommels is that their tumbling action can cause plastic shrink-wrap or wires to coil around the waste. This snaking or 'sausaging' effect hampers subsequent sorting processes. Another issue is that large objects such as boards or carpets can block the holes. Such larger items should either be shredded in advance or removed altogether from the input flow. Trommels like other automated equipment are noisy when running although some are fitted with a neoprene liner which reduces sound (Figure 24).

Figure 244 Close-up on holes in trommel showing neoprene lining

Trommels can easily be damaged by heavy rubble which is lifted and then dropped by the trommel's rotating motion so are best suited for screening smaller, lighter non-inert materials. Damp soil is a problem for trommels as it packs to the side of the screen and its weight is sometimes too much for the trommel's motor to cope with. Costs of the trommel depend on size – one MRF operator had spent £200,000 on a new machine.

6.2.2 Vibratory screens

Various forms of vibratory screen are used instead of, or in addition to, trommels. They typically consist of a series of tapered levels which are angled down. These levels shake vigorously, simultaneously sieving out the fines and moving it down the slope. Both waste fractions are metered evenly onto onward belts facilitating further segregation manually or automatically. One MRF operator pointed out that the teeth often snap off contaminating both the overs and unders waste fractions, although another argued that certain designs are superior to others, in that the sorting teeth are angled so as not to snag on waste.

Figure 25 Finger screen

The platforms of vibratory screens shake material only a few centimetres in the air, so are less prone to damage by falling heavy waste. This equipment is also less vulnerable than trommels to 'sausaging' waste and blockages, but as with disk screens (see Section 6.2.3 below), smaller waste may ride on larger items. Vibratory screens also take up more floor space than do trommels. For this reason, some MRF operators suggest that vibratory screens are appropriate for secondary screening of aggregates rather than for up-front segregation of mixed C&D waste. An additional drawback of vibratory screens is their reduced capacity compared with disk screens or trommels, but this may not be a problem as manual pickers can be overwhelmed if throughput is too high.

During wet months, the holes in screens sorting fine material – typically material less than 12mm in dimension – can be blocked by mud. This problem is inherent in trommels and standard vibratory screens. Flexible screens have been installed in some MRFs to tackle the issue (Figure). They work by tensioning and rapidly releasing a screening deck made from a flexible material. Waste objects are flipped in the air at accelerations approaching 50G and the screen's holes are kept clear. The holes also change shape during the process again helping shift blockages.

Figure 26 Flexible screen

6.2.3 Disk screens and star screens

Disk screens or star screens are sometimes used for up-front screening either with, or instead of, trommels. They are suited for input streams with a high proportion of inert material such as aggregate. Each screen is comprised of steel shafts to which spinning stars or disks, typically made from plastic, are fitted. Sometimes they have shock-absorbers. The screen itself is usually inclined to the conveyor belt. Large, light objects are gripped by the disks and carried up the slope, heavier items roll down, while a third fraction of smaller material such as soil and other fines falls through the screen. The spacing between the disks determines the size of material extracted, while adjustments to the disks' spin speed and the angle of the screen fine-tune the sorting process. Sorting speed is traded off against accuracy. Slowing the disks improves the removal of fines from the line but reduces sorting capacity. Similarly, a steep screen shakes out more contaminants and gives several opportunities to sort as materials may fall back down the slope, but again the processing rate is reduced as the waste must work harder to travel up the incline.

Figure 27 Loading a taper slot screen

Like trommels, disk screens are easy to use, have a fast throughput and are well established in the MRF industry. Although sturdier than trommels, a key weakness is that smaller materials such a soil may ride on top of larger objects. This issue can be mitigated to a small extent by angling the screens more steeply, but this may not always be practical. In addition, wire, rope, tape and plastic film can wrap around the disks jamming them up. The mechanical shovel operator in the tipping area should ensure such nuisance materials are removed from waste entering the MRF. Disk screens are typically 1.5 times more expensive than trommels.

6.3 Magnets

Powerful over-band magnets should be installed to extract ferrous metal from C&D waste. Relatively cheap, they generate high revenues, and provide a quick return on the investment. Magnets function better on lighter objects – the mechanical grab operator or manual pickers can more effectively extract larger metallic objects - and so should be installed over the smaller-sized waste fraction coming from the automated pre-sort. Despite this, many MRFs also fit magnets over the larger material fraction, and a few fit at the end. In addition, as discussed above, magnets are fitted as standard on wood shredders for extracting nails (Figure).

Figure 28 Ferrous metal recovered by a wood shredder

6.4 Picking cabin equipment

Little sorting technology is found in picking cabins (29). The conveyor belt passing through it needs to be of an appropriate width: in one MRF visited the belt was too wide for a person on one side to reach waste on the far side, requiring picking from both sides. In some MRFs, principally municipal plants, PET plastic bottles may be dropped down a chute containing a bottle piercer. This prevents the bottles from acting as pressure vessels and exploding in hot weather. The value of electrical wiring recovered in picking cabins can be boosted by investing in wire-strippers. The exposed metal, 'bright wire', fetches a slightly higher price and the stripped coating itself, typically uPVC, has a value.

Figure 29 Picking cabin

6.5 Water separation equipment

One of the MRFs visited used a flotation tank for separating wood from heavier aggregates (Figure 0). When the waste enters the tank, the bricks and rubble sink while timber and plastic floats and is skimmed from the surface using brushes. This rather basic technology appears suited for waste flows which have already had the bulk of other materials removed as these could contaminate both streams. Flotation tanks are best used indoors as they can freeze in the winter. They are messy to use and the example viewed was due to be replaced by more sophisticated air-separation technology.

Figure 29 Flotation tank for separating off lighter wood from heavier rubble

6.6 Air separation equipment

As discussed in Section 2.6, most MRFs install air- or wind-separation equipment, sometimes called 'lights separation units', to optimise the quality of aggregate outputs by removing lighter contaminants (such as paper, plastic and wood) from the heavier rubble leaving the picking cabin, or from fines separated out by trommels or vibratory screens. Various systems are in use, either sucking or blowing unwanted material away from the aggregate or soil. Sometimes both suction and blowing is used, with the air being recycled. Reliability of these air technologies is apparently an issue; at three sites kit was malfunctioning, either having problems distinguishing stones from mud pellets or failing to blow off material at all due to moisture in the aggregate.

The air-knife, likened by one MRF to a large hairdryer, works by blowing fine material from falling heavy three-dimensional objects such as bricks as they fall through a curtain of air (Figure 1). Wind-shifters, by contrast, suck light materials from the waste stream – the materials are then blown onto a belt.

Figure 30 Air knife - heavy items fall down, lights are blown forward (in the direction of the dotted arrow)

Density separators come in two forms. Some combine a vibratory screen with an air-knife. Material on the belt is fluidised by vibration so that light material (such as paper and plastic) rises to the top. The heavier waste, typically aggregate and metal, drops through a gap while the lighter material is blown over it. Other density separators perform an equivalent task on the unders fraction from the initial automated pre-sort process. Here they separate RDF-type material from fines of a similar density. They work by blowing fines from below and also simultaneously from the side.

6.7 Shredders

Most MRFs visited employ powerful wood-shredding machines to reduce the space taken up by recovered wood and thus increase transport efficiency (Figure 2). Energy from waste plants often require wood feedstock to be delivered in chipped form. Some shred up to 40 tonnes of wood per hour. Wood shredders can cost between £250,000 and £600,000.

Figure 31 Wood shredders

Shredders are used to prepare wood material for a range of end markets, such as higher value applications like animal bedding or mulches as well as RDF. As mentioned in Section 6.6, the fine material removed by air-knives and wind-shifters (or -sifters) is normally comprised of a wood, plastic and paper and is suitable for burning as fuel. MRFs across continental Europe, and several in the UK, have installed specialised flocking machines which reduce material to between 20 and 50mm by cutting it with blades and pressing it through a screen. The technology is expensive and requires substantial maintenance: one MRF operator informs us that installation of their flocking machine cost about £489,000 and they anticipate a payback period of up to three years. Material requires pre-treatment prior to its introduction into the flocking machine; this may involve primary shredding, the removal of all metals, wood, hardcore and other heavy particles which can damage or affect the accuracy of the blades. According to the same interviewee, the blades have to replaced every few weeks at a cost of £8,000 each, and two hours every day are spent are setting up the machine before it can be used.

Some highly automated plants visited had installed a shredder for size-reducing waste streams prior to their introduction into the rest of the MRF. An example of a machine used for the latter process is the twin-shafted slow-speed shredder (Figure 3). As discussed in Section 2.3, up-front shredding is best avoided in more manual operations as it creates unnecessary work for hand pickers.

Figure 32 Inside a twin-shafted slow-speed shredder

6.8 Advanced equipment

The preceding paragraphs have examined the basic equipment found in MRFs. Some highly automated plants have invested in additional advanced equipment more frequently associated with facilities sorting household waste.

Ballistic separators may sometimes be installed after a trommel. These perform a sophisticated separation process whereby heavy material such as brick or wood is walked up a slope, while lighter material such as paper travels down the incline. A screen deck can also be used to recover a third fraction of heavy fines. The heavy fraction may then pass on for handpicking, while the lighter material could then pass through an optical separator.

MRFs are increasingly investing in optical sorting technology. This sophisticated equipment identifies and positively or negatively sorts materials such as wood, paper and plastic based on how the latter's material composition reacts to varying wavelengths of light. The position of the target material on the conveyor belt is sensed and this information is passed via computer to a blower which at the appropriate moment shoots the item off the line onto a separate belt or directly into a storage bay or container. Although common in municipal MRFs, C&D plants are only now starting to install optical sorters, apparently in order to prepare better quality RDF materials (Section 7.5).

Eddy current separators, commonly used to recover aluminium from municipal mixed recyclables, are still rare in C&D MRFs. Several plants visited were, though, planning to install this technology which uses induces an electromagnetic field in aluminium cans allowing them to be separated from other recyclables.

6.9 Equipment maintenance

Constant care of equipment is crucial to the effective operation of any production line. As one operator puts it, 'MRF machinery tends to destroy itself.' On-site engineers should be available around the clock to clean and maintain kit during down-time, and to respond immediately to mechanical failure which can cost the MRF operator significant time and money. MRFs are well-advised to implement planned and preventative maintenance schedules, and to discipline staff failing to take proper care of the equipment. For example, the bearings on all equipment must be regularly greased – a failure to perform this simple task was identified as a reason for the breakdown in the trommel operation at one MRF visited. At another site, equipment manufacturers visited the MRF monthly to check on equipment.

CASE STUDY – Powerday, London: Investing in automation to improve the value of recyclates

Many MRF operators contacted during the study believed that the use of manual picking cannot be avoided if high quality recyclates are to be achieved from the sorting lines. However, one MRF operator (Powerday of London) was keen to demonstrate the benefits of maximising automation of the process and continues to invest in the latest sorting technologies.

Figure 33 Control panel for the Powerday MRF

■ Why automate?

For Powerday, the main driver for increased automation is that it reduces the need for labour, with its consequent high on-costs, whilst retaining, or improving, the quality of recovered materials.

Increased levels of automation can enable some MRF operators to maximise revenue by increasing the number of mixed waste consignments taken from the customer's sites at a higher per tonne charge. This argument is not, however, relevant to the Powerday site, where all waste consignments received contain mixed waste, charged at a flat rate. (This is a feature of construction projects in London where space is often at a premium, making waste segregation difficult for the constructor).

Powerday was already achieving a 96.4% recovery rate, with very low manual labour levels.

■ Current low labour/low technology MRF

The process lines at Powerday currently handle in excess of 100 tonnes of mixed C&D waste per hour. The operation has evolved quickly on the basis of avoiding the use of a manual picking cabin which was found to be too labour intensive. The general manager noted that this was tried when the line was first installed and "was found not to be economically viable".

The main line is currently running basic low-tech items of equipment which rely on:

- Manual diversion of unsuitable items at the tipping stage; and
- A waste reducer, which will either shred large materials down to a size suitable for the line to handle or will reject them.

In this way, the downstream process equipment, comprising simple trommels and single drum separators, are largely protected from damage. The line is duplicated so that two stages of sorting are achieved in one pass. Items that may have been caught up in the first stage are removed in the second stage.

The current process at Powerday is as follows:

- Incoming waste is tipped onto a bay where an on-foot operator identifies or removes the unsuitable items by hand. Unsuitable items may include sheets of plywood that would not get shredded or large lumps of

concrete that would damage the trommel. A safety protocol is in place whereby the mechanical grabs are working on another bay whilst this operation is taking place.
- The waste is loaded by the grab onto the line where a waste reducer splits any bags and shreds the waste into small items which are more suitable for managing automatically.
- Two overhead magnets take out most ferrous metals.
- The waste then passes into a 12 metre long trommel with 40mm apertures where small items (glass and fines) fall out.
- A single drum separator blows light material (mainly some timber, cardboard, paper and plastics) forward whilst heavy objects (bricks, ceramics, etc) fall out into a storage bay.
- The waste then passes into a similar but smaller line comprising a 9 metre long 40mm trommel, and a smaller drum separator. The remaining material is flock, which is sent to pelletizing or directly to EfW.
- There is no picking cabin and only three manual operators in the line removing for example dirty materials and aluminium.

Adding higher technology automation

Further investment is now taking place at Powerday to extend the line utilising higher-tech equipment to separate the residues automatically into higher value materials and, it is expected, to achieve 100% diversion of all feedstock from landfill. The extension will improve sorting of the flock by removing additional timber, cardboard, plastic, aluminium and copper. These materials are extracted both to improve the quality of the flock and to yield more materials which have a positive value, such as wood, which is being sent in increasing volumes to panel board manufacturers in the UK and the near Continent.
The extended line is expected to be fully operational by mid June 2009.

The line extension will comprise:
- A third single drum separator to remove most heavy materials;
- An eddy current separator to remove non-ferrous metals;
- An optical sorter, which removes plastics; and
- A wind-shifter, which extracts the flock from any remaining heavy material by a suction process.

The optical sorter has a memory, loaded by a scanner, which will remember specific shapes/colours of plastics that it may have missed and will identify equivalent items for removal next time.

The residual flock will be converted to residue derived fuel (RDF) for energy recovery.

7.0 Managing outputs

The production of high quality output materials should be a focus for the MRF operator, balanced with obtaining the best possible recovery efficiency. These measures may allow the operator to increase the plant's overall efficiency – and thus help customers using the MRF who have signed The Construction Commitments: Halving Waste to Landfill pledge to achieve their objectives. This section outlines ways for the MRF operator to maximise onward movement of, and revenues from, recovered materials.

7.1 The importance of good outputs

The best MRF operators aim to minimise the tonnage of output material sent for landfill, saving money and attracting new business from waste producers keen to limit their environmental impacts. Sorting the input stream into high quality material outputs is vital to achieve this aim.

Figure 34 C&D MRFs can recover a wide range of outputs

In addition to the avoidance of landfill, informants stressed that building a reputation for consistent high quality outputs is the key to maintaining throughput. One example is ensuring that the level of contaminants such as painted or hazardous treated material in wood destined for energy recovery does not exceed levels stipulated by the power plant. Keeping the MRF tidy and free of waste materials on the floors and in skips and balers is a simple way of preventing contamination. Material re-processors favour top quality suppliers in times of low demand. For this reason, MRF operators are well advised to check quality regularly at various stages of the process (some use digital photography) and provide a fully supervised audit trail for all material consignments.

At the very least, MRF operators should note feedback from re-processors on material quality and when necessary improve systems accordingly.

7.2 Flexibility

The fluctuation in material prices requires flexibility in the MRF operation. For example, if the price for a certain polymer dips then separating this from other plastics may not be worthwhile, and producing a mixed plastic bale may be a better approach. Similarly, if paper prices rise then effort spent segregating the material from cardboard could pay dividends. Some MRF operators have developed computer models to perform cost-revenue calculations for the recovery of each material, ensuring each output pays for itself. In practice, however, the

rising price of landfill now means that most materials will eventually be worth recovering and recycling and by following the above advice, revenues may be maximised

When choosing a location for a new plant, availability of alternative transport links such as road, rail and canal should be considered (Figure 3), offering flexibility in managing both inputs and outputs.

7.3 Contracts with re-processors

Contracts with customers for output materials are hard to obtain, and most MRFs sell on the spot market. An exception may be MRFs supplying wood or RDF to energy plants, because the latter require a predictable supply of fuel. In the absence of contracts, MRF operators sell to a limited number of re-processors or brokers. For this reason, MRF operators are well-advised to maintain good relationships with buyers. When market conditions are poor, re-processors are more likely to turn to MRFs with a track-record of high quality outputs.

7.4 Care of output materials

Unless specified by the buyer, outputs should be baled for ease of storage and transportation (Figure 6). Mill-sized bales are preferred as these can fetch higher prices. Bales should be stored in dry, secure and preferably enclosed areas (Figure 7). This maintains quality and reduces risks of contamination, theft and fire (including arson). Storage space is usually at a premium, so rapid onward movement of material is recommended, particularly as some recyclates will soon start to degrade. The bales should be checked regularly for quality. One MRF visited used under-floor heating in storage bays to dry certain recyclates.

Figure 35 Feed belt for baling machine

Figure 36 Storage of baled recyclates under cover

7.5 Energy recovery

While the majority of material entering a C&D MRF can be recovered and recycled, achieving 100% diversion from landfill is unlikely to be possible without energy recovery through combustion[12]. Certain material may simply be too awkward to recover, perhaps due to contamination, size, moisture content, or other physical or chemical properties (Figure 8). All the MRF operators visited for this study rely – or are planning to rely - on energy recovery in some form in order to divert waste from landfill. With outlets currently few and far between, many MRFs are applying for permission for their own EfW equipment such as gasification or CHP (combined heat and power) plant. Preparing RDF is not straightforward. Energy recovery plants, such as cement kilns or EfW plants, each have strict specifications in terms of RDF particle size, bulk density, whether fibres or briquettes are required, PVC content and moisture content which are determined by the type of combustion process and the type of scrubbers in place, as well as by local environmental and planning conditions. MRFs typically flake RDF to the correct size using shredders or flocking machines (see Section 6.7). One MRF operator reports that the cement kilns it supplies require particle sizes and moisture content not exceeding 30mm and 10% respectively. An EfW plant manager interviewed for this study allows fuels with moisture not exceeding 20% and is looking for a particle size between 30mm and 60mm. Care should also be taken to ensure that metal, soil, brick and glass are not present in the material. Several MRF operators planning to supply EfW plants are currently investing in optical sorting technology to improve the quality of their RDF outputs.

Figure 37 Low grade waste material

[12] *Combustion results in ash or char which will probably have to be landfilled – although it can sometimes be incorporated into new building materials. Ash yield is estimated at 10-15% of the original mass of the material combusted, depending on the latter's composition.*

CASE STUDY: What can the Dutch teach us?

In studying the efficacy of C&D waste recovery systems in the UK it is of interest to make comparisons with the equivalent systems elsewhere in Europe. An example of a European country with a well-developed waste materials recovery infrastructure is the Netherlands, where there has been a lack of suitable space for landfilling operations and a long term historical need to provide substantial quantities of recovered aggregates sands and soils for land reclamation.

Our review of three MRFs operated by companies in the Shanks Group found that the processing systems used in C&D MRFs, the technology involved and the reliance on manual labour were similar in the Netherlands and the UK. The difference lay in the more advanced culture of recycling and energy recovery that exists in the Netherlands, and this has led to a more developed waste recovery infrastructure.

Before making the comparison, however, it is important to note the significant differences between the materials recovery cultures in the two countries. In Holland, the lack of space for landfilling has led to tight regulation on the use of landfill and punitive landfill costs. Only waste, such as bituminous roofing and insulation, which cannot be burned in an incinerator for technical reasons is permitted to be disposed to landfill. Landfill costs currently average €125 per tonne inclusive of taxes, compared to £55 in the UK (April 2009). The high landfill cost enables the waste industry to offer significant savings through waste recovery operations to construction companies and provides a large incentive for them to plan their project waste management arrangements in some detail. It also means that the over-riding measure of performance for a Dutch MRF is the final disposal cost per tonne of feedstock.

Another difference is that regulations arising out of the Dutch National Waste Management Plan (LAP) effectively prohibit the landfilling of active wastes from any source. All mixed waste containers must, therefore, be sent to a facility such as a MRF for recovery of these materials.

Compared with the UK, the energy recovery sector in the Netherlands is well established, and for household and non-process commercial and industrial waste is the preferred disposal route. The commercial reasons for this are clear:

- Firstly, that the sorting of many mixed waste streams into clean, single constituent materials for re-processing into new products becomes prohibitively expensive at the margins, using currently available technology;
- Secondly, the market for materials is very volatile, whilst that for energy is relatively stable; and
- Thirdly, renewable energy certificates are available for EfW producers that are compliant with the Waste Incineration Directive.

For C&D waste - which represents the greatest proportion of Dutch waste arisings[13] - recycling is still favoured over incineration as in the UK because this reduces the demand for primary resources and is promoted through regulation. Nevertheless, the relatively more established EfW infrastructure allows Dutch MRFs to achieve similar levels of landfill diversion of C&D waste to those seen in the UK (i.e. in excess of 90%) with reduced costs. This is because there is less need for sophisticated equipment to segregate residue, or flock (smaller materials from the C&D sorting operation containing, largely, mixed wood, paper and plastics with a high energy content), into separate clean materials.

In one particular MRF operation it was found that, after sorting, the C&D line had a 20-25% residue of which around half was not suitable for incineration because the calorific value was too high or comprised items such as nylon ropes or roofing materials which were too awkward for burning. As a general rule, if a calorific value between 7 and 12 MegaJoules/kg can be achieved with this residue, it is sent to energy recovery rather than to landfill. If the energy recovery route is chosen, effectively 100% recovery is achieved since the bottom ash from the incineration process has an outlet such as in road construction works but with special exemption permit.

There appeared to be a greater commitment in the Netherlands in arranging for the waste to be sorted on the construction site as far as is practical before being shipped to the MRF. It was felt that pre-sorted C&D waste yields a better quality product and is more profitable. Indeed, it was noted that the banning of active wastes

[13] *The annual waste arisings of the Netherlands is 62 million tonnes, of which C&D waste represents 28 million tonnes. Municipal waste and commercial/industrial waste represent 5.5 million tonnes and 3.8 million tonnes, respectively (Shanks Netherlands, Personal Communication).*

going to landfill under the LAP improves the quality of segregation achieved at source when compared to UK practices. Where limited space on a small or urban construction site limits the options for multiple skips, then builders simply use smaller containers or even waste sacks. It was further argued that there were considerable benefits to be gained by training the customer's staff or placing recycling 'experts' at depots and building sites to encourage and monitor the quality of segregated wastes before the containers leave the sites.

A further feature of the Dutch waste recovery sector is the inter-relationships between recovery facilities. The geographic proximity of suitable MRFs across the country facilitates the accumulation and shipment of bulk waste at low cost, both financially and environmentally. Partly sorted mixed waste is often transferred to a second site which specialises in recovering, say, wood for the panel board industry, or which separates ferrous and non-ferrous metals, or which can identify and sort a range of polymers from a mixed plastics stream. In this way, the per-tonne revenue of recyclates may be raised considerably. This infrastructure is, of course, more commercially and environmentally feasible in a small country such as the Netherlands, which also has a considerable network of canals and rivers suitable for the transportation of bulk materials.

Elsewhere, it was found that the processing systems used and the reliance on manual labour were similar between the Netherlands and the UK. One informant confirmed that "there is no technology in use in Dutch MRFs that is not in use in the UK". One general manager visited summarised what he thought was best practice in C&D materials recovery: it is in getting the right mix between logistical systems, technological development and the 'human factor'. There was only a limited amount of automation of the process that was possible. It follows that it is important to maintain well-motivated manual pickers to ensure quality of material outputs. His company made the working conditions of the (largely immigrant) workforce as pleasant as possible by installing a centrally heated picking station, changing rooms, a canteen, and a smoking room.

8.0 Environmental impacts and health and safety

Regulation requires that MRFs are run safely, and with minimal impact on the environment. Pleasant working conditions can motivate employees and make good business sense. This section outlines measures for the MRF operator to consider.

8.1 Reducing environmental impacts

When operational, MRFs can cause various environmental impacts such as dust and odour emissions, noise and vibration, toxic leaching and lorry movements. Scheduled and unannounced visits from Environment Agency officials ensure facilities comply with agreed regulatory limits for these impacts. Many MRF operators highlighted the importance of keeping neighbouring businesses and local residents happy.

An obvious first step to minimising most impacts is to enclose as much of the sorting process as possible in a shed (Figure 39). At the very least, perimeter netting or bunding should be erected to prevent light material blowing off the site. Clearly, the latter measure will also reduce noise pollution.

Figure 39 Shed enclosing part of a MRF

Dust in the air, usually produced by vehicle movements, is a key problem for C&D MRFs, particularly in dry weather. When inhaled, fine particulate matter can be dangerous to human health, but it can be reduced in several ways. Sorting equipment such as trommels or vibratory screens should be fitted with functioning air-filtering units. In addition, water misters fitted to the shed roof are frequently used (Figure 0); some MRFs favour the use of time-delay inorganic foam suppressants sprayed directly onto waste.

Much of the dust is created by vehicle movements, so water-bowser trucks should be used regularly to dampen down roads (41). However, a balance must be struck because excessively wet conditions will degrade baled output materials – particularly wood and cardboard.

Figure 38 Water misters reduce dust in the air

Figure 39 Water bowser

Noise from sorting equipment, mechanical grabs, forklift trucks, bulldozers and other plant can be reduced by installing white noise filters or silencers. MRFs should also implement policies – communicated with signage - preventing vehicle movements and plant operation in unsocial hours.

The harmful impacts of oil spillages can be reduced by storing fuel in properly bunded areas and by fitting underground fuel interceptors, removing oil from water run-off before it enters sewers.

MRFs can indirectly impact on the wider environment in terms of high energy and water consumption, as well as through congestion resulting from skip-trucks and also from greenhouse gas emissions. Steps can be taken to mitigate most of these impacts. These include: collection and storage of rainwater for use in dust-suppression;

generation of renewable energy using on site using biomass boilers, gasification plants or wind turbines; use of local waterways or rail-links for transporting materials; and use of power factor correction. In addition to the measures suggested in Section 4.5, the operator should avoid multiple handling of waste and where possible operate fuel-efficient equipment.
At some MRFs, a member of staff regularly walks the perimeter of the site to check on emissions – any problems can then quickly be identified and addressed.

As discussed in Section 3.7, many MRFs are now implementing internationally recognised standards for managing environmental impacts (ISO 14001) and safety risks (OHSAS 18001). Maintaining these accreditations requires companies to demonstrate continuous improvement in performance.

8.2 Reducing health and safety risks

The noise, dust, dirt, hazardous materials, vehicle movements and heavy machinery mean MRFs can be dangerous places to work. As much as possible should be done to reduce the risk of accidents. As discussed in Section 5.1, health and safety (H&S) advice may be best sought from outside the waste industry: a general H&S expert will bring a fresh perspective the issue. One site visited hired H&S consultants in partnership with other MRF operators in the region.

Basic measures to reduce the risk of accident include:

- never using personnel to pre-sort incoming waste on the tipping floor in front of mechanical grab;
- implementing a one-way system for skip-trucks;
- clear safety and warning signage (42) translated into other languages when appropriate;
- the availability of two-way radios in all vehicles and at all equipment locations; and
- segregated walkways

MRFs should not be open to the public as this increases the likelihood of accidents, as well as obstruction by vehicles.

Figure 40 Clear signage reduces the risk of accidents

Regular safety training exercises are important, as is the availability of first aid equipment (e.g. eye wash, bandages etc) and at least one first aider on site at all times. Regular independent inspections and audits are also important. As on construction sites, all personnel must wear safety equipment: hard hats, high-visibility jackets, boots with toe and mid-sole protection, dust masks and ear-protectors (Figure 3). Anti-stab gloves are obviously vital for hand pickers.

Figure 41 Safety clothing at a MRF

Appendix 1: Contact details for MRFs visited or interviewed

- **P.F. Ahern (London) Ltd.**,
  - Oliver Close, West Thurrock, Essex, RM7 0HA, UK
  - T: 01708 865599
  - W: www.ahern.co.uk

- **Commercial Recycling Ltd.**,
  - Canford Recycling Centre, Magna Road, Wimborne, Dorset BH21 3AP, UK
  - T: 01202 577944
  - W: www.commercialrecycling.co.uk

- **Eastern Waste Disposal Ltd.**,
  - Morses Lane Industrial Estate, Brightlingsea, Essex CO7 0SD, UK
  - T: 01206 307070
  - W: www.easternwastedisposal.co.uk

- **Ethos Recycling Ltd.**,
  - Grand Union Office Park, Packet Boat Lane, Cowley, Uxbridge, Middlesex, UB8 2GH, UK
  - T: 0844 844 0180
  - W: www.ethosrecycling.co.uk

- **Irish Recycling Services (IRS)**,
  - 40 Springwell Road, Groomsport, Bangor, Co Down, BT19 6LX, Northern Ireland, UK
  - T: 028 90 74371
  - W: www.irsskiphire.us/

- **JBT Waste Services Ltd**,
  - Barrington Industrial Estate, Bedlington, Northumberland NE22 7DL, UK
  - T: 01670 827820
  - W: www.recycleitall.com

- **Malcolm Construction Services**,
  - 865 South St, Glasgow, G14 0BX, Scotland, UK
  - T: 0141 435 5200
  - W: www.whm.co.uk

- **M & M Skip Hire Ltd.**,
  - Worton Farm, Cassington, Witney, Oxon, OX29 4SU, UK
  - T: 01865 880559
  - W: www.mmskiphire.com

- **McGrath Group**, London
  - McGrath House, Hepscott Road, Hackney, London , E9 5HH, UK

- T: 020 8985 5000
- W: www.mcgrathgroup.co.uk

- **McKinstry Skip Hire Ltd**,
  - 81 - 83 Belfast Road, Nutts Corner, Crumlin, Co Antrim, BT29 4TL, Northern Ireland, UK
  - T: 02890 825362
  - W: www.mckinstryskiphire.co.uk

- **Nick Brookes Group**,
  - Wardle Industrial Estate, Green Lane, Wardle, Nr Nantwich, Cheshire, CW5 6DB, UK
  - T: 01829 260687
  - W: www.nickbrookes.co.uk

- **Pearsons (Thetford) Ltd.**,
  - Howlett Way, Thetford, Norfolk IP24 1HZ, UK
  - T: 01842 752386
  - W: www.pearsonsthetford.ltd.uk

- **Powerday plc**,
  - Crossan House, 28-31 Hythe Road, London, NW10 6RS, UK
  - T: 020 89604646
  - W: www.powerday.co.uk

- **Premier Waste UK Ltd.**,
  - Premier House, 209-211 Walsall Road, Perry Barr, Birmingham, B42 1TY, UK
  - T: 0121 366 4900
  - W: www.premierwasteuk.com

- **Shanks Waste Management Ltd (Northamptonshire)**,
  - Furnace Park, Telford Way, Telford Way Industrial Estate, Kettering, Northants, NN16 8UN, UK
  - T: 01536 412 180
  - W: www.shanks.co.uk

- **Smiths (Gloucester) Ltd.**,
  - Alkerton Court, Eastington, Stonehouse, Gloucestershire, GL10 3AQ, UK
  - T: 01453 822 227
  - www.smiths-gloucester.co.uk

- **William Tracey Ltd.,**
  - 49 Burnbrae Road, Linwood Industrial Estate, Linwood, Renfrewshire, PA3 3BD, Scotland, UK
  - T: 01505 321000
  - W: www.wmtracey.co.uk

- **Icova BV**,
  - Kajuitweg 1, (Postbus 59372), 1040 KJ Amsterdam, NETHERLANDS
  - +31 (0) 20 447 66 66
  - W: www.icova.nl

- **Smink Groep**,
  - Lindeboomseweg 15, 3828NG, Hoogland, Postbus 2527, 3800GB Amersfoort, NETHERLANDS
  - T: +31 (0) 33 455 82 82
  - W: www.smink-groep.nl

- **Van Vliet Groep**,
  - Grote Wade 45, 3439 NZ Nieuwegein, NETHERLANDS
  - T: +31 (0) 30 285 52 00
  - W: www.vanvlietgroep.nl

Appendix 2: Items reviewed during site visits

- General description of facility
- Process flow
- Area/region serviced
- Commercial and municipal? If both, how is each stream handled?
- Contractual arrangements, for feedstock and outputs?
- List of waste materials received and what are the drivers of this?
- List of sorted waste materials produced. Any re-use or re-manufacture?
- Range of end markets to which waste is successfully transferred
- Licensed capacity for C&D waste & annual waste volumes actually processed
- % waste diverted from landfill
- Plant layout schematic diagram
- Manning and shift patterns – how many site based staff, how many pickers?
- Identify automated and manual processing technologies or systems
- Overall efficiencies of equipment
- Assess material flows (receipt, handling, storage, through-flow)
- Quality of feedstock (plus how measured and if fed back to source?)
- Quality of product (plus how measured?)
- Environmental impacts (dust, noise, odour, emissions, etc.)
- Use of management systems (e.g. QMS, Environmental, H&S and so on.)
- Strengths and weaknesses of the operation
- Financial information if available:
  - Annual fixed and variable running costs (£)
  - Overall cost per tonne feedstock (£/t);
  - Gate fee (£);
  - Sales revenue/disposal costs per tonne feedstock (£/t);
  - Energy and water consumption per tonne feedstock (£/t);
- What does the management team consider to be good practice at this site?
- Are there any barriers to maximizing recovery? If so, what are they?

Appendix 3: Gypsum-containing materials waste management

Under the Landfill Directive, the disposal of gypsum waste (such as plasterboard) together with biodegradable waste into ordinary landfill cells has been banned in England and Wales since July 2005. The policy was designed to encourage recycling of plasterboard because disposing the material in dedicated gypsum mono-cells is expensive. However, the Environment Agency took a position whereby waste containing a small amount of gypsum could fall outside this restriction and so separate disposal was not required. The so-called '10% rule' allegedly encouraged some to stockpile gypsum materials and then filter it into ordinary landfill with no attempt to recycle it. The EA therefore revised its rules, scrapping the 10% guideline as of 1 April 2009. The revision also states that plasterboard waste management should follow the waste hierarchy, with landfill a last resort. The plasterboard recyclers claim to have spare capacity and landfill operators state that they can also respond to demand for gypsum mono-cells. While not banning builders from disposing of gypsum waste in mixed skips, the EA position statement does encourage against this practice, and furthermore, requires waste management companies to separate gypsum waste from any biodegradable waste for either recycling or disposal in a gypsum mono-cell. Waste management companies may therefore insist builders collect gypsum waste separately on site.

The EA revised guidance is available at: http://www.environment-agency.gov.uk/business/topics/waste/105953.aspx

Information is also available at: http://www.wrap.org.uk/construction/plasterboard/

In March 2007 by the Gypsum Products Development Association, representing the UK plasterboard manufacturers, and WRAP signed the Ashdown Agreement setting out shared objectives for the diversion of waste gypsum from landfill. Further details are available at: http://www.wrap.org.uk/wrap_corporate/news/plasterboard.html

This website also includes three manufacturers' plasterboard take-back schemes. http://www.wrap.org.uk/construction/plasterboard/ashdown.html

This regulatory change only affects England and Wales. The position in Scotland and Northern Ireland may be different - further information is available from SEPA and NIEA.

Waste & Resources Action Programme

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