UK SECTOR STUDY REPORT

Recycling and Waste Management

Pontypridd February 2002

Dr. Cliona O'Neill
Environmental Technology and Management Centry
Pontypridd 2001
CF37 1DL
UK
Tel. 0044 1443 483379
Email: coneill@glam.ac.uk

The project is carried through with support of the European Community programme LEONARDO DA VINCI II.

The content does not necessarily reflect the official opinion of the European Commission in these questions.

LEONARDO DA VINCI is a vocational training action programme of the European Community.

RECYCLING SECTOR STUDY REPORT

1. Introduction

Waste production in the UK is approximately 400 million tonnes per annum, and increasing. Therefore recycling studies are essential from the environmental perspective. Recycling has been described as representing both a challenge and a new business opportunity (Marsh, 2001). Recycling processes use energy, which in many cases is derived from the burning of fossil fuels. However, normally the energy used for recycling is significantly less than that used for extraction and import of virgin materials. Recycling is currently being driven by EU legislation, and regulations such as the Packaging and Packaging Waste Directive and the End of Life Vehicles Directive are assuming great significance.

Recycling has become an important item on the UK government's agenda. In 1999 the government published a set of 15 headline indicators and 135 supporting indicators to identify trends in quality of life in the UK. Several of the indicators relate to management of waste and resources, covering the waste produced by industry, commerce and households, recycling, energy recovery, and landfill (DETR, 2000). However, despite the recognition of the importance of recycling, a 1999 survey suggested that, although 79% of people in the UK considered themselves environmentally conscious, only 41% recycled every week and 11% never recycled, mainly due to laziness, inconvenience and inadequate local facilities (Evison and Read, 2001). A wide range of materials is now recycled in the UK, including paper, plastic, metal, and glass, in the form of either industrial source or post-use materials.

2 Current Waste Production

Approximately 400 million tonnes of waste is generated annually in England and Wales (Woodard *et al.*, 2000; Adams *et al.*, 2000). About 294 million tonnes consist of construction and demolition wastes, agricultural wastes, sewage sludge and dredged spoil. Industrial and commercial waste account for about 48 and 30 million tonnes respectively, of which 35% is recycled, and another 5% recovered (Adams *et al.*, 2000). Estimates of municipal solid waste (MSW) arisings vary from about 28 million tonnes (Woodard *et al.*, 2000; Adams *et al.*, 2000), to 34 million tonnes (Darley and Bowell, 2001). In England and Wales almost 500 kg per person per year of MSW was produced in 1997/98 (DETR, 2000b). The waste produced by divisions within each business sector is presented in Table 1.

Table 1. Waste produced by divisions within each UK business sector (after DETR, 2000b).

Business Sector	*Annual Waste (x 10^6 Tonnes)
Industrial Companies	
Food, drink and tobacco	8
Textiles, wood, paper	7
Chemicals, rubber, mineral products	9
Metals, metal products	8
Other manufacturing	7
Coke, oil, gas, electricity, waster	3
Transport, storage, communications	4
Miscellaneous	2
Total industrial	***48***
Commercial companies	
Wholesale	4
Retail	7
Hotels and catering	4
Education	2
Other business and public administration	13

Total commercial ***30***

Total industrial and commercial **78**

Waste Type	*Annual Waste (Tonnes x 10^6)
Inert, in-house (small scale) construction	2
Paper and card	7
Food	3
Other general and biodegradable	9
Metals and scrap equipment	6
Contaminated and healthcare	5
Mineral waste and residues	6
Chemicals	4
General commercial	23
General industrial	13
Total	**78**

*Estimated

Household waste in the UK typically includes:

31% paper and card
21% putrescible wastes
9% glass
8% miscellaneous combustible wastes
7% fines
6% ferrous metals
6% dense plastics
5% plastic films
2% textiles
2% non-ferrous metals
2% miscellaneous non-combustible wastes

(DETR, 2000b).

The quantity of household waste produced is predicted to increase by about 3% annually (Adams *et al.*, 2000), due to increasing global populations and standards of living (Nystrom *et al.*, 2001). The UK Government's requirement for an additional 3.8 million homes by 2016 will increase waste arisings by a further 15% (Adams *et al.*, 2000). Each 1% growth in biodegradable municipal waste compounded over a 20 year period indicates the production of an extra 10 million tonnes of waste (Hogg, 2001). Therefore if waste production continues to increase at the current rate nearly twice as many new waste management facilities will be required by 2020 as if the waste arisings remained constant (Adams *et al.*, 2000). Therefore the UK government aims to break the link between economic growth and waste production (DETR, 2000).

2.1 Waste Management

In 1998/9 83% of municipal waste was landfilled, compared to 66% of commercial waste and 47% of industrial waste. Legislation aims to increase the recovery of this waste. Waste disposal authority areas with 1998/9 recycling and composting rates of <5% are now required to achieve 10% by 2003. Those with rates of 5-15% have been told to double their recycling rate by 2003, and the remainder (>15%) need to recycle or compost at least 33% by 2003. This should deliver an overall recycling rate of about 17% by 2003. Between 9 and 39% of waste was recycled in 1998/9, depending on its type (DETR, 2000). Although some industries have developed effective it easier. However, there are no supporting laws outside Europe and in East Europe, which limits the effectiveness of these policies, as new cars are being designed for specific markets, rather than a global market. Additionally, as cars are considered to have a life span of approximately 12 years, design for recycling will take time to have an impact (Bellmann and Khare, 2000).

2.2.3 Packaging regulations

Packaging waste comprises about 9% of industrial, commercial and municipal waste, and is currently estimated at about 10 million tonnes annually, of which about 4.5 million tonnes arises in the household waste stream. In the UK in 1998 33% of packaging from household, commercial and industrial packaging was recovered, of which 29% was recycled. Plastics account for approximately one fifth of waste packaging materials, with 1.2 and 0.5 million tonnes coming from domestic and industrial sources respectively (DETR, 2000b). Table 7 illustrates the proportion of total packaging waste arising in each stream.

Table 7. Proportions of packaging materials in household and commercial/industrial waste streams (DETR, 2000b).

Material	Household Tonnes	Commercial/ Industrial Tonnes
Aluminium	104,500	4,500
Steel	573,000	162,000
Plastic	1,100,000	600,000
Glass	1,850,000	350,000
Paper	500,000	3,470,000

Packaging waste is subject to producer responsibility regulation through the European Directive on Packaging and Packaging Waste, which set recovery and recycling targets for all packaging materials. The UK Government has transposed the Directive into UK law through the Producer Responsibility Obligations (Packaging Waste) Regulations 1997, which came fully into effect on 1 January 1998. These apply to any UK businesses manufacturing, filling or selling packaging or packaging materials in excess of 50 tonnes per year and have an annual turnover in excess of £5 million (www.britishsteel.co.uk). Member states were required to recover 50-65%, and recycle 25-45%, of packaging waste by the end of June 2001, with a minimum of 15% recycling of each material (DETR, 2000b). A consultation paper published in 2001 on recovery and recycling targets for packaging waste, proposed the raising of UK business targets from 52% (recovery target) and 16% (material specific target) to 58% and 18% to achieve the packaging directive targets (DEFRA, 2001).

The Regulations require all companies to have a specific, quantified recovery target, dependent upon the weight of packaging handled and whether packaging is made, filled, or sold by the organisation (www.britishsteel.co.uk). Responsibility for achievement of targets is shared between the four activities as follows (Table 8).

Table 8. Responsibility for achievement of targets

Activity	Share

recycling systems, only a small percentage of industrial wastes are recycled in the UK. As waste production increases, raw materials and landfill space will become more limited and expensive, making recycling more viable and commonplace. However, there are currently a number of barriers to recycling, including its high cost compared to its benefits. Low disposal costs, cheap raw materials and small quantities of material to recycle make profitable recycling difficult (Nystrom *et al.*, 2001). Table 2 demonstrates the management of waste produced in England and Wales.

Table 2. Waste management in England and Wales 1998/99 (after DETR, 2000).

	Landfill %	Recovery % (including recycling & composting)	Recycling/ composting %
Industrial waste*	47	45	39
Commercial waste	66	33	29
Municipal waste	83	17	9

*excluding construction and demolition waste

The UK's waste/resource management industry accounts for about 0.5% of the GDP, or in excess of £4 billion p.a. (ESAUK, 2002). Recycling is more labour-intensive than other waste management options and the government and the Welsh National Assembly believe that increased recycling will lead to significantly greater employment opportunities in this field. These will include jobs in collection, sorting, reprocessing and innovative use of secondary materials. Recycling therefore gives rise to a substantial amount of employment, and in 1996 the waste management and recycling industries employed about 90,000 people in the UK (DETR, 2000). This is now thought to have risen to 100,000–120,000 employees (WAMITAB, pers. comm.). However, it is likely that, below the top 10% of staff, the numbers of professionally qualified staff are fairly minimal. Discussions with experts and with organisations used as case studies revealed that employees in the waste management and recycling industry are largely unqualified at operative level, although at management level a range of waste management qualifications and COTCs are seen. However, firms treating more specialised types of waste such as solvents tend to employ larger numbers of qualified individuals, particularly those who have completed apprenticeships. This is principally attributable to the fact that a higher level of technology is used in these firms, and therefore trained and qualified staff are necessary to operate and maintain it. The most common qualifications and training desired were engineering and electrician's apprenticeships. A number of organisations questioned had sent staff to obtain vocational qualifications on waste management and treatment. The qualifications included HNDs, HNCs and NVQs. The legal requirement for COTC holders in waste management operations has led to a number of organisations encouraging staff to obtain this qualification.

Waste management services offered by Local Authorities (LAs) include kerbside collections, Civic Amenity (CA) sites, and refuse collection for landfilling. Over 2.8 million households (11.4%) in the UK are served by kerbside collections of mixed recyclables (Smith, 2001). In 1998/99 English LAs spent £1.3 billion on waste management, with a further £73.7 million spent by Welsh authorities. Their spending will have to be used to achieve a recycling rate of 17% by 2003. Standards for 2005 and 2010 will be set after consultation. However, progress towards national recycling targets and limiting landfill use has been slow. In order to attain waste recycling targets, waste disposal authorities will permitted to require that certain wastes be delivered to them separately to facilitate recycling (Adams *et al.*, 2000).

Recycling helps to counteract resource scarcity, decreases demand for landfill space and results in energy savings. However, the collection of materials for recycling also has environmental impacts, including the energy used in collection and sorting, and impacts arising from the use of the recovered materials in new products (Craighill and Powell, 1996). Many LAs are now offering kerbside collections for recyclates, which serviced 37% of UK households in 1997/98, an increase from 17% in 1995/96 (DETR, 2000b). This is necessary in order to enable the recycling targets to be met. LAs also provide almost 800 CA sites for use by the public, implemented through the 1967 civic amenities act. These sites handle over 55 million tonnes (25%) of municipal waste arisings annually, and in some areas over 35% of household waste is handled. Garden waste is the largest component of CA waste arisings, forming up to 63% by weight, and the sites have also become important recycling centres. However, relatively little is known of the composition of waste leaving the sites (Woodard *et al.*, 2000). The number of bring sites and CA sites is now approximately eight sites per ten thousand households (DETR, 2000b).

Recovery of MSW has been poor to date, due to the low cost and ready availability of landfill. However, there is substantial variation in the treatment of MSW in different regions of the UK (Table 3), with landfill varying from 61% of MSW in the West Midlands to 95% in Wales, and recycling/composting ranging from 4% in the North East to 16% in the South West. The regional variation is compounded by decreasing amount of void space for landfill in some areas of England, such as the South East (Adams *et al.*, 2000).

Table 3. Management of MSW arisings for 1998/1999 by region, after Adams *et al.*, 2000.

Region	Waste Arisings 000 tonnes	Landfill %	Incineration %	Recycled/ Composted %
North East	1450	78	16	4
North West	3100	92	0	8
Merseyside	730	93	0	7
Yorkshire & Humberside	2730	90	2	8
East Midlands	2120	83	7	10
West Midlands	2760	61	31	8
Eastern	2780	86	1	12
London	4130	74	19	7
South East	4090	83	0	14
South West	2520	84	0	16
Wales	1560	95	0	5

The services offered by LAs are now greatly affected by the publication of the Waste Strategy for England and Wales (DETR, 2000; DETR 2000b). The strategy suggested a need for 20-130 Energy from Waste plants, 100-200 materials recovery facilities averaging 50,000 tonnes each, and 150-300 composting facilities averaging 20,000 tonnes each p.a. (Adams *et al.*, 2000). The aims of the Waste Strategy were:

- Greater diversion of waste from landfill, and substantial increases in recycling and energy recovery
- Involvement of the public in increased reuse and recycling of household waste
- To curb the growth in waste production
- For waste management decisions to be increasingly based on assessment of the best practicable environmental option (BPEO)
- To promote greater awareness of the end of life environmental impacts of products, beginning with product design
- The development of the market for secondary (recycled) materials
- Fulfilment of the UK's legal obligation under the 1990 Environmental Protection Act (amended by the 1995 Environment Act) to prepare a national waste strategy
- Fulfilment of requirements of the Landfill Directive, the Hazardous Waste Directive and the Packaging Waste Directive
- To ensure that waste management contributes to more sustainable development.

The activities of LAs have also been affected by the introduction of Best Value legislation in April 2000. This entails

- The establishment of authority-wide objectives and performance measures
- Performance reviews of selected areas of expenditure using the 4 Cs of Challenge, Compare, Consult and Compete
- Setting and publishing performance and efficiency targets
- Independent audit/inspection and certification (Adams *et al.*, 2000).

Best Value aims to ensure that all LA services are reviewed every five years, and the weakest areas of service provision should be addressed first. LAs are required to use Best Value as a tool to attain statutory and national recycling targets, and to achieve continuous improvement in sustainable waste management. They must also ensure that the quality and cost of their services reflect what local people want and can afford; that the efficiency and quality of services improve continually; and that they aspire to reach the best standards. Best Value requires the achievement of continuous improvement, and will impact on all waste services provided by waste collection and disposal authorities (Adams *et al.*, 2000).

It is aimed to apply the proximity principle in waste management and recycling. This means that waste should be disposed of as close as possible to its place of origin, partly to ensure that problems are not exported to other regions. It also recognises that the transportation of wastes can have a significant environmental impact. The proximity principle is a tool for planning authorities and businesses when considering the requirements for, and location of, waste management facilities and regional self-sufficiency and helps raise awareness in local communities. The proximity principle is particularly applicable to hazardous wastes, as transporting them over long distances may increase the risk of damage arising. It is also important that hazardous wastes are dealt with at facilities where they can be treated in an environmentally sound manner (DETR, 2000b).

In order to facilitate the management of waste in new ways, new and stronger markets need to be developed for recycled materials. A major new Waste and Resources Action Programme (WRAP) has been established to achieve this aim, by delivering more recycling and reuse, developing markets and end-uses for secondary materials, and promoting an integrated approach to resource use. WRAP is also responsible for facilitating markets, promoting investment in reprocessing; managing research and information, and providing advice, guidance and technical support (DETR, 2000).

2.1.1 Landfill

Currently significant quantities of valuable material are landfilled. Society cannot afford to continue wasting these materials, many of which are available in limited quantities in the environment, or are difficult or environmentally damaging to extract. The DETR (2000) feels that the development of more cyclical production and consumption processes will enable the reduction of raw material consumption and reduce the need for landfill. However, this will entail the greater provision of single material waste streams, greater reprocessing capacity, and more use of recycled or secondary materials in production processes.

The first major policy initiative to increase recycling in the UK was the introduction of landfill tax in 1996. This aimed to make landfill increasingly expensive, thus increasing the competitiveness of alternatives such as recycling (Woodard *et al.*, 2000). This was particularly important, as in 1996 the UK had the fourth lowest landfill costs per tonne of 10 countries studied. Landfill tax was initially set at £7 per tonne for non-inert wastes (most household and municipal wastes) and £2 per tonne for inert wastes (Read *et al.*, 1997). The 1999 Budget implemented an annual increase of £1 per year in landfill tax, to be reviewed in 2004. This provides waste producers and local authorities with a strong incentive to landfill less waste and also provides a clear basis for planning future waste management. A landfill tax credit scheme was developed to help deliver increased recycling, particularly of household waste. This enabled landfill operators to claim up to 90% tax credit against donations made to approved environmental bodies, not exceeding 20% of their annual landfill tax bill. Supported activities include reclaiming polluted land, research and education to promote reuse and recycling, providing public parks and amenities, and restoring historic buildings (DETR, 2000).

2.1.2 Energy recovery

The UK government and the Welsh National Assembly believe that energy recovery from waste has an important role to play in a system of sustainable waste management, and should be considered as a waste management option when recycling is not viable (DETR, 2000). Recovering energy from waste can have net environmental benefits relative to landfill because transport distances for sending waste for incineration are typically shorter. Also, the generation of electricity from waste reduces fossil fuel consumption. This provides an environmental benefit, particularly where the waste incinerated contains non-fossil carbon and where the electricity source displaced is more polluting than waste incineration (DETR, 2000b). It is anticipated that over the next two decades the number of EfW plants may increase substantially in the UK to partly meet the targets of the EC Landfill Directive (Purcell and Stentiford, 2000). It has been calculated that energy may need to be recovered from 4.9, 5.6 and 14.8 Mt MSW in 2005, 2010 and 2015 respectively, in order to meet the requirements of the Landfill Directive (Chilton, 2001).

Energy can be recovered from wastes by incineration; use of waste as a fuel substitute; recovery with energy release as a by-product (e.g. anaerobic digestion); and disposal with fuel recovery as a by-product (e.g. landfill gas). Emerging technologies include pyrolysis, fermentation, anaerobic digestion, gasification, and feedstock recycling or substitution. The most common method of energy recovery in the UK is incineration (DETR, 2000b). However, not all wastes are suitable for use as fuel (DETR, 2000), and incineration is typically considered the last resort for substances such as plastics (Bellmann and Khare, 1999). It is not suitable for inorganic wastes such as glass and metals, which have no calorific value and are highly suitable for recycling. Incineration is therefore only appropriate for these materials in circumstances where they cannot easily be separated from other combustible materials (DETR, 2000). Incineration of 34 million tonnes MSW can theoretically produce over 200 x 106 GJ of thermal energy (Darley and Bowell, 2001). Currently 200 MW of electricity is recovered annually from the combustion of 2.5 million tonnes (Mt) of MSW at 11 EfW plants in England and Wales (Chilton, 2001).

2.1.3 Composting

With the exception of paper, wood and some textiles, most biodegradable organic materials cannot easily be recycled. However, they can be made into compost, to replace peat and fertilisers. The UK government now believes that the proportions of biodegradable (53%) and kitchen and garden waste (20%) estimated to be present in MSW are now dated, and appear to greatly underestimate the amount of garden waste produced (Slater and Frederickson, 2001). Composting emits greenhouse gases as a by-product. If the process is managed carefully carbon dioxide is released, but if insufficient oxygen is present, methane is. Emissions from home composting are unlikely to cause environmental harm as they are diffuse (DETR, 2000b). Composting is important in sustainable waste management for the UK and could have a vital role to play in meeting the obligations of the Landfill Directive.

Composting is not widely used due to the comparatively low cost of landfill and the lack of a market for the product, as there is a negative perception of composted waste as a product and an absence of accepted standards for waste-derived compost (DETR, 2000b). However, the US and Germany have developed profitable markets (Gentil, 2001). A number of EU member states have established standards for compost, and the Composting Association has provided a voluntary scheme to enable producers to demonstrate that their compost is produced according to approved procedure and is of consistent high quality. Quality requirements for compost are designed to reflect acceptable risk to handlers, plants or the environment during normal use. Despite the potential problems of odour, high capital investment, and careful management required, the awareness of compost-derived products is growing, as is the demand for them (The Composting Association, 2002).

In 1999 about 619,000 tonnes of municipal organic waste was composted, of which 74% was municipal waste, the majority (93%) of which was green waste. This was comprised of 72% from CA sites, 17% from local authority parks and gardens, and only 4% from kerbside collections (Slater and Frederickson, 2001). Local authorities estimate that 200-300,000 tonnes of waste are composted at home (DETR, 2000b). The amount of municipal waste composted in 1999 was 21% greater than the previous year (512,000 tonnes) and the results were predicted to increase by a similar amount in 2000 (Slater and Frederickson, 2001). The proportion of organic waste collected from the kerbside has remained relatively constant since 1997, but is likely to increase in the future as many Local Authorities are planning or considering kerbside collection schemes for organics (Slater and Frederickson, 2001).

The UK recovery rate compares badly to the 77% achieved in Germany in 1997, particularly as about 10 million tonnes of municipal organic waste are theoretically available for composting. The centralised composting industry handles about 92% of all waste composted in the UK, differing significantly from other, more advanced, European countries (Slater and Frederickson, 2001). In 1999 90 operators were running 197 sites and processing 833,044 tonnes of material. Of these, 80 were centralised, processing 765,155 tonnes and employing 62 staff; 65 were on-farm sites operated by 18 co-ordinators/operators and processing 66,401 tonnes; and 52 were community sites, run by 10 co-ordinators/operators and processing 1,488 tonnes (Slater *et al.*, 2001). However, there are concerns about the composting industry's ability to deliver sustainable waste management in the longer term in the UK, given the large number of small sites with typical throughputs of 5000-6000 tonnes or less p.a. Additional concerns are that the UK industry is highly dependent on composting relatively benign garden wastes, which means that the industry is largely based on unsophisticated composting technology and systems, with 90% of sites employing open air windrow systems. Continued reliance on this source of waste will be insufficient to meet targets, and therefore kerbside collection and composting of kitchen and green waste need to be addressed (Slater and Frederickson, 2001). This will require major structural changes in the industry. It is aimed to reduce biodegradable municipal waste to 35% of 1995 levels by 2020 (Purcell and Stentiford, 2000). However, although composting can provide a treatment solution for many organic wastes, different wastes have specific characteristics, problems and legislation, which must be considered when selecting a composting system (Perryman, 2001).

It is estimated that about 70 million tonnes of potentially recoverable organic waste is produced in the EU each year. France produces 24% of this; Germany, Italy and the UK 15% each; Spain 11%; Austria 4%; Belgium, Greece and the Netherlands 3% each; Sweden and Portugal 2% each, and Denmark, Finland and Ireland 1% each. It is estimated that 15% of European biodegradable municipal waste is recovered through composting. The 5 countries with source segregation policies and infrastructure in place (Austria, Belgium, Denmark, Germany and the Netherlands), are responsible for about 85% of all organic waste collected and composted in the EU (Slater and Frederickson, 2001). However, it is thought that compost represents the use for only 1% of municipal waste in the UK, although for industrial and commercial wastes the figures are slightly higher (Gentil, 2001). The trend is towards increasing source segregation, but countries with poorly developed segregation schemes tend to compost unsegregated MSW, producing large quantities of low quality compost (Slater and Frederickson, 2001). Data on collection and composting of organic waste in the EU is presented in Table 4.

Table 4. Separately collected and composted household organic waste plus amounts of compost produced in various EU member states in 1997 (cited by Slater and Frederickson, 2001).

State	Household organic waste Quantity organic waste recovered (000 tonnes)	% of the total amount recoverable	Compost produced Quantity (000 tonnes)
Netherlands	1800	90	650
Denmark	500	55	250
Austria	1100	50	500
Germany	4000	45	2000
Belgium	320	34	160
Sweden	250	16	100
Luxembourg	7	14	3
Finland	70	10	30
UK	317	6	159
France	400	3	150
Italy	200	2	100
Portugal	0	0	0
Spain	0	0	0
Greece	0	0	0
Ireland	0	0	0
Total	8964		4102

2.2 Impact of various regulations

Waste legislation in England and Wales is driven by the need to manage waste safely and effectively, and also by international commitments and undertakings, particularly in the EU. The principal directive controlling waste management throughout the EU is the Framework Directive on Waste. The provisions contained in this Directive are implemented into UK law by the Environmental Protection Act 1990, as amended by the Environment Act 1995, together with other regulations on various aspects of waste management. These also provide a strategy for dealing with waste diverted from landfill as required by the Landfill Directive (DETR, 2000b).

A wide range of directives has been introduced to promote recycling. These include the End-of-Life Vehicles (ELVs) Directive and the Packaging and Packaging Waste Directive. The Landfill Directive, and the Integrated Pollution and Control (IPPC) regime will also have a great effect. An aggregates levy is being introduced in 2002 to reflect the environmental costs of quarrying more fully in prices, and encourage the use of alternative materials, such as mineral wastes and recycled construction and demolition waste. It will also help to address the high levels of waste in the use of construction materials (DETR, 2000). Therefore regulations have an important role to play in recycling and waste reduction. It is predicted that bans on sending post-use material into landfill will come into force, and that more customers will require recycling solutions to be incorporated into new acquisition programmes. End-of-life products will increasingly be dismantled to enable the collection, sorting and recycling of materials (Marsh, 2001).

2.2.1 Landfill Directive

This directive will ensure that landfill sites face strict regulatory controls on their operation, environmental monitoring and long-term care after closure. Many of the controls are similar to those in existence under the UK Waste Management Licensing Regulations1994 and the Environmental Protection Act 1990 (DETR, 2000b). The UK is one of the major users of landfill disposal in the EU, and opposed the site classification and waste treatment aspects of the Directive. It has been reported that more effort has been spent opposing the Directive than preparing for its implementation, and thus the UK is behind schedule (Barry, 2001). The most important measure in meeting the Landfill Directive targets is likely to be the minimisation of biodegradable municipal waste (Hogg, 2001).

Landfill results in the production of greenhouse gases as a by-product of the decomposition of biodegradable materials such as paper, food wastes and green waste in the absence of oxygen. Therefore legislation sets targets for the reduction of biodegradable municipal waste to landfill, and aims to reduce the quantity of biodegradable municipal waste landfilled to 75% of that produced in 1995 by 2010, 50% by 2013 and 35% by 2020. Meeting these targets will be a major challenge, and the halting of growth in UK waste production will be critical. If waste production stabilises at current levels then by 2020 about 10 million tonnes of biodegradable waste would have to be diverted each year. The Landfill Directive also requires all landfill sites accepting biodegradable wastes to capture and use methane where possible. This results in the conversion of methane to the less potent carbon dioxide, and can displace some electricity generation from fossil fuels. A DETR research study estimated that these measures are likely to produce savings of 0.1 to 0.4 million tonnes of carbon in UK greenhouse gas emissions by 2010 (DETR, 2000). Estimates of the quantities of biodegradable MSW and organic waste to be diverted from landfill to meet the Landfill Directive Targets are provided in Table 5. This data assumes 1995 UK municipal waste arisings of 29 million tonnes, with a 3% annual increase, that composting of the biodegradable fraction remains constant at 53-60%, with the organic fraction ranging from 20-30%. It also assumes that the Landfill Directive targets will apply equally to each type of biodegradable MSW; and that the UK opts for the four year derogation period (Slater and Frederickson, 2001).

Table 5. Estimates of the quantities of biodegradable MSW and organic waste to be diverted from landfill to meet the Landfill Directive Targets (after Slater and Frederickson, 2001).

Year	Total BMSW to be diverted (million tonnes p.a.)	Organic fraction to be diverted (million tonnes p.a.)
2010	12.4-15.5	4.9-7.7
2013	18.5-219	7.3-10.9
2020	26.8-310	10.6-15.5

The Landfill Directive requires landfill sites to be categorised as hazardous, non-hazardous or inert, effectively ending the traditional UK practice of co-disposing of hazardous waste with non-hazardous waste. This will necessitate the modification of landfill sites and the development of alternative means of dealing with hazardous wastes, as hazardous materials will have to be sent to specifically designed facilities. Because of the relatively low level of arisings of some of these wastes, there are likely to be relatively few suitable facilities available initially. It is therefore important that waste planning authorities and businesses consider the need for a network of specialised disposal facilities, and collaborate accordingly. The Landfill Directive will also result in an increased requirement for pre-treatment of waste prior to landfilling. The directive bans the disposal of certain materials to landfill, e.g. if they posses corrosive, oxidising, flammable or liquid properties. The implications of this on waste management in the UK are extensive, as in 1997/8 and 1998/9 53% and 47% of hazardous wastes were disposed of to landfill respectively (DETR, 2000b). The landfill of whole and shredded tyres will have to cease by 2003 and 2006 respectively. Additionally the Directive makes provisions for the control, monitoring, reporting and closure of sites, which already form the core of UK waste management legislation (DETR, 2000).

2.2.2 End of Life Vehicles (ELVs)

There are estimated to be about 27 million motor vehicles in use in the UK (Ambrose, 2000). Typically just over 2 million new vehicles are registered, and 1.5-2 million scrapped, annually in the UK (Grant, 2001; Ambrose, 2000). Tens of millions vehicles are scrapped annually in Europe (Aboussouan *et al.*, 1999), either because of their age (typically around 12 years) or because they have been heavily damaged in accidents (DETR, 2000b). The automotive sector generates about 5% of the world's industrial waste (Bellmann and Khare, 1999). Automobiles are among the most highly recycled consumer products, with about 75% by mass being recycled though used-parts sales and metal recovery and recycling (Ambrose, 2000; DETR, 2000b). However, the European dismantling industry has a market structure characterised by a large number of operators, most of which are small and technically ill-equipped, labour intensive, and with limited geographical activity (Bellmann and Khare, 2000). Recycling of materials other than metal e.g. plastic, glass and rubber, is more technically and economically difficult, and currently these substances are disposed of to landfill in the form of automobile shredding residue (ASR). This form of waste has been variously reported to account for 0.3% of total UK controlled waste production (DETR, 2000b) and 450,000 tonnes of the waste landfilled annually (Ambrose, 2000). The composition of a typical (13 year old) car tends to be as illustrated in Table 6 (Ambrose, 2000).

Table 6. The composition of a typical 13 year old car.

Ferrous	65.0%	Tyres	3.0%
Non-ferrous	8.0%	Polyurethane seat foam	2.0%
Thermoplastics	8.0%	Thermoset plastics	1.5%
Rubber seals hoses etc.	4.0%	Fluids	1.0%
Other	3.5%	Battery	1.0%
Glass	3.0%		

The waste fraction includes plastics, fabric, wood fibre, rubber, glass and paint, in addition to hazardous substances such as polychlorinated biphenyls and heavy metals and fluids such as petrol, motor and gear oil, hydraulic and brake fluids, and anti-freeze. Air conditioning systems containing CFCs and airbags with explosive components also enter the waste stream from more modern cars. Therefore shredder waste and vehicle oil waste is considered to be hazardous by EC and national waste legislation (Bellmann and Khare, 1999). However, substances such as PVC, mercury, lead, cadmium and hexavalent chromium will be banned from cars from 2002 (Bellmann and Khare, 2000).

Plastics typically form about a third of the non-metallic fraction, and usually more than 20 types are present (Bellmann and Khare, 1999). However, although 10-20 kg of mixed plastic can be recovered relatively quickly, there is potential for material contamination, and the contribution towards attaining the recycling targets is relatively small (Ambrose, 2000). Surveys have shown that only about 40% of plastics used in vehicles are suitable for mechanical recycling. However, insufficient quantities of suitable waste, low quality of waste, lack of markets for the products, and negative marginal features of the business environment, reduce the figure to 15-20% (Bellmann and Khare, 1999). Therefore, addressing plastic recycling is important in solving the ELV waste problem, the alternative being the decrease of plastics in car materials. This means that many plastic producers and recyclers consider the ELV Directive to be a threat. However, the limited competition for materials such as glass, textiles and rubber used in the automotive industry, means that some industries affected by the legislation appear to be relatively passive towards the problem (Bellmann and Khare, 2000).

The ELV Directive requires manufacturers to reuse or recover about 95% by weight of a used automotive vehicle's structure by 2015, of which at least 90% should be recycled (Bellmann and Khare, 2000; Marsh, 2001). Manufacturers will be required to reuse or recover at least 85% by weight of ELVs by 2002, of which at least 80% should be recycled (Bellmann and Khare, 2000). Therefore the proportion of waste that can be incinerated with energy recovery is limited, which means that substantial improvement in mechanical and chemical recycling rates are required. This would reduce the amount of automobile waste sent to landfill to 15% and 5% by 2006 and 2015 respectively. However, meeting the targets is an enormous challenge, particularly when the packaging waste targets and implications of the WEEE Directive are taken into account (Ambrose, 2000). The Directive also requires manufacturers to design vehicles with recyclability and reuse in mind, and systems to be established to ensure that all ELVs are collected and brought to recognised treatment facilities (DETR, 2000). This includes the introduction of certificates of destruction, issued when the vehicle is discarded by the last owner (DETR, 2000b).

The cost of returning the ELV to the manufacturer would be too high, and so take-back means that the manufacturer must assume responsibility for the ELV and arrange for reuse, recycling or disposal. However, the automobile industry is opposing the strict application of the producer responsibility principle (Bellmann and Khare, 2000). Car manufacturers are lobbying for a visible fee on new products sold to cover the costs of their take-back (Grant, 2001). The main barrier to ELV recycling is the cost of recycling and disposal, exacerbated by the manual labour required for dismantling. These costs will ultimately be reduced with the introduction of design for recycling, and the development advanced dismantling systems, although automated systems are unlikely to be able to produce good quality secondary materials due to the variety of materials contained within cars (Bellmann and Khare, 2000). If the problems of recycling can be overcome, over 90% by weight of a used vehicle could be recycled (Bellman and Khare, 1999).

The new regulations have motivated car manufacturers to think of redesigning their products for Europe, taking into account the requirements of post-use collection, sorting and recycling, which should ultimately reduce the costs of recycling and make

Controlled waste (registration of carriers and seizure of vehicles) regulations 1991, SI 1624
Controlled waste regulations 1992, SI 588 (as amended)
Council Directive 1999/31/EC on the Landfill of Waste
Council Directive 96/59/EC of 16 September 1996 on the disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCB/PCT)
Directive 75/439/EEC on the Disposal of Waste Oils (amended by 87/101/EEC and 91/692/EEC)
Directive on Integrated pollution prevention and control (96/61/EC)
Directive on Packaging and packaging waste (94/62/EC)
Environment act 1995
Environmental Protection (Duty of Care) Regulations 1991 SI 2839
Environmental protection (Duty of care) regulations 1991, SI 2839
Environmental protection (waste recycling payments) regulations 1992, SI 426
Environmental protection act 1990
Finance act 1996
Local government act 1985
Merchant shipping and maritime security act 1997
Packaging (Essential requirements) regulations 1998, SI 1165.
Planning and compensation act 1991
Prevention of air pollution from waste incinerators (Directive 89/369/EEC; 89/429/EEC)
Producer responsibility obligations (packaging waste) regulations 1997, SI 648
Special waste (amendment) regulations 1997, SI 251
Special waste regulations 1996 SI 972 (as amended)
The Batteries and Accumulators (Containing Dangerous Substances) Regulations 1994 (SI 232; amended by 93/86/EEC, 98/101/EEC)
The Hazardous Waste Directive (91/689/EEC; amended by 94/31/EEC)
The Hazardous Waste Incineration Directive 94/67/EEC
The Landfill Tax Regulations 1996 (SI 1527)
The Local Government (Best Value) Performance Plans and Reviews Order 1999 (SI 3251)
The Pollution Prevention and Control (England and Wales) Regulations 2000 (SI 1973)
Town and country planning (General Development Procedure) order 1995, SI 419
Town and country planning (General Permitted Development) order 1995, SI 418
Town and country planning act 1990
Town and country planning general development order 1988, SI 1813
Waste Management Licensing Regulations 1994 SI 1056, as amended
Waste management licensing regulations 1994, SI 1056 as amended
Waste Minimisation Act 1998
Waste Shipments Regulation 1993

Selling packaged goods	48%
Filling packaging	37%
Making packaging	9%
Making raw materials for packaging	6%

The capacity to reprocess sufficient packaging waste to meet targets in 2001 and beyond varies greatly from material to material. External factors such as virgin material prices and global waste material prices, which affect the demand for waste materials in the UK, further influence investment in recycling. The lack of capacity to collect and recycle plastic packaging waste remains the most significant obstacle to the UK's overall reprocessing ability. In 2000 the capacity to recycle plastic packaging waste was 150,000 tonnes, and was anticipated to reach 255,000 tonnes in 2001. If this level is attained, the UK is likely to meet the minimum recycling requirement under the packaging directive, but this will only contribute marginally to the much larger recovery target (DETR, 2000b).

2.3 Materials

2.3.1 Plastic

It is estimated that 2.8 million tonnes of various types of plastic waste are generated in the UK annually. Packaging currently accounts for approximately 60% of this. However, plastics can only be recycled a few times, as the material loses some of its useful properties every time it is recycled, and thus recycling only delays the final disposal (Bellman and Khare, 1999). Typically recycled plastic is mixed with virgin material to manufacture high quality products (Smith, 2001). The construction industry consumes about 25% of all plastics and is a potential outlet for plastic recyclates (Marsh, 2001).

Waste plastics are currently mainly disposed of to landfill, with some incineration and recycling. Traditionally, they have tended not to be recycled due to cost and decontamination implications. Plastics contribute about 11% of material in the household waste stream (DETR, 2000b), while plastic bottles typically account for 1.9%, which means that an average house throws away 12.9 kg of plastic bottles annually. Most plastic food packaging ends up in the domestic waste stream, contaminated with food or other waste which, combined with the low weight of much of the material, makes recycling uneconomic. Post-consumer plastic recycling schemes have concentrated on used bottles because the markets for these exist, the bottles are readily identified and separated from other refuse by the consumer and, although only a minor part of the waste stream by weight, bottles comprise a significant volume. Recycling of post-consumer polyethylene terephthalate (PET), polyvinyl chloride (PVC) and high-density polyethylene (HDPE) bottles is expected to make a significant contribution to the target of 15% recycling of plastic packaging waste by 2001. Plastic bottle recovery from domestic waste has grown steadily since 1990. However, it is generally unprofitable, and so the vast majority of UK schemes are run or sponsored by Local Authorities (Smith *et al.*, 1999). In 1999 11,300 tonnes of plastic bottles were collected for recycling in the UK, less than 5% of those used, and included about 4,500 tonnes of PET bottles (Smith, 2001). The types of plastic in the domestic waste stream can be seen in Table 9.

Table 9. Percentage quantities of plastic types in household waste in Europe (after DETR, 2000b).

Type	Percentage
Low density polyethylene (LDPE)	23%
High density polyethylene (HDPE)	17%
Polypropylene (PP)	19%
Polystyrene (PS)/Expanded Polystyrene (EPS)	12%
Polyvinyl Chloride (PVC)	11%
Polyethylene Teraphthalate (PET)	8%
Other plastic types	10%

In 1999 demand for recycled PET outstripped supply capacity for the first time in 10 years due to its increased consumption in packaging, where it is taking market share from glass and PVC. Recycled PET is particularly desirable as the molecular weight can be increased to a higher value, thus generating material with a performance superior to the virgin material. This is not achievable with other plastics. It is forecast that 500,000 tonnes will be collected in 2004 and 700,000 in 2008, but this is not considered sufficient to meet market requirements. The prices of virgin PET are therefore likely to increase together with prices for recycled PET. Globally 17% of PET bottles are collected for recycling, about 900,000 tonnes. About 219,000 tonnes (~14%) is collected in Europe, where Italy, France, Belgium and Switzerland contributed 75% of the total (Smith, 2001).

2.3.2 Paper

The volume of paper and paper products in household waste (31%) combined with the scarcity of landfill capacity are major problems, and a driving force behind legislation, and therefore increased recycling is assumed to be desirable and necessary. Fibre strength decreases during recycling and individual fibres cannot be used indefinitely. Therefore the addition of virgin paper helps to maintain the overall quality of the recycled product (DETR, 2000b). Recovery and recycling more of this waste stream could save up to £150 million on disposal and tax costs (Read *et al.*, 1997). However, it is not possible to recover all paper, as 0.9 million tonnes is used for hygiene purposes, while more is stored as books, wallpaper and office files (DETR, 2000b).

The top ranking countries in Western Europe for waste paper recovery in 1993 were Austria and the Netherlands, which had 71% and 63% recovery respectively, followed by Germany and Sweden with 56% and 52% respectively. The mean recovery rate for the EU was 42%, for Finland and Canada was 46% and the USA was 39% (Byström and Lönnstedt, 1995). In 1994 the UK consumed about 11.6 million tonnes of paper and board. Thirty-one per cent of this was recycled, and the remaining 8 million tonnes were landfilled (Read *et al., 1997*). The rates are now increasing for most regions and counties, and the EU increased from 31% in 1974 to 42% in 1992, with a global increase from 29% to 38% (Byström and Lönnstedt, 1995). In 1998 the UK imported 60% of its annual paper requirement, which was 7.4 million tonnes of paper from overseas, with major suppliers being Finland and Sweden. Over 4.6 million tonnes of all paper was recycled into the UK's production of 6.5 million tonnes in 1998. An additional 0.4 million tonnes were exported while imports were minimal. Paper and card accounted for nearly 40% of the household waste collected for recycling in 1997/98. Waste paper and virgin pulp are world traded commodities and are therefore subject to fluctuations in demand and price (DETR, 2000b).

Newspapers are a significant part of the household waste stream (DETR, 2000). They are recycled in large quantities, together with magazines, mainly for newsprint, while office waste is a key source of high quality grades used to make mainly new hygienic and graphic papers (DETR, 2000b). In 1999 the estimated recycled content of newsprint increased to 54%, compared to the 28% achieved in 1991. The UK government has been working with the Newspaper Publishers Association and in April 2000 agreed on the achievement of 60% recycled content in newspapers by the end of 2001, 65% by the end of 2003 and 70% by the end of 2006. Other problematic elements of the waste stream include junk mail, which can be a significant and often unwelcome element. It is also growing, and grew from 1.5 billion to 3.3 billion between 1990-1999 in the UK (DETR, 2000). The type of paper and their percentage of UK production can be seen in Table 10.

Table 10. Types of paper, the tonnage and percentage of UK production in 1998 (DETR, 2000b).

Type of paper	UK production (tonnes)	% of UK production
Newsprint	1,043,000	16%
Printings and writings	1,767,000	27%
Corrugated case materials	1,760,000	27%
Packaging papers	160,000	2.5%
Packaging board	667,000	10.5%
Household and sanitary	635,000	10%
Other paper	441,000	7%
Total	6,473,000	100%

2.3.3 Rubber

Within the petroleum chemical industry over one hundred million tons of polymer materials are discarded as waste world-wide every year. These are not biodegradable, and are thus classified as non-environmental materials. Rubber is one of the three main polymer groups, and much waste is produced every year. The main source of waste rubber is discarded products such as tyres, pipes, belts, shoes, and edge scraps, and process waste (Fang *et al.*, 2001). It is estimated that about 40 million tyres (465,000 tonnes) were scrapped in 1998, of which value was recovered from almost 70%. Recovery methods included retreading (18%), energy recovery (18%), re-use (18%), recycling (10%) and landfill engineering (5%). A forecast of developments up to 2003 showed an upward trend in the recovery rate over the next four years, with the growth in the use of tyre-derived fuel in cement kilns being a particularly notable feature. A 90% recovery of scrap tyres is anticipated by 2003 (DETR, 2000b).

Tyres can be retreaded safety, as wear accounts for only 10% of the total weight. This consumes much less energy and material than original production, and accounts for 85% of the demand for truck and bus tyres, although it is only 50% of this market. However, a large percentage of old automobile tyres is useless due to excessive wear, and the public has a poor perception of remoulded tyres, which are in competition with cheap imports. The cost of sorting the usable from unusable tyres, and safe disposal of unsuitable tyres, makes the process uneconomical (Ayres *et al.*, 1997). Recycling of waste rubber protects the environment, conserves energy, and reduces the quantities of raw materials used (Fang *et al.*, 2001).

The status of scrap tyres has evolved from waste to environmental problem to resource in just over a decade. Old tyres are generally processed into smaller pieces for reuse or further processing. For basic uses shredding is usually sufficient. However for most other uses tyre chips must be reduced further to produce more usable, higher value materials such as crumb rubber. Crumb rubber can also be coated to improve its bonding characteristics, or pyrolised to produce char, oil and gas. Recycled rubber typically lacks some of the elasticity and other characteristics and flexibility of virgin rubber, and therefore usually sells for 20-30% less than the virgin material. However, in some applications suitable grades of recycled material can achieve higher prices, provided their use does not increase the total process costs (Owen, 1998). Tyres can only be used as fuel in specially designed power plants or cement kilns, and only the oil refining value is recovered, about 1.5% of the total value in the tyre (Ayres *et al.*, 1997). The main recycling approach for waste rubber is the manufacture of powdered rubber (Fang *et al.*, 2001), although modification into asphalt is being seriously investigated (S. Ikin, Retread Manufacturers Association, pers. comm.).

Traditionally tyres were buried in landfill. This has now been banned because tyres take up a lot of space and tend to work their way to the surface over time, damaging topsoil, and causing leaching problems. In the US monofills have been under consideration, as this avoids the environmental problems of mixing tyres with other landfill materials. However, it requires capital for land, shredding and handling. When landfilling of tyres was banned in the US 2-3 billion tyres were estimated to be stockpiled (Owen, 1998). Large stockpiles of worn-out tyres are also accumulating in many other countries, and constitute fire hazards (Ayres *et al.*, 1997). They also collect rainwater and thus promote the breeding of mosquitoes, and provide breeding grounds for rats and other pests. However, the stockpiles can also prove a steady source of materials for recycling companies attempting to develop long-term tyre acquisition strategies (Owen, 1998).

2.3.4 Electrical items

The substantial rise in home ownership of computers and related equipment has led to a rise in obsolete or outdated equipment being thrown out (DETR, 2000b). Disposal represents 3% of direct production costs of cars, and 12.5% of refrigerators and freezers (Ayres *et al.*, 1997). The Industry Council for Electronic Equipment Recycling estimated that 398,000 tonnes of data processing and electronic office equipment were disposed of in 1998, of which only 25% was recycled. It is estimated that about 7 million tonnes of post consumer waste electrical and electronic equipment is produced annually in the EU (Precious Metal Industries (Wales) Ltd., 2001). However, the circuitry in such equipment can often be put to good use in other products (DETR, 2000b).

The Waste Electrical and Electronic Equipment (WEEE) Directive requires manufacturers to recycle a specified proportion of each product's weight, ranging from 50% for toys to 75% for large appliances such as refrigerators (Grant, 2001). Trials throughout Europe have typically collected 30-40% of large items and 10% of small items, although there is a wide variation between the results of different trials. For some types of equipment, particularly IT, the markets for refurbished equipment are growing (DETR, 2000b). However, the low rate of return of used IT equipment constrains recovery and recycling (Ayres *et al.*, 1997).

There have been no detailed analyses of the electrical and electronic equipment waste streams, so data on the amount of electrical and electronic equipment entering the waste stream has been estimated using predicted product lifetimes and market saturation information. Estimates indicate that about 1 million tonnes of this equipment is entering the UK waste stream each year, although it comprises less than 1% of the total waste stream. It is estimated that large household appliances, such as refrigerators, freezers and washing machines, and IT equipment comprise more than 80% of this. A growth in waste production may lead to an increased proportion of electronic equipment in the waste stream (DETR, 2000b).

2.3.5 Glass

Glass recycling involves the collection of waste glass bottles and jars and crushing them into cullet, which is used with virgin material to make new products. The recycled glass is separated by colour, usually at the collection point, and all non-glass materials are removed prior to crushing. The main barrier to the recycling of glass is the shortage of brown and white cullet in the UK. However, some markets have emerged for mixed glass, thus reducing the need for separation. The major obstacle to the more traditional glass recycling markets is the excessive imports of green glass, principally wine and beer, and the absence of UK markets for this material as the UK mainly produces white and amber glass. Approximately 22% of glass is recycled (DETR, 2000b). The data for UK consumption and recycling of glass container cullet can be seen in Table 11.

Table 11. UK consumption and recycling of glass container cullet (DETR, 2000b).

Year	Total Consumption (tonnes)*	Total recycled (tonnes)*	% recycled	No of sites in UK Bottle Bank scheme
1993	1,810,000	395,000	21.8%	10,965
1994	1,800,000	404,000	22.4%	12,858
1995	1,900,000	412,000	21.7%	14,300
1996	2,000,000	430,000	21.5%	15,609
1997	2,100,000	440,000	21.0%	19,341
1998	2,200,000	476,000	21.6%	-

* Estimates

The percentage of glass in an average household waste stream is estimated to be about 9%. Recycling legislation should help to reduce this, as Landfill Tax is expected to encourage LAs to develop alternative reuse and recycling schemes for glass wastes. It is also likely that the packaging regulations will cause the UK to improve its glass recycling performance, with over 300,000 tonnes of packaging and container glass being recycled by 2001 (DETR, 2000b).

2.3.6 Metals

Until the relatively recently metals were never discarded, due to their value and scarcity. However, today waste is the norm, even for metals such as gold, silver and platinum. The principal exceptions to the dissipative uses of metals are jewellery, coins and long-lived structural materials (Ayres, 1997). The average recycling rate for metals was fairly stable between 1984 and 1998, at about 40% (DETR, 2000b). The amount of metal obtained annually from secondary sources rose steeply between 1987 and 1996 for aluminium (from 30 to 40%) and lead (from 56 to 69%) but has remained fairly constant in the other cases (Ayres, 1997). Many environmental benefits can be gained from reuse of metals, e.g., one ton of recycled copper avoids the mining of at least 200 tons of copper ore, one ton of explosives, one tonne of hydrocarbon fuel, and half a ton of flotation chemicals (Ayres *et al.*, 1997). The mining and production of metal from ore is energy-intensive and, with the exception of iron and aluminium, the quantities of wastes produced by mining for ores is far greater than the quantities of metals produced (Ayres, 1997). Therefore as specialised technologies and markets have arisen for recyclable metals, recycling benefits the environment.

Scrap metal is derived from two sources: new scrap derived from metal processing e.g. off-cuts, stampings, turnings, etc., of which almost 100% is recycled. Old scrap is derived from end of life or obsolete products and includes heavy scrap from dismantling industrial plant, railway rolling stock and track, and light scrap from the processing of consumer goods. Currently there is no practical limit to the amount of steel packaging waste that can be recycled by industry, and therefore the challenge is to increase collection, particularly from the household waste stream. Increasing collection is critical and the rate of collection will determine how much of this capacity will be utilised (DETR, 2000b). The scrap used as a percentage of consumption is given in Table 12.

Table 12. Scrap reused as a percentage of consumption

Year	Iron	Lead	Copper	Zinc	Aluminium
1992	45%	64%	35%	21%	39%
1993	42%	67%	35%	21%	29%
1994	42%	74%	32%	20%	39%
1995	40%	71%	34%	20%	53%
1996	44%	73%	36%	19%	44%
1997	45%	69%	37%	19%	40%
1998	39%	66%	38%	18%	43%

2.3.7 Batteries

The 1991 Batteries and Accumulators Directive applies to primary and secondary batteries containing lead, mercury or cadmium (less than 10% of all batteries sold). (DETR, 2000b). Most member states failed to implement the requirements of the directive by the specified date in 1992 (Ahmed, 1996). All batteries contain hazardous substances in various quantities. Therefore the EU is considering proposing collection and recycling targets for all waste batteries, and hope to restrict the marketing of nickel cadmium batteries from 2008 where suitable substitutes exist (DETR, 2000).

Batteries can be generally be classified into two main types: automotive and consumer. Automotive batteries are normally recycled, but the majority of consumer batteries are thrown away. This will have to change if EC legislation sets collection and recycling targets for these wastes. About 10 million lead acid automotive batteries are sold in the UK annually, and a similar number disposed of. In 1997/98 140,000 tonnes of lead acid batteries were recycled in England and Wales, rising to 144,000 tonnes in 1998/99. They are classified as special waste due to their sulphuric acid and lead content. Consumer batteries can be categorised into single-life types e.g. zinc-carbon, alkaline-manganese and button cells, and rechargeable varieties e.g. nickel-cadmium and nickel-metal hydride. About 600 million consumer batteries, or 20,000-40,000 tonnes, are thrown away annually, much of which enters the household waste stream. At present less than 1000 tonnes of consumer batteries are classified as special waste annually in England and Wales, and disposed of accordingly, and only nickel-cadmium consumer batteries are collected in any numbers (DETR, 2000b). Although 15,000 tons of Ni-Cd batteries are scrapped annually in Europe (10,000 tons sealed and 5000 tons industrial units) it is thought that only 28% of used industrial units and 3% of sealed units were recycled, giving total recycling of 11% (David, 1995). An industry-led programme (REBAT) in the UK is now recovering increasing quantities of batteries from industrial and commerce, which are being shipped to France for recycling, as part of the implementation of the 1991 directive. The scheme aims to recycle 1,550 tonnes of waste batteries over four years (DETR, 2000b).

2.3.8 Textiles

Estimates for the annual generation of textile waste vary from 550-900,000 tonnes. This is in the form of post industrial wastes, generated through yarn and fabric manufacture, garment-making and from the retail industry, and post consumer wastes. It is estimated that 25% of post-consumer waste is recovered annually. Of these, 43% becomes second-hand clothing, 12% wiping cloths, 22% filling materials, 7% fibre reclamation, 9% are reusable second-hand shoes, and 7% is rejected. Textiles made from both natural and man-made fibres can be recycled. Prices for both waste textiles from clothing banks and sorted textiles increased significantly in mid 1996. However, prices have dropped since 1997 and are now similar to or less than their 1995 values, which may be detrimental to textile recovery (DETR, 2000b).

2.3.9 Oil

Waste oils include mineral oil from automotive, industrial and other sources. Most lubricating oils contain additives to produce specified oil performance. These may include rust inhibitors, detergents and alkaline compounds, and constitute 5-25% of oil formulation. This means that waste oils often contain traces of additives and contaminants, including metals or combustion products. Waste oil can be regenerated, combusted after treatment; or combusted without treatment. However, priority is attached to the regeneration of waste oils for reuse in lubrication, in line with the Waste Oils Directive. The next best option is to it burn as fuel, and approximately 390,000 tonnes of waste oil is burnt p.a. (DETR, 2000b).

3. Training

Historically, those employed in the waste management industry acquired practical skills on the job and required no formal qualification to demonstrate operational competence. This situation has changed significantly in the last 10 years, commencing with the introduction of the Environment Protection Act in 1990 and continuing with waste management licensing legislation in 1994. This legislation introduced the concept of competence and the need to be able to demonstrate it against a recognised occupational standard. Additionally, new waste management skills will be needed in the 21st Century as the industry responds to the challenge of introducing more sustainable waste (resource) management practices, as expounded in the Government's Waste Strategy 2000 and the EC Landfill Directive (WAMITAB, http://www.wamitab.org.uk).

Business growth depends on producing high quality products and services, and these depend on people's skills and commitment to the business. It is therefore necessary to improve the skills of the workforce to keep pace with the new technologies that are affecting the waste management industry. Skills, qualifications and competence all improve competitiveness and the quality of services. Qualifications provide the platform for learning and continuous improvement, both in terms of career development and corporate objectives. New qualifications for work have emerged to help industries and their employees cope with these changes. These comprise Scottish Vocational Qualifications (S/NVQs) (Scotland), and National Vocational Qualifications (NVQs) (England, Wales & Northern Ireland). Individuals completing S/NVQs gain skills, knowledge and a better understanding of their job in addition to documentary proof of their abilities to show prospective employers and regulators. S/NVQs can help to encourage people to work to their full ability. Many companies have noticed that employees working towards S/NVQs are more confident. Any company, whether in the public or private sector, that is committed to investing in its people by training and developing them to their full potential, will benefit from reduced staff turnover and the significant associated costs of recruitment and retraining (WAMITAB, http://www.wamitab.org.uk). More information on training currently being carried out within the sector can be seen in the Expert Interview Report.

4. Recycling businesses in the UK

An analysis of companies involved in recycling was undertaken using the FAME database. FAME contains detailed information on public and private companies in the UK and Ireland. It is reputed to be the leading UK company information solution, and was originally launched in 1988. It contains information on all UK registered companies including those that have recently formed and have yet to file their first set of accounts. Detailed information exists on 500,000 companies, summarised information for a further 1.7 million companies, giving coverage of 2.3 million firms. However, as the DTI estimated that there were 3.7 million active businesses in the UK at the start of 2000, it can be seen that there are some gaps in the FAME database.

The FAME database uses SIC codes. SIC codes have a number of limitations, including misclassification of companies, and the fact that some companies involved in activities which may be considered recycling, may not be identified as such using the SIC codes. This includes companies involved in the sale of recycled products, which are considered to be retailers, or those transporting waste for recycling. For this reason the results obtained from FAME were compared to information from the DTI. Small and Medium-sized Enterprise (SME) Statistics for the UK, 2000. The results were then used to determine the most appropriate company types to include in the case studies.

4.1 Number of live, active recycling companies

It was estimated that there were 3.7 million active businesses in the UK at the start of 2000. Only 1.1 million of these were employers, the rest being sole traders. Small businesses, including those without employees, accounted for over 99% of businesses, 44 percent of non-government employment and 37 percent of turnover (DTI Press Release, 2001). Recycling businesses are located within the manufacturing sector, and form group 37 in the SIC system. Manufacturing accounts for 8.9% of all enterprises, 18.9% of employment and 23.7% of turnover (DTI Statistics, 2001). The SIC codes break recycling activities down into two categories:

3710 Recycling of metal waste and scrap
3720 Recycling of non-metal waste and scrap

Companies in these categories were identified through the FAME database. A total of 721 companies were in these two categories in England, Wales and Scotland. Of these companies, 276 (38.3 %) were involved in 'Recycling of metal waste and scrap', while 445 (61.7 %) were involved in 'Recycling of non-metal waste and scrap'. The FAME data was analysed to determine the number of live companies. The results achieved are illustrated in Table 13.

Table 13. The activity status of recycling companies in the UK.

Status	Number
Ceased	1
Receivership	2
Liquidation	33
Dissolved	59
Live	626
Total	721

It was found that 95 (13.2 %) of the firms had ceased to exist, through receivership, liquidation, dissolving of the firm, or unspecified means. Of these, 59 (62.1 %) were involved in the recycling of non-metal waste and scrap, while 36 (37.9 %) were involved in the recycling of metal waste and scrap. The proportions of the two types of recyclers which ceased to exist was therefore the same as the overall breakdown of business activities. Hence it was concluded that the type of recycling did not affect whether or not the companies continued to trade. The total number of live firms was therefore 626.

It was observed that a number of the live companies had dormant account types. The accountancy systems of the firms were therefore examined to isolate those which were actively trading. The results were as illustrated in Table 14.

Table 14. The accounts types of the live firms identified through FAME.

Accounts Type	Number
Dormant	58
Full	199
Small Company	310
Medium Company	6
N.A./not given	41
Group	12
Total	626

It was seen that 9.3 % of the firms had dormant accounts, indicating that, although the firm is technically live, it is not trading. A further 15 companies were dormant in terms of their activities. Therefore a potential maximum of 553 companies, or 77% of the total number of companies identified in the UK, were identified as being active through the FAME database. The final figures identified 212 businesses as being involved in metal recycling, and 341 as being involved in non-metal recycling. It was found that the percentages of companies involved in recycling of metal and non-metal waste and scrap remained broadly similar to those identified previously, at 38.3 and 61.7 % respectively. Again it was seen that the nature of the recycling business did not appear to determine the success of the business. When Table 15 was examined it was found that the DTI estimated all recycling enterprises to total 2,220, although 880 employed staff. This indicates that the FAME database greatly underestimates the amounts of businesses in the recycling category. Businesses excluded from FAME are likely to principally include those with few or no employees.

Table 15. Distribution of Businesses within the recycling sector in terms of enterprises, employment and turnover (DTI, 2001).

37 RECYCLING	Number			*Percent*		
	enterprises	employment ('000)	turnover (£ million)	*enterprises*	*employment*	*turnover*
All enterprises	2,220	13	1,414	*100.0*	*100.0*	*100.0*
With no employees	1,340	2	81	*60.4*	*14.4*	*5.7*
Employers	880	11	1,333	*39.6*	*85.6*	*94.3*
1-4	445	1	123	*20.0*	*10.7*	*8.7*
5-9	195	1	127	*8.8*	*10.5*	*9.0*
10-19	150	2	231	*6.8*	*16.3*	*16.3*
20-49	55	*	*	*2.5*	*	*
50-99	20	*	*	*0.9*	*	*
100-199	10	*	*	*0.5*	*	*
200-249	0	*	*	*0.0*	*	*
250-499	5	*	*	*0.2*	*	*
500 or more	0	*	*	*0.0*	*	*

* replaces data for groups of fewer than 20 enterprises to avoid disclosure. Also used in some larger groups, presumably also for avoidance of disclosure.

4.2 Nature of business

Only 172 of the 553 companies listed their business activities in more detail than that given by the SIC codes. The activities included the following:

Recycling of metal waste and scrap
Collection and sale of salvable materials, through local authority kerbside collections
Construction, demolition and industrial dismantling.
Disposal of test and prototype vehicles for motor company.
Electronic equipment recycling
Extraction and processing of precious metals from electronic/computer/telecommunication waste
Fluorescent tube recycling
Industrial, commercial and domestic waste disposal.
Motor salvage dealers
Precious metal recovery and trading.
Scrap metal dealing/processing/marketing/recycling/distribution/export
Skip hire, waste recycling, tipping
Waste management system development
Waste recovery for manufacturers, processors and major users of photographic chemicals and materials.

Recycling of non-metal waste and scrap
Acquisition, sorting and grading of waste cuttings for re-manufacture
Chemical recycling
Collection and sale of salvable materials
Concrete/building waste recycling/ sale
Education
Environmental disposal of spent lamps.
Glass importing/ recycling
Importing & exporting of blast furnace slag
Organic waste systems
Plastic/ rubber/ polystyrene cup/ PVC recycling, reprocessing, sale
Printing and photographic waste control specialists.
Recycling and skip hire
Recycling inferior oil products into superior products.
Recycling electrical oils.
Recycling waste material to produce woodchip
Remanufacture and sale of high quality laser printer and ink
Reprocessing of waste materials for the food industry
Sale and renovation of furniture and house hold items
Scrap acrylic merchants
Supply and distribution of electricity
Textiles recycling/merchanting
The collection/recycling/ disposal of both domestic and industrial waste.
Tyre retreading & managing the collection of used tyres
Waste disposal/re-processing/recycling/ management
Waste management solution providers & suppliers of material recycling facilities
Waste paper/board/reading material/newsprint collection, transportation, processing and sale.

Little information was available on the most important activities in the recycling and waste management sectors, as data was only broken down into recycling of metal and non-metal waste and scrap. However, discussions with experts in the field revealed that the Local Authorities were the most significant organisations in the field, given their responsibility for waste collection, and the onus laid on them regarding recycling targets. Recycling of non-metal waste and scrap formed the largest proportion of organisations involved in recycling, however, it is likely that the activities are more diverse than the organisations involved in recycling of metal waste and scrap.

4.3 Company size

When the businesses within the recycling sector, as identified through FAME, it was seen that of the 568 companies identified as being live and active, only 61 (10.7 %) had submitted employee numbers. These ranged from 2 to 635, with a mean of 86 (sd 131). Clearly these statistics are meaningless, due to the size of the standard deviation. The results can be seen in Table 16.

Table 16. Numbers of employees in live active firms

Range	Number of firms
≤ 10	10
11-50	14
51-100	23
101-250	8
>250	6
Total	61

The majority (90 %) of firms giving employee numbers fell into the small to medium sized enterprise category, as 55 had under 250 employees. Only 6 (10%) of the 61 firms were large. This is likely to be an over-representation of large firms when compared to the DTI Small and Medium-Sized Enterprise (SME) Statistics for the UK, 2000 (Table 3). This data found 89% of firms to have less than 10 employees, including sole traders (73 % of those employing staff), and only 0.2% to be large, with over 250 employees (0.6% of those employing staff). Hence the vast majority of firms have less than ten employees. Firms with less than 20 staff accounted for 34 % of the turnover (36 % when only those employing staff were considered). The remainder of the data was unrevealed by the DTI for competitiveness reasons. It was calculated from Table 3 that businesses with less than 20 people accounted for 46 % of employment within the sector. Hence the bulk of employment is attributable to larger firms. Firms with no employees accounted for only 5.7 % of turnover within the recycling industry. The turnover data was incomplete, doubtless due to reasons of confidentiality. However, the DTI report that in business in the UK as a whole the 7,000 largest businesses accounted for 49 % of turnover in 2000 (DTI Press Release, 2001). Hence it is likely that the majority of turnover is attributable to the largest firms in this case also.

5. Conclusions

Recycling is now important on the UK Government's agenda, partly as a result of new EU legislation, and partly because of resource and landfill scarcity. However, there are still some barriers to recycling, including the relatively high cost compared to the benefits. This has led to the need to address recovery and recycling, together with the predicted increase in waste production. Kerbside collections and civic amenity sites are now being used to facilitate waste recycling. Local Authorities are currently addressing waste management practices through the implementation of Best Value. A wide range of materials is now recycled both in novel and traditional ways. Much potential for growth is seen, provided suitable technology can be sourced.

Waste management options have developed greatly over the last few decades, and will assist in waste reduction. Legislation is driving recycling forward. It is likely that legislative pressure will increase substantially over the coming years, and thus increase the regulatory control on waste management. It is predicted that the use of landfill will decrease substantially over the coming years due to the introduction of new legislation. It is likely that the use of composting will increase in the UK, and this means that substantial changes in that field are required, as the UK is currently lagging behind other EU countries. Incineration has improved markedly, but attempts are being made to ensure that it is not used in preference to recycling.

Case studies carried out in the course of this project revealed that some changes in tasks are occurring. These appear to be principally due to the introduction of new technology, which is resulting in process changes. Tasks that have changed include increased automation of processes. This means that staff are in some cases controlling procedures by computer, which were previously done manually, for example tank farms used to mix waste solvents to form cement kiln fuel being filled automatically rather than being controlled manually. Computer control has also changed the ways in which environmental samples are analysed by recycling and waste management organisations, as the information is stored centrally rather than being recorded by hand, and much of the analysis is now automated. This means that staff have had to adapt to the new technology, and increases the speed at which analysis can be carried out. Measurements from weighbridges providing entrance to landfill sites are now also carried out using information technology, reducing the potential for human error, and ensuring that the Environment Agency are provided with accurate records.

The demands of legislation have led to increased sorting requirements, which has led to the establishment of more materials recycling facilities, instead of sorting materials collected en route. Firms questioned indicated that this was a trend likely to continue. A number of firms have cited interest in automated systems for the separation of plastics, which will lead to further operational changes if such systems are introduced. The introduction of new technology is partly driven by changes in legislation, which requires better separation of wastes and high standards for recyclates. Organisations perceive increasing importance of information technology in their operations, which will also lead to changes in tasks by increasing automation further, and resulting in the need for new instrumentation. Therefore the recycling and waste management sector is continually evolving.

Training has become very important for is recycling in the UK, as it assists in business growth, and enables staff to work to their full ability. The introduction of the

COTC has had a substantial impact in ensuring that waste managers are qualified and competent. NVQs and SVQs have also come to the fore, and having an impact in this area by increasing skills, and thus the competitiveness and quality of services.

The nature of businesses engaged in recycling is varied, but can be split into metal and non-metal waste and scrap. The majority of firms are SMEs, but there are some very large firms engaged in the field of recycling. However, use of SIC codes to determine recycling activities excludes Local Authorities, who perhaps form the largest section of waste management. Additionally, the information available through use of SIC codes is limited, and means that it is difficult to discover the precise nature of recycling in the UK. Nevertheless, it is apparent that recycling and waste management are expanding due to changes in legislation and practices, and that substantial changes have yet to occur in order for the UK to meet European requirements.

Bibliography

Aboussouan, L., Russo, Ph., Pons, M.N., Thomas, D., Birat, J.P., Leclerc, D. 1999. Steel scrap fragmentation by shredders. *Powder Technology* **105** 288-294.

Adams, K.T., Phillips, P.S., McClatchey, J. 2000. The impact of Best Value on the management of municipal solid waste: pilot authorities in England and Wales. *IWM Scientific and Technical Review* **2** 4-12.

Ahmed, F. 1996. The battery recycling loop: a European perspective. *Journal of Power Sources* **59** 107-111.

Ambrose, C.A. 2000. End-of-life (ELV) vehicle waste arisings, disposal and legislation. *Wastes Management* **November** 44-46.

Ayres, R., Ferrer, G., van Leynseele, T. 1997. Eco-efficiency, asset recovery and remanufacturing. *European Management Journal* **15** 557-574.

Ayres, R.U. 1997. Metals recycling: economic and environmental implications. *Resources, Conservation and Recycling* **21** 145-173.

Barry, D. 2001. The landfill directive: milestone or millstone? *Wastes Management* **Jan** 29-30.

Bellmann, K., Khare, A. 1999. European response to issues in recycling car plastics. *Technovation* **19** 721-734.

Bellmann, K., Khare, A. 2000. Economic issues in recycling end-of-life vehicles. *Technovation* **20** 677-690.

Byström, S., Lönnstedt, L. 1995. Waste paper usage and fiber flow in Western Europe. *Resources, Conservation and Recycling* **15** 111-121.

Chilton, M. 2001. EfW – present and future roles in an integrated waste strategy. *Wastes Management* **Mar** 31-32.

Craighill, A.L., Powell, J.C. 1996. Lifecycle assessment and economic evaluation of recycling: a case study. *Resources, Conservation and Recycling* **17** 75-96.

Darley, P., Bowell, R. 2001. Power generation from waste incineration. *Wastes Management* **Mar** 27-29.

David, J. 1995. Nickel-cadmium battery recycling evolution in Europe. *Journal of Power sources* **57** 71-73.

DEFRA 2001. The Producer Responsibility Regulations (Packaging Waste) Regulations 1997: recovery and recycling targets for packaging waste in 2001 (regulatory impact assessment). http://www.defra.gov.uk/environment/waste/packria/index.htm Accessed 23rd January 2002.

DETR. 2000. Waste Strategy 2000 England and Wales Part I.

DETR. 2000b. Waste Strategy 2000. England and Wales. Part 2.

DTI Press Release. 21 June 2001. http://www.sbs.gov.uk/press/news44.pdf Accessed 23rd January 2002.

DTI Statistics. 2001. *Small and Medium-sized Enterprise (SME) Statistics for the UK, 2000.* http://www.sbs.gov.uk/content/statistics/stats2000.xls

ESAUK. Environmental Services Association. Accessed 15th January 2002. www.esauk.org.

Evison, T., Read, A.D. 2001. Local Authority recycling and waste – awareness publicity/promotion. *Resources, Conservation and Recycling* **32** 275-291.

Fang, Y., Zhan, M., Wang, Y. 2001. The status of recycling of waste rubber. *Materials and Design* **22** 123-127.

Gentil, E. 2001. Compost – a diversification opportunity for the waste management industry. *Wastes Management* **Jan** 44-45.

Grant, J. 2001. Who pays? *Envirotec* **3** 12

Hogg, D. 2001. Achieving the Landfill Directive targets: the 'best' way forward? *Wastes Management* **Jan** 31-34.

Marsh, G. 2001. Facing up to the recycling challenge. *Reinforced Plastics* **45 June** 22-26.

Nystrom, H.E., Kehr, W.R., Pollock, J. 2001. Impediments to refractory recycling decision-making. *Resources, Conservation and Recycling.* **31** 317-326.

Owen K.C. 1998. Scrap Tires: A Pricing Strategy for a Recycling Industry. *Corporate Environmental Strategy,* **5** 42-50(9).

Perryman, G. 2001. The local perspective. *Wastes management* **Jan** 46.

Precious Metal Industries (Wales) Ltd. 2001. Recycling for Computer Equipment

Purcell, B., Stentiford, E. 2000. Co-treatment: fuelling recovery of organic wastes. *Wastes Management* **August** 32-33.

Read, A.D., Phillips, P.S., Murphy, A. 1997. Environmental bodies and landfill tax funds. An assessment of landfill operators in two English counties. *Resources, Conservation and Recycling* **20** 153-182.

Slater, R.A., Frederickson, J. 2001. Composting municipal waste in the UK: some lessons from Europe. *Resources, Conservation and Recycling* **32** 359-374.

Slater, R.A., Frederickson, J., Gilbert, E.J. 2001. *The State of Composting 1999.* The Composting Association. On-line Resource http://www.compost.org.uk/dsp_publication.cfm, accessed 23rd January 2002.

Smith, A. 2001. Waste reclaim: turning recycling into economic reality. *Plastics additives & Compounding* **3 March** 18-22.

Smith, D.N., Harrison, L.M., Simmons, A.J. 1999. A survey of schemes in the United Kingdom collecting plastic bottles for recycling. *Resources, Conservation and Recycling* **25** 17-34.

The Composting Association. 2002. *The Composting Association Standards for Composts.* SCA03. Internet resource http://www.compost.org.uk/dsp_standards.cfm accessed 23rd January 2002.

Woodard, R., Bench, M., Harder, M. 2000. Determination of civic amenity (CA) waste components. *IWM Scientific & Technical Review* **July** 18-21.

Appendix

The following legislation impacts on waste management in England and Wales (DETR, 2000b).

Chemicals (Hazard information and packaging for supply) regulations 1996
Chemicals (Hazard Information and Packaging for Supply) Regulations 1996
Control of pollution (Amendment) act 1989
Control of pollution act 1974