Plastics in the UK economy

a guide to polymer use and the opportunities for recycling

Biffaward Programme on Sustainable Resource Use

Waste Watch is a leading environmental organisation promoting sustainable resource management in the UK by campaigning for all areas of society to: reduce resource consumption, maximise resource reuse, and increase the percentage of waste recycled.

The work of Waste Watch falls into six areas: research and policy, the Wasteline Information Service, education, communication campaigns, business services, and membership. Waste Watch is a national charity established in 1987, supported by members, business, local Government, central Government's Department for Environment, Food and Rural Affairs (DEFRA) and funding via the Landfill Tax Credits Scheme and the National Lottery. Waste Watch works with community organisations, local and national Government, businesses and the public to raise awareness and effect change on waste.

This report is the result of a partnership between Waste Watch, Valuplast and Recoup. It is based upon initial data collection and analysis carried out by Valuplast, and subsequent detailed analysis and reporting by Recoup. *Plastics in the UK economy* was written by Andrew Simmons and Sarah Dandy of Recoup, with additional data and analysis provided by Brian Smith of Valuplast. The report has been edited by Claudia Kuss-Tenzer and Cathy Crofts of Waste Watch.

The report is funded by Biffaward and together with a complementary study providing information on the flow of plastic materials through the economy, forms part of the Biffaward Programme on Sustainable Resource Use. The material flows analysis was carried out by Bowman Process Technology and is presented in a report entitled *Plastics Mass Balance UK* which is included as Appendix D in this report. Both reports, including additional analyses, are available at a dedicated website (www.plasticsintheuk.org.uk) or can be accessed from the Waste Watch website.

Biffaward Programme

Objectives - The aim of this programme is to provide accessible, well-researched information about the flows of different resources through the UK economy based either singly, or on a combination of regions, material streams or industry sectors.

Background - Information about material resource flows through the UK economy is of fundamental importance to the cost-effective management of resource flows, especially at the stage when the resources become 'waste'. In order to maximise the programme's full potential, data will be generated and classified in ways that are consistent both with each other, and with the methodologies of the other generators of resource flow and waste management data. In addition to the projects having their own means of dissemination to their own constituencies, their data and information will be gathered together in a common format to facilitate policy making at corporate, regional and national levels.

Recoup

Recoup is the UK's technical centre for post-consumer plastics recycling. Recoup's work improves the opportunities to recycle plastics - developing and providing practical information, guidance and specialist resources for local government, packaging supply-chain and waste management professionals. Projects are funded by members, grants and donations. Recoup's work helps recycling scheme planners, investors and operators in the UK to extend household plastics recycling facilities.
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Valuplast

Valuplast Ltd is the "not for profit" Plastic Materials Organisation set up to represent the UK Plastics packaging industry. Valuplast exists to facilitate the recovery and recycling of all used plastic packaging in the most economical and environmentally sensible way. It acts as a crucial link with Government on packaging waste regulations and implementation.

Bowman Process Technology

Bowman Process Technology is a consulting company specialising in process innovation and analysis for environmental improvement. The company has applied skills in waste management and minimisation, environmental improvement, fugitive emissions, recycling and treatment/remediation in a number of sectors, including the chemical and manufacturing industries.

Spiral relief in polyester resin by Claude Blin

Claude Blin / Sandretto Plastics Art Museum

www.plasticsintheuk.org.uk

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Abbreviations and acronyms

ABS	Acrylonitrite Butadiene Styrene
ACORD	Automotive Consortium on Recycling and Disposal
ACP	Advisory Committee on Packaging
APC	American Plastics Council
APME	Association of Plastics Manufacturers in Europe
ASA	Acrylonitrile Styrene Acrylate
BPF	British Plastics Federation
BRE	Building Research Establishment
CA site	Civic amenity site
CARE	Consortium for Automotive Recycling
CECET	Centre for Energy Conservation & Environmental Technology
CFC	Chlorofluorcarbon
C & I	Commercial and industrial
CIRIA	Construction Industry Research and Information Association
CIWM	Chartered Institution of Wastes Management
CN code	Combined nomenclature code
DEFRA	Department for the Environment, Food and Rural Affairs
DTI	Department of Trade and Industry
EA	Environment Agency
EC	European Commission
EfW	Energy from Waste
EIA	Environmental Impact Assessment
ELV	End-of-life Vehicle
EMR	European Metal Recycling
EPDM	Ethylene Propylene Diene Monomer
EPFLOOR	EuPC PVC Flooring Sector Group
EPPA	European PVC Window Profile and Related Building Products Association
EPS	Expanded Polystyrene
HDPE	High Density Polyethylene
HIPS	High Impact Polystyrene
ICER	Industry Council for Electronic Equipment Recycling
IGD	Institute of Grocery Distribution
LCA	Life Cycle Assessment
L/LLDPE	Low/Linear Low Density Polyethylene
MRF	Materials Recycling Facility
MSW	Municipal Solid Waste
MVDA	Motor Vehicle Dismantlers Association
NHS	National Health Service
PA	Polyamide
PBB	Polybrominated Biphenyls
PBDE	Polybrominated Biphenylethers
PBT	Polybutylene Terephthalate
PC	Polycarbonate
PC/ABS	PC and ABS blend
PE	Polyethylene
PERN	Packaging Export Recovery Note
PET	Polyethylene Terephthalate
PIFA	Packaging and Industrial Films Association
PMMA	Polymethyl Methacrylate
PO	Polyolefins
POM	Polyoxymethylene (Acetal)
PP	Polypropylene
PPS	Polyphenylene Sulphide
PRN	Packaging Recovery Note
PRoVE	Plastic Reprocessing Validation Exercise
PS	Polystyrene
PUR	Polyurethane
PVC	Polyvinyl Chloride
R&D	Research and Development
RECOUP	Recycling of Used Plastics Ltd
RoHS	Restriction of Hazardous Substances Directive
SAN	Styrene Acrylonitrile
SI	Statutory Instrument
SIC	Standard industrial classification
SME	Small and medium enterprises
SMMT	Society of Motor Manufacturers and Traders
TEPPFA	The European Plastics Pipes and Fittings Association
TNO	Toegepast-Natuurwetenschappelijk Onderzoek (Netherlands Organisation for Applied Scientific Research)
UPR	Unsaturated Polyester Resin
WEEE	Waste Electrical and Electronic Equipment
WRAP	Waste and Resources Action Programme

Executive summary

Introduction

Plastics use has grown substantially over the last 50 years and plastics are today found in a wide range of applications, encompassing a wide variety of polymer types. The intended life-span of plastics products varies from several months, for example many packaging items, to over 50 years for building/construction components. In the UK, almost 4.5 million tonnes of plastics products were used in 2001 and it is anticipated that plastics consumption will grow by up to 4% annually. It is estimated that during 2000, between 3 and 3.5 million tonnes of waste plastics required disposal.

Figure 1 shows a breakdown of UK plastics consumption by selected polymer types and sectors. Figure 2 (p.12) illustrates the flow of plastics materials through the UK economy. In 2000, 4.13 million tonnes of primary plastics materials were consumed by the UK manufacturing sector. In addition, the import of plastic goods and components exceeded exports by an estimated 320,000 tonnes. A total of approximately 4.45 million tonnes of plastic were consumed in the UK during 2000. The full material flows analysis, carried out by Bowman Process Technology and presented in a report entitled *Plastics Mass Balance UK*, can be found in Appendix D.

This report is intended as an initial study and aims to identify the opportunities for, and the barriers to, recycling of plastics waste in the UK. The report considers the use of plastics, the key regulatory drivers and the practicalities of recycling in the packaging, automotive, electrical/ electronic, building/construction, agricultural, medical and furniture/housewares sectors. It sets out priorities for action within each sector and proposes a framework for further analysis.

The prioritisation of these recommendations has been based on their likely ability to increase the level of sustainable plastics recycling. A number of factors were used in considering priorities, including the impact on the quantity of material diverted from landfill; the availability of commercial technology and market capacity to enable recycling and the economic viability of recycling.

Plastics in the packaging sector

Packaging represents the single largest sector of plastics use in the UK economy. An estimated 1.64 million tonnes of plastics were used in packaging applications during 2002. In this report, household and industrial/commercial packaging are discussed separately because material flows, technological development and the resulting opportunities for recycling differ in each area.

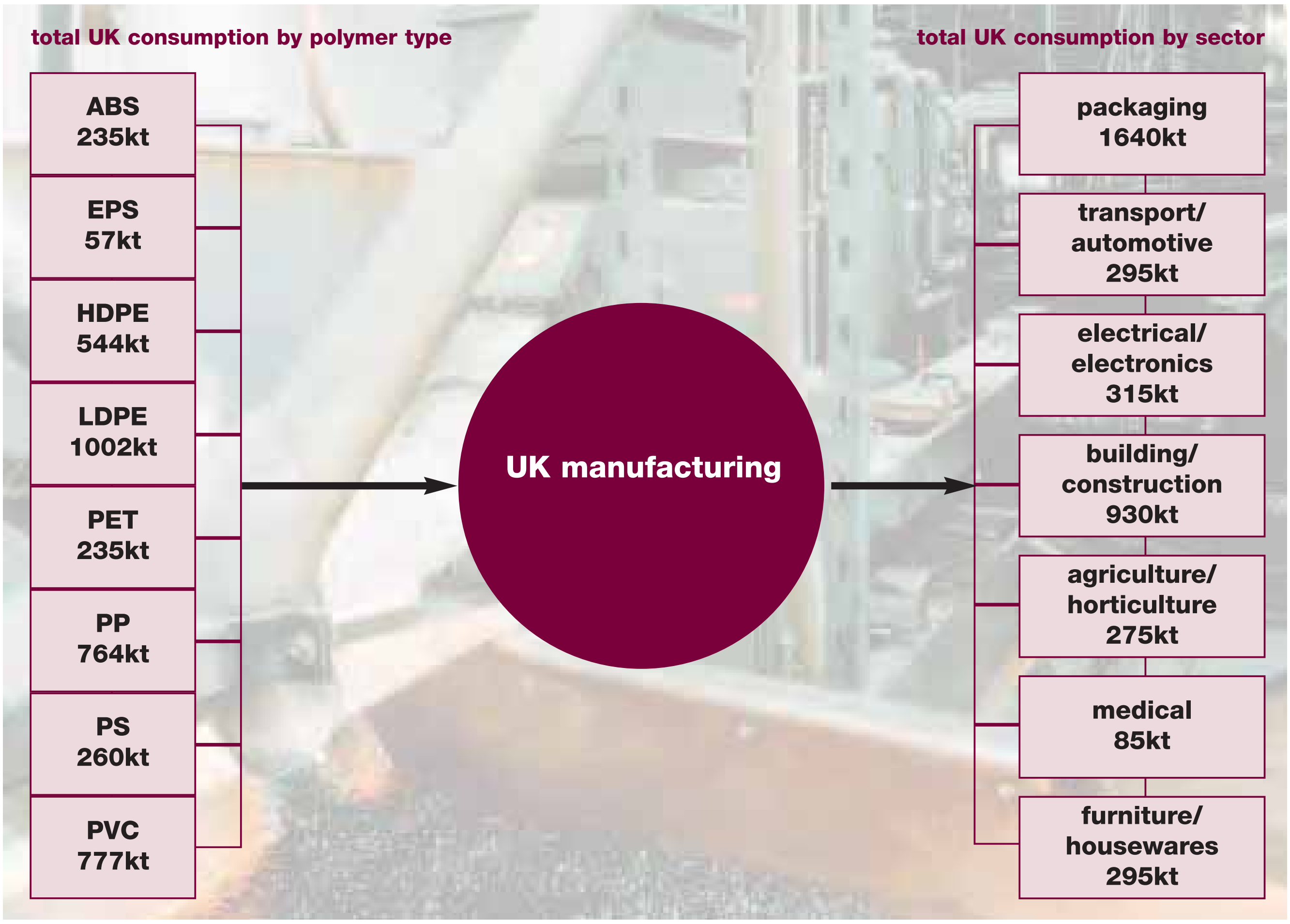
In 2001, plastics packaging made up approximately 7% (1.428 million tonnes) of UK household waste arisings. Discounting the weight of contaminants such as food and moisture, the quantity of potentially recoverable plastics packaging is estimated to be 1.2 million tonnes. A large percentage of these arisings are plastic bottles, which are easily identified and separated and have a relatively high weight with comparatively little contamination. Plastic bottle collection systems have been established by just over half of all local authorities and 4.1 million households are currently served by a multi-material kerbside collection scheme which includes plastic bottles. The UK's current collection levels are low compared to that of other European states. However, the high consumption of plastic bottles in the UK combined with the potential for extending existing local authority collection systems to include plastics bottles at little or no additional cost, make this a prime target for increasing plastics recycling in this sector.

In the commercial/industrial sector, an estimated 690,000 tonnes of plastics packaging were used during 2002. The majority of this comprises polyethylene (PE) films, used in pallet shrink wrap, heavy duty sacks and industrial liners, of which approximately 266,000 tonnes are potentially recyclable. Limited information exists on the remaining quantity of plastics packaging. In 2001, an estimated 195,000 tonnes of plastics packaging from commercial/industrial sources were recycled in the UK. A further 60,000 tonnes were exported for recycling. Approximately 90,000 tonnes were used in the manufacture of new film products. PE film represents the single most common type of recyclable plastics packaging from this sector, and PE recycling processes are well-established. Other recyclable plastics packaging includes PE and polypropylene (PP) crates and trays and expanded polystyrene (EPS) packaging. There has been significant growth in reusable packaging, particularly in the retail sector, such as PP crates used by supermarkets. Between 1992 and 2002, the use of returnable PP crates has risen from 8.5 million to 35.8 million.

The primary legislative drivers in both sectors are the EC Directive on Packaging and Packaging Waste 94/62/EC (the Packaging Directive), which has been implemented in the UK through the Producer Responsibility Obligations (Packaging Waste) Regulations 1997 and the Packaging (Essential Requirements) Regulations 1998. The former sets targets for the recovery and recycling of packaging wastes, including plastics, whereas the latter specifies minimum design standards.

Figure 1 - UK plastics consumption, 2000

(selected polymer types and sectors)



Source - data supplied by Valuplast (2001)

Note - Only the most commonly used polymer types have been included in this breakdown (PA, PMMA, POM, PUR, PC/ABS, UPR, Epoxy resin and phenolic are not included). The analysis also excludes the toys, leisure and fashion sectors. Discrepancies between the totals presented in this figure and totals listed in Table 1 are due to the exclusion of these polymer types and sectors.

Plastics in the automotive sector

In terms of volume, today's cars contain a larger proportion of plastics than any other material. Due to their light weight, however, plastics only account for an average of approximately 10% of the total weight of a vehicle. In the UK, between 1.8 and 2 million cars reached the end of their lives and approximately 2.2 million new cars were registered in 2000. Assuming an average life-span of 14 years and an average weight of 1100 kg for a new vehicle, plastics waste arising from vehicular sources can be expected to exceed 240,000 tonnes in 2014.

Although vehicles are one of the most effectively recycled products in the UK, currently only small quantities of waste plastics from end-of-life vehicles (ELV), such as PP battery cases and bumpers, are recycled. PP accounts for 41% of plastics used in vehicles and its use is expected to increase in the production of new vehicles. This is partially driven by cost considerations, but also represents an attempt to reduce the number of different polymers used to produce individual parts in order to facilitate recycling.

The separation of waste plastics from ELV can take place at either the dismantling or shredding stage. The cost-effectiveness of ELV dismantling decreases as more parts are being recovered, which is a strong disincentive for complete dismantling. The greatest potential for increasing recycling exists in generating polymer streams from shredder residue and there has been considerable development in technologies to identify and separate plastics at this stage.

The ELV Directive 2000/53/EC is the main legislative driver in the automotive sector. It aims to reduce the waste from ELV and sets rising recovery and recycling targets. However, these targets are non-material specific and it is likely that they will be reached without significant increases in plastics recycling from ELV. The UK government is currently in discussion with industry on the most appropriate options for implementation. A consultation paper and draft regulations have been published recently. In addition, a number of associations entered into the voluntary cross-sector Automotive Consortium on Recycling and Disposal (ACORD) agreement in 1997. This agreement committed ACORD members to recovery rates of materials of 85% in 2002, rising to 95% in 2015. However, uncertainty over the implementation of the ELV Directive has delayed investment in essential treatment facilities and it is unlikely that these targets will be achieved.

Plastics in the electrical and electronics sector

Plastics are used in a wide variety of electrical and electronic equipment due to their durability, light weight, resistance to corrosion and insulation properties. In 2000, plastics made up approximately 20% of the total weight of electrical and electronic equipment. In 1998, 915,000 tonnes of post-consumer electrical and electronic equipment required disposal, of which 22% was plastics. However, the majority of this was sent to landfill.

The wide range of appliances and polymer types involved makes recovering plastics from waste electrical and electronic equipment (WEEE) a challenging task. Different styrenics and PP account for approximately 70% of plastics used in this sector. Large household appliances, IT equipment and brown goods make up over 90% of the weight of WEEE. Therefore these types of equipment and polymers should be the prime target for efforts to increase plastics recycling in this sector.

The most significant legislative driver in this sector is the Waste Electrical and Electronic Equipment (WEEE) Directive proposed by the EC. Following the finalisation of the directive, member states will be expected to implement it within 18 months, possibly by September 2004. The directive aims to increase the re-use and recycling of WEEE by setting recovery and recycling targets and by introducing producer responsibility for disposal.

Plastics in the building and construction sector

This sector is the second-largest consumer of plastics after the packaging sector. Approximately 800,000 tonnes of plastics are used annually in this sector. Compared to other materials, the percentage of plastics used is

Courtesy of Duales System Deutschland AG

Mixed plastics recyclate at four different stages of preparation

relatively small. However, they form part of a wide range of applications, many of which have an intended life of several decades. Common uses include pipes and ducts, insulation, floor and wall coverings, windows, linings and fitted furniture. Polyvinyl chloride (PVC) is by far the most common plastic type used (60%). Other plastics used include polyurethane (PU), expanded polystyrene (EPS), high-density polyethylene (HDPE), low-density polyethylene (LDPE) and polystyrene (PS).

It is estimated that 100,000 tonnes of PVC plus significant quantities of HDPE are buried below ground and are unlikely to be removed for disposal. A further 25,000 tonnes of PVC is contained within building structures and will only be removed upon demolition. It is estimated that a total of 575,000 tonnes of the plastics used per year can potentially be recovered. In addition, plastics packaging makes up approximately 25% by weight of packaging waste arising at construction sites. PE sheet wrapping accounts for the largest proportion of this (11.6%) and it is estimated that over 17,000 tonnes could be recovered annually.

There are currently no significant legislative drivers relating to plastics recycling in this sector, but the Producer Responsibility Obligations (Packaging Waste) Regulations 1997 discussed above also apply to packaging waste arisings from building and construction sites. A number of sector associations have committed to recycle 50% of recoverable PVC arising from end-of-life products under the Voluntary Commitment of the PVC Industry ('Vinyl 2010'). There is also growing emphasis on 'sustainable construction', which includes environmentally responsible building design and international standards such as ISO 14001, to facilitate waste minimisation and recycling during the construction phase.

Plastics in the agricultural sector

The use of plastics in the agricultural sector has grown considerably and plastics are common in products such as packaging, permanent/semi-permanent buildings, crop covers, irrigations systems, tools and equipment. Figures for 1998 indicate that approximately 93,000 tonnes of waste plastics arose during that year. Currently, no significant quantities of plastics are recovered.

Although there currently are no obligations to recycle materials from these sources, the implementation of the EC Framework Directive on Waste will soon be extended to include agricultural waste. This will introduce a waste management licensing system, a legal duty of care and a registration system for businesses transporting agricultural waste. Certain farm plastics, such as feed bags, fall under the provisions of the Packaging Directive, but silage films and crop covers are not classed as packaging. In the early 1990s the film manufacturing industry, recognising that many farmers had an end use disposal problem, set up a national scheme to recover 'farm films' for recycling. This voluntary agreement did not succeed, however, because two overseas suppliers gained a competitive advantage through evading the associated charge.

Recycling efforts have largely focused on films, but waste film arisings per enterprise are relatively low and the high levels of contamination of silage films, mulch and crop covers pose a challenge to recycling. There is currently one recycler of farm films in the UK and grant-subsidised film collection schemes exist in Wales, Cumbria and Scotland. However, schemes are not financially viable unless farmers are charged for the service or there is some form of subsidy.

Plastics in the medical sector

Plastics are used in the medical sector in a variety of applications, ranging from highly sophisticated items such as prosthetics to more common objects like drip bottles and instrument trays. The latter are often readily disposable and will be used and discarded within one year of purchase. In addition, plastics waste arises in electronic equipment, such as personal computers and medical monitoring equipment. Quantitative data on plastics use within this sector is limited. It is estimated that 95,000 tonnes of polymer are used in the production of medical applications, with PS accounting for approximately 10,000 tonnes. PVC is also commonly used.

There are no specific recycling requirements relating to this sector and most medical products are excluded from the WEEE Directive. Any plastics recycling scheme will be required to comply with the Clinical Waste Regulations 1992.

Research suggests that over 50% of waste generated by hospitals can be classed as domestic waste, which includes recoverable plastics. Many NHS Trusts perform some form of material separation, but this is usually restricted to glass, metal and paper. The inclusion of plastics in separation schemes could significantly increase plastics recycling in this sector.

Plastics in the furniture and housewares sector

A wide variety of household items are manufactured from plastics. The largest quantities of plastics are used in the production of outdoor furniture and fittings, with over 70% of UK households owning some form of plastic garden furniture. More recently, demand for plastics has risen due to the manufacture of containers for recyclables, wheeled bins, composters and water butts.

Data for the sector is limited, but suggests that PP and PS are most commonly used in furniture production, with PP and HDPE most commonly found in houseware items. A range of garden product suppliers use recycled plastics from polyolefins (PO) and PS and it is estimated that over 20,000 tonnes of recycled plastics per annum are used in these applications within the UK.

There are a number of social enterprise schemes across the UK, which collect furniture for reuse or recycling. Opportunities to promote reuse and recycling exist in utilising and expanding this collection collection infrastructure to include plastic furniture. Currently there are no specific legislative drivers relating to the recycling of plastic furniture and housewares waste.

The way forward

The opportunities for, and challenges to, increasing the recycling of plastics vary considerably between sectors and applications. Environmental impact assessments have shown that the resources required in recycling systems, including collecting, transporting and processing waste plastics into recyclate, are significantly lower than the resources required to produce virgin polymers. The substitution of virgin polymer with recycled plastics will also lead to greater resource savings than efficiency improvements in virgin polymer production alone.

The most significant opportunity to maximise the recyclability of waste plastics is through development of separation technology. Commercially viable systems for the separation of plastic items such as bottles already exist. For other sectors, in particular WEEE and ELV, the greatest potential lies in developing commercial systems for high-speed, high-quality separation of different polymer flakes arising from shredding operations.

Technology for mechanical recycling of plastics is well-established and it is likely that there will be continued improvements in the efficiency of these processes. Mechanically recycled materials can already be found in highly specified applications such as food-grade packaging and automotive components. The main opportunity for developing mechanical recycling lies in the processing of mixed plastics into commercial products. Although viable processes do not appear to exist currently, the progress of many researchers and entrepreneurs in this relatively new area is encouraging.

It is recognised that the development of end markets for recyclates is one of the most important drivers for increased plastics recycling. Demand for recycled plastics will increase when there is a reliable supply of appropriate quality recyclates. These need to be priced competitively in comparison to virgin materials to enable manufacturers to improve profitability by switching to recyclates. It is essential for recycled materials to be promoted on the same basis as virgin materials – according to cost and fitness for purpose – and not primarily because of their ‘green’ credentials. Recyclate suppliers also need to provide an equivalent service, quality assurance and marketing capacity to the virgin polymer industry.

Priorities for action

The most significant opportunities for increasing plastics recycling in the sectors considered in this study are

- increase post-consumer plastic bottle recycling through the inclusion of plastic bottles in integrated multi-material kerbside collection schemes
- maximise the recycling of plastics packaging from the commercial and industrial waste stream
- develop technologies for the efficient mechanical recycling of plastics from shredder residue
- develop a range of end markets for recovered plastics and promote public sector procurement of recycled plastics products
- increase the cost of disposing of plastics waste, for example, through application of a higher landfill or disposal tax
- ensure that the environmental and economic trade-offs of recycling certain types or quantities of plastics are properly understood by policy makers

Introduction

Plastics in the UK economy

The modern plastics industry can trace its origins back over a century and a half when, in 1862, Alexander Parkes unveiled Parkesine, the first man made plastic.

In 1891, Rayon was introduced, followed by Cellophane in 1900 and Bakelite in 1907. There are in excess of twenty different polymer types in common usage today. These include polyvinyl chloride (PVC), polyethylene (PE), polyamide (PA), polystyrene (PS) and polypropylene (PP), which had been developed by the 1960s.

The term 'plastics' refers to a range of different polymeric materials. These can be broken down into two distinct groups: thermoplastics and thermosets. Thermoplastics soften and melt on heating and may be mechanically recycled into new products when the original product life is finished. Thermoplastics represent some 95% of plastics use. Thermosets do not soften or melt on heating once moulded and, therefore, cannot be mechanically recycled in the same way as thermoplastics. They may be ground to a powder and used as filler. Alternatively, they may be feedstock recycled or used in energy recovery processes. There are some developments in thermoset recycling, but these are considered beyond the scope of this report.

Plastics use has grown significantly in the last 50 years. Globally, consumption has risen from 5 million tonnes to some 100 million tonnes. This growth is attributable to the beneficial properties of plastics. They are relatively strong, lightweight and cost-effective. They can be precisely engineered to perform many different functions - as evidenced by the range of sectors and applications where plastics are used. The plastics industry is a major contributor to the UK economy. Tables detailing the overall use of plastics by polymer type are shown in appendix A.

The UK used approximately 4.5 million tonnes of plastic products during 2000 and 4.68 million tonnes during 2001. It is estimated that the plastics sector accounted for approximately 7.5 percent of the UK demand for chemicals in 1998 (Biffaward Enviros 2002). A comprehensive analysis of the UK chemicals industry is presented in the 'Sectorial Mass Balance Study for the UK Chemicals Industry'.

Table 1 shows the UK consumption of plastics by market sector in 2000. Figure 3 illustrates the percentage of UK consumption of plastics by individual market sectors and the percentage of UK consumption by polymer type.

Polymers are used in a wide range of applications, some of the items sold become waste within a year, for example, many packaging applications. Others, such as building materials may have a functional life of over fifty years. It is estimated that during 2000, between 3 and 3.5

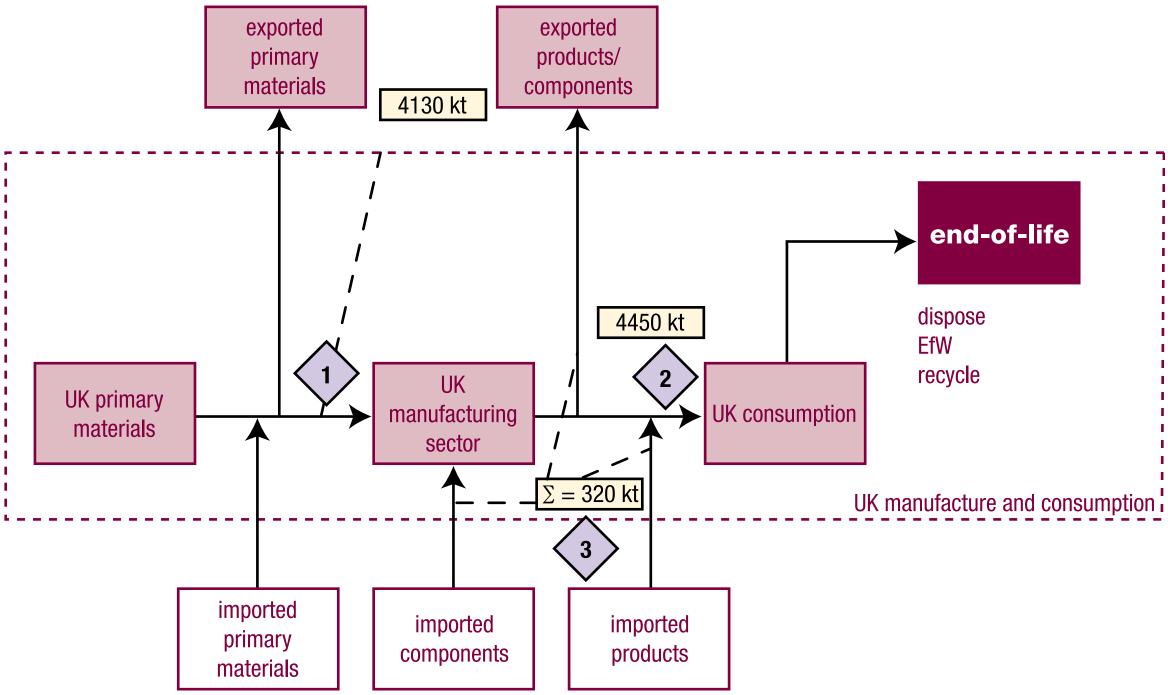
Table 1 – UK consumption of plastics by market sector, 2000

market sector	UK manufactured kt	net imports kt	total kt
packaging	1640		1640
building/construction	930	120	1050
electrical/electronics	315	40	355
transport	295	40	335
furniture/housewares	295	40	335
agriculture/horticulture	275	35	310
toys/leisure/sport	130	15	145
medical	85	10	95
mechanical engineering	85	10	95
footware	45	5	50
other	35	5	40
total	**4130**	**320**	**4450**

Source - data supplied by Valuplast Ltd (2002)

Note - The DTI indicate that the import of plastics goods and components exceeded exports by £800 million. At a conversion rate of £2500 per tonne (BPF 2001), net imports amount to an equivalent of 320kt. This figure has been pro-rated over all market sectors except the packaging sector, where imports/exports have already been taken into account (Valuplast 2001).

Figure 2 - flow of plastics materials through the UK economy, 2000



Source - Bowman Process Technology with data supplied by Valuplast (2002)

million tonnes of post-use plastics products entered the UK waste stream and it is anticipated that plastics consumption will grow year on year by up to 4%.

The characteristically low weight of plastics is translated into resource savings throughout the product life cycle. Examples of this are the energy savings achieved during the transportation of goods or the continued light-weighting of vehicles through the use of plastics.

This highlights the importance of considering the management of plastics waste in the wider context of product life-cycles. There is evidence of a shift in thinking away from 'end-of-pipe' solutions to waste towards an integrated product policy approach. Such an approach requires consideration of increasingly complex trade-offs between environmental impacts and benefits of particular products during their life-cycle. Evidence suggests that this life-cycle approach will favour continuing growth in plastic products. An important aspect to consider in this context is the environmental impact of plastics products at the end of their intended life and how to minimise these.

Project aims and objectives

This report, together with a material flows analysis carried out by Bowman Process Technology and presented in a report entitled *Plastics mass balance UK* (Appendix D), forms part of the Biffaward Programme on Sustainable Resource Use. Both reports, including additional analyses, are available on a dedicated website (www.plasticsintheuk.org.uk) or can be accessed from the Waste Watch website.

This report aims to identify the opportunities for, and barriers to, the recycling of plastics in the UK. The report considers the use of plastics, the current issues relating to plastics waste management and key regulatory drivers within the following sectors of the economy:

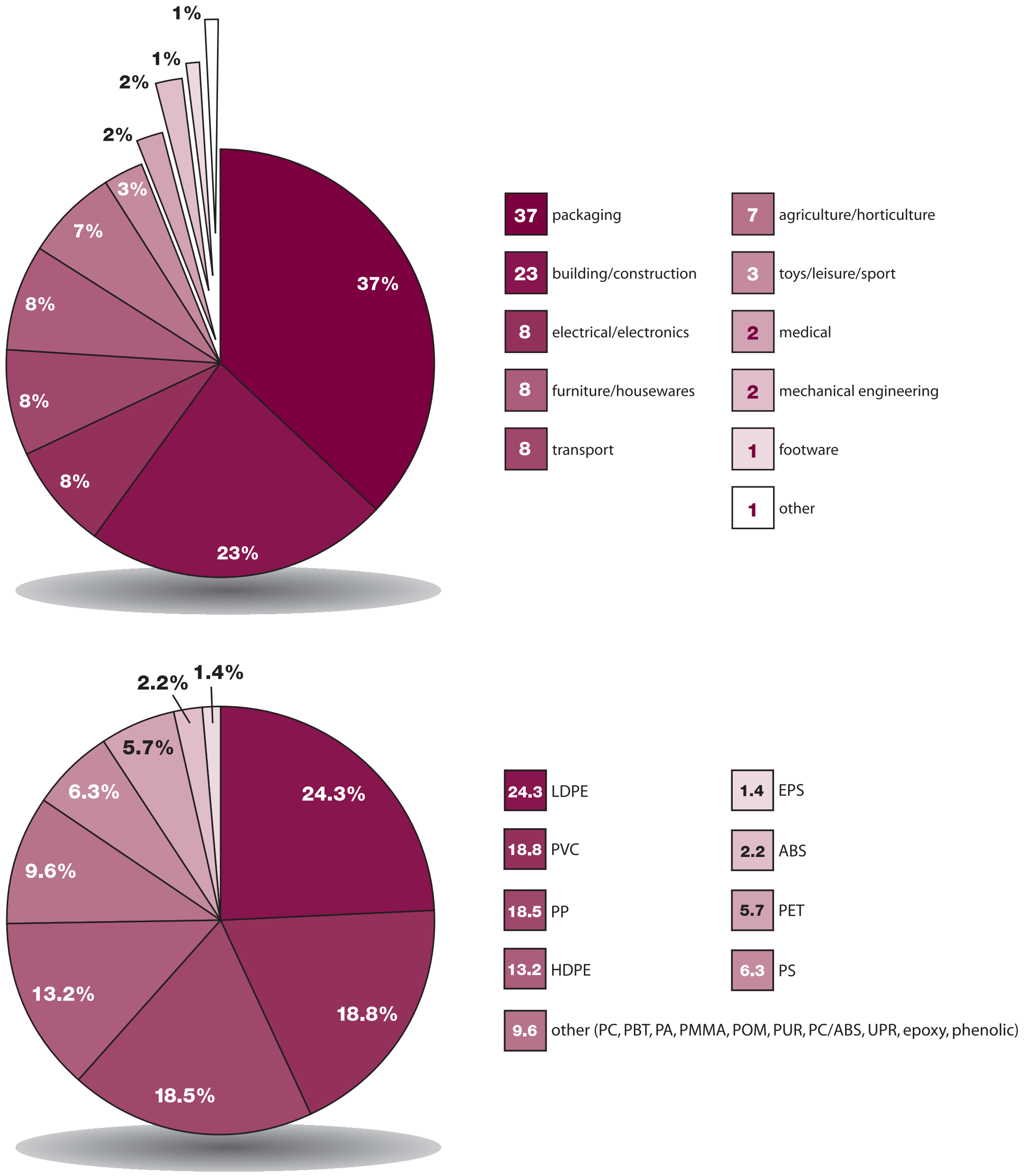
- packaging
- automotive
- electrical and electronics
- building and construction
- agricultural
- medical
- furniture and housewares

[1] *The recycling of process-scrap generated within production processes, which is frequently re-used in the manufacture of either the same or secondary applications, is considered beyond the scope of this report. There is a growing interest in the potential of biodegradable polymers in certain applications. This is a complex area in itself and also beyond the scope of this report.*

Emphasis is placed on the areas offering most significant opportunities to improve resource efficiency through mechanical recycling[1]. A survey of existing environmental impact assessments (EIAs) and a synopsis of their key conclusions are provided for each sector. However, this does not represent a comprehensive critical review of published research.

The report is intended as an initial study and does not attempt to define a comprehensive management framework for plastics waste. It sets out priorities for action within each sector and offers a framework for further analysis of the issues identified. The prioritisation of these recommendations has been based on their likely ability to increase the level of sustainable plastics recycling. A number of factors were used in considering priorities including: the impact on the quantity of material diverted from landfill; the availability of commercial technology and market capacity to enable recycling and the economic viability of recycling. Extensive references are provided in each section to enable the reader to obtain further information on issues of particular interest.

Figure 3 – percentage of UK consumption of plastics by market sector and by polymer type, 2000



Source - Data supplied by Valuplast Ltd (2002)

Packaging sector

Packaging represents the largest single sector of plastics use in the UK economy. It is estimated that 1.64 million tonnes of plastics were used in packaging applications during 2000 (Valuplast 2001). Plastics packaging tonnage is growing at 3% per annum.

Plastic packaging types are broadly divided into two categories: rigids and flexibles. The term flexibles refers to film applications such as pallet stretch and shrink film, bubble film, sacks and liners. The term rigids refers to applications such as drums, bottles, tubs, trays, cups and foamed packaging.

Plastics packaging is also categorised according to its purpose. Primary packaging is the unit sales packaging of a product, for example a plastic bottle. Secondary and tertiary packaging are terms describing the packaging required to distribute the packed product and ensure it reaches the point of retail without damage, for example pallets, stacking trays and pallet wrap.

Primary packaging typically has the shortest life-cycle of the plastics applications, with almost all used and requiring disposal in less than one year. There is a growing trend towards reuse of distribution packaging and there are considerable innovations in minimising resource use in this area.

It is useful to consider plastic packaging use and arisings in two separate areas: commerce/industry and households. This is because the material flows, technology implications and the drivers for change differ in each area.

Courtesy Duales System Deutschland AG

PET bottles prior to sorting

Household packaging

Analysis of plastics waste arisings

Household waste arisings have been analysed using market supply data for plastics packaging and a review of local authority waste surveys.

The market data analysis suggests that 1.05 million tonnes of plastics were used in household plastic packaging applications in 2002 (ACP 2001). Estimates by Valuplast suggest the amount of potentially recoverable plastic is slightly higher at 1.1-1.175 million tonnes (Smith 2002).

Our analysis of household waste data suggests that plastics make up 1.833 million tonnes of household waste, or approximately 7% of total household waste arisings. Table 2 below shows a breakdown of household waste, based on local authorities waste arisings studies (MEL 2002). Non-packaging plastics contents have been included in the data below for easy comparison.[2]

It is estimated that plastics packaging accounts for 1.428 million tonnes of household waste. The remainder is made up of refuse sacks (0.145 million tonnes) and other non-packaging plastics (0.260 million tonnes). It is important to note that these estimates includes contamination, for example by food and moisture, paper labels and other materials such as aluminium caps, which are estimated to amount to up to 15%. This reduces the amount of potentially recoverable plastics packaging waste from household sources to approximately 1.214 million tonnes.

In addition to these arisings, there are quantities of PET bottles purchased and consumed outside the home. These are usually not disposed of via the domestic dustbin and will form part of public bin or street cleansing waste arisings. It has not been possible to establish an

Table 2 – plastics packaging household waste in the UK

plastic item	% of household waste (weight)	quantity of household waste (plastics & residual contamination, tonnes)	potentially recoverable plastic (tonnes)
carrier bags	1.85[3]	227,700	193,600[4]
refuse sacks		138,800	118,000
packaging film	1.77	356,700	303,200
other film	0.23	46,300	39,400
PET clear bottles	0.78	157,200	133,600
PET coloured bottles	0.16	32,200	27,400
HDPE natural bottles	0.71	143,100	121,600
HDPE coloured bottles	0.5	100,800	85,600
PVC clear bottles	0.08	16,100	13,700
PVC coloured bottles	0.02	4,000	3,400
other plastic packaging	1.71	344,600	292,900
other dense plastics	1.29	259,900	221,000
sub-total plastic packaging	7.07	1,428,700	1,214,400
sub-total non-packaging plastics	2.01	405,040	344,300
total plastics	**9.09**	**1,833,700**	**1,558,700**

Source - MEL (2002) and RECOUP (2002)

[2] *We undertook two assessments: 'Top down', based on DEFRA national statistics of total household waste and 'bottom up', based on average amounts of plastics in household waste surveys (80.2kg/annum). The results were within 2% of each other, suggesting the data is robust.*

[3] *We have extrapolated refuse sack and carrier bag weights from MEL Research 2002 and PIFA 2002 data.*

[4] *We have estimated material contamination of the plastic film at 15% by weight. This figure may be understated, based on PIFA data indicating 146kt of carrier bags in total entering the wastestream. This would imply that waste arisings assessments of films may be overstated by 56% due to material contamination. Applying this hypothesis would imply a lower overall level of plastics packaging in domestic waste - approximately 945,000 tonnes. Such a notable disparity in the data warrants further investigation.*

exact figure, but a comparison of PET arisings from household waste (161,000 tonnes) and market supply of PET (261,000 tonnes) suggests that approximately 100,000 tonnes are disposed of outside the home.

Legislation and voluntary agreements

Recycling and recovery targets for packaging

Packaging is regulated by the EC Directive on Packaging and Packaging Waste 94/62/EC (the Packaging Directive). This sets targets for recycling and recovery of packaging materials, including plastics, and also requires that specified minimum standards of design be achieved. It requires that member states set up packaging recovery systems which achieve the following 5 year targets, to be reached in 2001.

- 50–65% overall recovery of all packaging
- 25–45% overall recycling of all packaging
- 15% minimum recycling to be attained for each material

Two regulations implement Directive 94/62/EC in the UK: the Producer Responsibility Obligations (Packaging Waste) Regulations 1997 (SI 1997/648)/(SI 2002/813) and the Packaging (Essential Requirements) Regulations 1998 (SI 1998/1165).

The Producer Responsibility Obligations (Packaging Waste) Regulations 1997 place a requirement on producers to recycle and recover specified amounts of packaging each year. The annual targets for 2002 and 2003 have been set at 19% for recycling and 59% for recovery of packaging covered by the directive (DEFRA 2002). Businesses across the packaging chain with an annual turnover of more than £2m, handling more than 50 tonnes of packaging, are obliged to comply. The regulations draw no distinction between packaging recycled from household or commercial/industrial sources.

The regulations are based on a tradable permit system. Under this system, businesses achieve compliance with the regulations by acquiring certificates of recycling and recovery (either directly from recyclers or through service-providing 'compliance schemes'). These are known as 'packaging recovery notes' (PRNs) or packaging export recovery note (PERNs). In theory, when actual recycling levels are below the target requirements, supply of PRNs will be short and businesses will increase the prices they charge for the PRNs to enable them to generate additional supplies. When there is more recycling activity than the statutory targets require, the market will be oversupplied with PRNs and producers will reduce PRN purchase prices.

The second phase of the Packaging Directive, which is currently being completed by the EU, will set higher targets for the next 5 years. It is expected that the plastics recycling target will increase to at least 20% and will include both mechanical and certain forms of chemical recycling in the acceptable processes.

The Packaging (Essential Requirements) Regulations 1998 implement the single market provisions of the Packaging Directive. The Regulations cover the manufacture and composition of packaging, and the reusable/recoverable nature of packaging. The Regulations apply to packaging placed on the market in the UK as packed or filled packaging and require that

- packaging must be kept to a minimum subject to safety, hygiene and suitability for the packed product and for the consumer
- noxious or hazardous substances in packaging must be minimised in emissions, ash or leachate from incineration or landfill
- packaging must be reusable or recoverable through at least one of the following: material recycling, incineration with energy recovery, composting or biodegradation
- heavy metal limits: packaging (and individual packaging components) must not contain a combined total of more than 100 parts per million of the following: lead, cadmium, mercury, hexavalent chromium

Responsibility for compliance lies with the legal entity that places the packaging or packaging components on the market. The Trading Standards Departments of local government regulate the essential requirements regulations.

There are no voluntary agreements on packaging. Some packaging businesses have voluntarily invested in initiatives to progress recycling through RECOUP or have backed specific voluntary projects in the sector such as sponsoring new collection programmes, or providing training on plastics recycling.

Household recycling targets

Local government in England and Wales has a statutory responsibility to achieve specified recycling/composting targets. These targets are weight-based and non-material specific. On average, authorities must recycle or compost 25% of household waste and recover value from 40% of municipal waste by 2005. These targets escalate to 30% for recycling and 45% recovery by 2010 and will increase further in 2015. Targets for English authorities have been established based on their previous recycling performance. The Scotland Executive and Welsh Assemblies are currently progressing non-statutory target approaches.

Practicalities of recycling

There is a well-established network of recyclers for plastics packaging, which are accredited by the Environment Agency (EA) or the Scottish Environmental Protection Agency (SEPA). Accreditation enables these businesses to issue packaging recovery notes (PRNs), as described above. There were 92 accredited recyclers and 30 accredited exporters of plastics packaging at the end of 2001.

In 2001, 203,149 tonnes of plastics packaging were recycled in the UK and 66,813 tonnes were exported for recycling. Of this amount, it is estimated that a little over 15,000 tonnes (5.5%) was from household sources. This suggests a national plastics bottle recycling rate of 3%.

Plastic bottles

The main plastic applications targeted for recycling from domestic sources are bottles. Bottles are prioritised for several reasons. They are readily identified, they have a relatively high weight with little contamination compared to other plastics packaging and there are markets for the collected materials. EIAs have demonstrated that recycling of bottles provides environmental benefits such as energy savings and a reduction in residual waste arisings.

Although the UK has one of the highest consumption levels of plastic bottles in Europe, its collection levels are low compared to other member states such as Italy and France. In total, European sorting stations offered 344,000 tonnes of sorted and baled PET to recycling outlets, of which the UK contributed approximately 7,000 tonnes (2%).

The main barrier to increasing plastic bottle recycling in the UK is the lack of an adequate collection infrastructure. Just over half of all local authorities provide a plastic bottle collection service. It is estimated that 4.1 million households are currently served by multi-material kerbside collections, which include plastic bottles. In addition, there are 4000 collection banks for plastics bottles in the UK (Foster and Simmons 2002).

Collection systems which are not based on multi-material kerbside collection are relatively expensive to operate. Combined with low market values of recycled materials and low alternative disposal costs this creates a financial disincentive to recycle. Research has shown that typical costs of operating a discrete plastic bottle collection and handling programme are £200-250 per tonne inclusive of income from materials (Foster and Simmons 2002, Simmons 2000).

Courtesy Duales System Deutschland AG

However, a growing number of local authorities in the UK indicate their ability to collect plastic bottles as part of a multi-material kerbside collection programme at little or no additional cost. These schemes are typically based on either co-collection of recyclables and residual refuse in compartmentalised vehicles, or increasingly by weekly collections of recyclable materials combined with a fortnightly collection of residual waste.

Recyclers' demand for plastic bottles has been sustained and reprocessing capacity and markets have grown both in the UK and globally. Facilities for handling co-mingled recyclables are increasingly sophisticated and offer efficient centralised sorting. There are a small number of such facilities in the UK. As collection volumes grow, the opportunities to reduce sorting costs will increase.
The most significant opportunity for increasing plastics packaging recycling is to incorporate plastic bottle collection into multi-material kerbside systems and supply these material to high-volume, automated sorting facilities for mixed recyclables. This model offers the potential to provide extensive post-consumer plastic bottle recycling at little or no additional cost.[5] Currently, the main obstacles to such an approach are the lack of investment in appropriate infrastructure and the resistance of some local authorities to move to a fortnightly residual refuse collection.

Other household plastics

Currently, only a limited number of recycling schemes exist for other post-consumer plastics packaging. These include carrier bag recycling programmes run by some retailers and projects to collect thermoformed pots and tubs. These schemes have generated modest tonnages (an estimated 200 tonnes per annum) and are less financially viable than bottle collection schemes.

The EPS Recycling Group has undertaken initial work to evaluate recycling of expanded polystyrene (EPS) from household sources. Markets would exist for post-consumer EPS if collected to recyclers' specifications (Barnetson 2002b), but to date such schemes have not proved viable due to collection limitations. There have been efforts to establish mixed plastics collection and handling systems in the UK, which would accept predominantly unsorted plastics from municipal waste. Development work continues but to date, the technology has not proved commercially viable.

The Association of Plastics Manufacturers in Europe (APME) commissioned a study (TNO 2000a) to undertake inventories of specific plastics recycling schemes for the recycling of post-consumer and industrial packaging throughout Europe.[6] This report is a useful source of further information on the types of scheme operating throughout Europe and their level of success.

Review of EIAs

There is a growing body of work that compares the relative environmental and economic impacts of different plastic packaging waste management options. The majority of this work considers municipal plastics waste management and primarily focuses on the optimum level of mechanical recycling. Most research measures energy use as the primary indicator of environmental impact.

The environmental benefits of mechanical recycling of plastic bottles and other monomer-separated plastic packaging with low material contamination are well demonstrated by a large number of studies.[7] The main benefits relate to the categories of 'primary energy consumption' and 'greenhouse gas emissions'.

By far the highest level of energy use takes place during the initial production of the polymer. For example 90.67% (81.5MJ/kg) of the energy required to produce HDPE pipe


Pennine Fibres Ltd.

Spinnerette extruding PET fibres made from recyclate

relates to the supply of virgin polymer whilst process energy requirements represent only 7.93% (7.1MJ/kg) of total production energy requirements. The figures vary depending on the product manufactured: for HDPE plastic bottles process energy requirements increase to 19.53% of the total energy requirement (21.9MJ/kg). Resin production represents 90% of LDPE film production energy whilst process energy is 6% (Boustead 1996).

By contrast, the energy used in plastic packaging recycling systems, from waste collection to production of pellets or flakes intended to substitute virgin polymers, is significantly lower. For example, the production energy for bottle grade virgin PET is 78.8MJ/kg (Boustead 2001); the energy required to produce recycled PET flake ranges from only 8 to 30MJ/kg (Matthews 1998). Even given the need for

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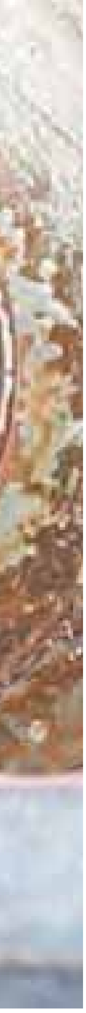
5 *RECOUP estimates that it would be possible to increase plastic bottle recycling levels to more than 200,000 tonnes per annum with minimal additional costs if this approach was adopted across the UK.*

6 *Included are examples of PET and HDPE bottles, distribution/commercial films, crates, coffee cups, EPS industrial packaging and mixed plastics schemes. Schemes for the collection of agricultural film, PVC pipes, window profiles and vehicle bumpers were also covered.*

7 *The specific conclusions of such studies vary depending on the system boundaries employed.*



further processing of the flake to achieve a virgin-equivalent specification, with a reduction of between 62 and 90% (71 to 49MJ/kg), considerable energy savings can be made through recycling.

The impact of transport and sorting of plastic packaging waste is a relatively minor factor in the overall environmental impact of recycling systems (Wollny and Schmied 2000). Plastics recycling systems for municipal waste are relatively new and it is likely that improvements in the efficiency of collection, handling and reprocessing technology will further reduce environmental impacts.

A further important consideration in environmental impact assessments of recycling relates to how the recyclate is used in new applications. The greatest benefits are demonstrated where recycled plastics substitute virgin polymer at a ratio of 1:1 and achieve an equivalent performance. For example, this is typically the case in recycling of plastic bottles into new plastic bottles. Some studies have suggested that the use of recycled plastic packaging in other than their original applications (for example, fenceposts and palisades) results in a lower environmental benefit than feedstock recycling or incineration with energy recovery of the same material (Otto 1999). On this basis APME recommend that 15% is the optimum level of mechanical recycling, on the assumption that only 15% of plastic packaging can be recycled into products that substitute virgin polymer (APME 1998).

Analysis of the use of recycled plastics is currently quite limited. Further work is required before conclusions can be made regarding the environmental gains from using mechanically recycled plastics as replacements for concrete, steel and wood. Such studies need to consider factors relating to the whole product life-cycle. For example, the use of plastics to replace concrete products is likely to result in significantly lighter products, which will have substantial benefits in reducing energy consumption associated with the distribution and installation of such products. Similarly the substitution of wood by plastics may lead not only to extended product life but reduced maintenance requirements and use of environmentally damaging chemical treatments.

study	key findings
Boustead (2001)	recycling of HDPE and PET bottles reduces raw material use and solid waste generation energy savings are only achieved under specific logistical circumstances kerbside collections are more resource efficient than bring systems
Centre for Energy Conservation & Environmental Technology (1997)	mechanical recycling of plastics has clear environmental benefits compared to MSW incineration feedstock recycling has moderate advantages compared to MSW incineration a combination of mechanical and feedstock recycling provides the greatest environmental gain
Freising (1999)	collection and treatment of plastics for recycling are marginal factors in the overall environmental impact of the recycling system efficient energy recovery and feedstock recycling are environmentally comparable, but feedstock recycling is more costly mechanical recycling is environmentally preferable to feedstock recycling
Holland & Wood (1996)	the energy used to recycle plastic bottles is 8 times less than is required to manufacture the same type of virgin polymer
Matthews (1998)	mechanical recycling of PET bottles is preferable to landfill and notably better than chemical recycling or energy recovery

study	key findings
Otto (1999)	energy recovery and most recycling processes achieve a significant environmental benefit compared to landfill mechanical recycling resulting in replacement of plastic products achieves greatest environmental gains feedstock recycling where plastics are used as a reducing agent or where thermolytic processes produce petro-chemical feedstocks are environmentally preferable to syngas production mechanical recycling in applications replacing wood or concrete products showed little benefit over landfill within the system assumptions made
Russell (1996)	recycling of PS vending cups results in reduced energy and water consumption by 25% compared to disposal to landfill
Russell, O'Neill & Boustead (1994)	the more environmentally efficient system for managing post-consumer HDPE is a combination of mechanical recycling and energy recovery
TNO (2000b)	landfill is the least expensive disposal system but has the highest environmental impacts increasing mechanical recycling of MSW plastics over 15% generates little additional benefits at significantly increased costs increasing mechanical recycling from 15% to 50% would increase costs by a factor of three
Wollny and Schmied (2000)	feedstock recycling is environmentally preferable to incineration of plastics waste

Recommendations and priorities for action

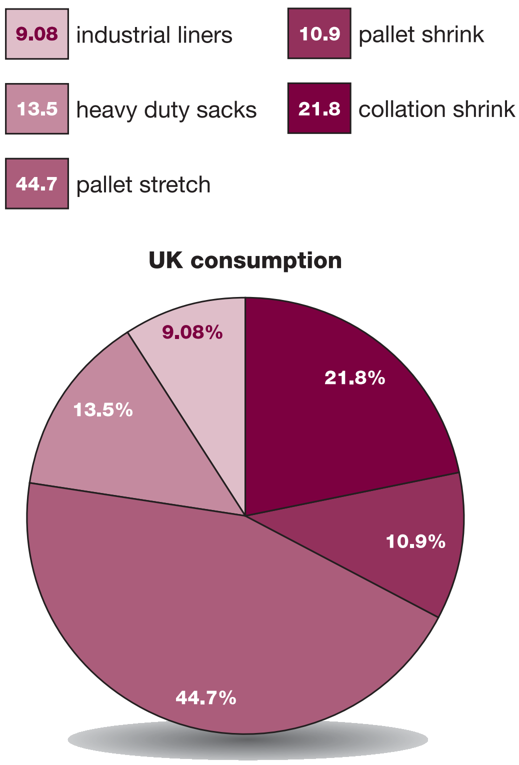
Recommendations and priorities for action for the household packaging sector are listed in the section on commercial and industrial packaging.

Commercial and industrial packaging

Analysis of plastics waste arisings

The Advisory Committee on Packaging (ACP) estimates that 690,000 tonnes of plastic packaging have entered the commercial and industrial sectors in 2002 (ACP 2001). The majority of this will be polyethylene (PE) films. Of these films, 266,000 tonnes are particularly suitable for recycling, as they arise in sufficient quantities and there are existing markets for them. Figure 4 and table 3 provides a breakdown of these types of film.

Figure 4 – percentage of main polyethylene film grades from commercial and industrial waste, 2001



Source - Applied Market Information Ltd 2002 (PIFA 2002)

It has not been possible to ascertain a clear breakdown for the remainder (approximately 430,000 tonnes). It has been suggested that the ACP figure is likely to be understated, and further research is required to verify this data.

There has been a significant growth in the use of reusable plastics packaging, especially in the retail sector. For example, the use of reusable polypropylene (PP) crates by the major supermarkets has increased four-fold from 8.5 million in 1992 to an estimated 35.8 million in 2002 (Twede 1999). The overall market for returnable plastic packaging systems has doubled in this period from 24.6 million to an estimated 47 million units. In addition, there is now a pool of over 500,000 reusable plastic pallets in the UK and this figure is increasing.

The standardisation of pallet sizes by the Institute of Grocery Distribution (IGD) in 1997 has facilitated this progress. At a typical weight of 2.1kg per crate, it is estimated that almost 100,000 tonnes of PP is in circulation in reusable packaging systems. Crates and boxes are used in excess of 25 trips per year and have an intended life-span of 5 to 20 years. There are strong commercial incentives that have contributed to this development; the IGD reports that some retailers have generated annual savings of £10m by moving to such returnables systems.

Table 3 – plastic packaging entering the commercial and industrial sector, 2001

packaging type	Quantity kt
films and bags (PE, PVC, PP)	335 - 455[8]
EPS packaging	30
PP large containers	30
HDPE/HMPE drums	52
PS cups[9]	13
PP crates	45
HDPE crates	37
other	28 -148[10]
total	**690**

Source - Data supplied by RECOUP (2002)

Legislation and voluntary agreements

Legislation relating to this sector has been considered under in the previous section on household packaging.

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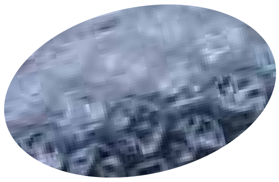
8 *RECOUP estimate based on PIFA and APME data*
9 *Source: Save a Cup, personal communication*
10 *Extrapolation of this category based on APC 2001 data. More detailed verification is recommended.*



Practicalities of recycling

There were 92 accredited plastic packaging reprocessors and 30 exporters at the end of 2001, all of which processed commercial and industrial plastics waste. It is estimated that 195,000 tonnes of plastic packaging waste from commercial and industrial sources was recycled in the UK and a further 60,000 tonnes were exported for recycling.

Data for the period from January to June 2002 indicate this figure has grown further, with 124,719 tonnes accepted by UK reprocessors in the period and a further 60,880 tonnes exported. Assuming similar quantities for the second half of 2002, plastics packaging recycling levels could be as high as 371,000 tonnes, of which over 350,000 tonnes would have come from commercial and industrial sources. This data highlights an unexpected trend and further research is required to establish where this material is being generated.

Of the commercial and industrial plastics packaging recycled, the Packaging and Industrial Films Association (PIFA) report that 90kt of recyclate is used in the manufacture of new film products (PIFA 2002). The Waste and Resources Action Programme (WRAP) highlight further uses for recyclate (Davidson 2002). Table 4 below summarises the current UK markets for recyclate using PIFA, WRAP and RECOUP data.

Table 4 – recycle use in various applications

application	recyclate use (kt)
polyethylene films	90[11]
damp proof membranes	15
pallets	2
PE lumber	20
pipes	8
fibres	3.5
EPS loose fill & insulation EPS lumber	4.500
other mouldings	35
total	**179**[12]

Source - PIFA (2002),WRAP (2002), RECOUP (2002)

Polyethylene films from commercial and industrial sources provide the main source for plastics recycling. Crates, trays and expanded polystyrene (EPS) packaging represent the majority of other plastics recycled from this sector.

The main challenges in the sector relate to the quantities of arisings, contamination, identification of materials, handling facilities and the culture of disposal. Barriers to and opportunities for recycling are considered in detail for different polymer types below.

The most significant scope for recycling schemes exists where there are relatively high volumes of single types of material that are readily identified and easily stored. For this reason, much of the current recycling of commercial and industrial packaging waste is related to films from large distribution and retail centres, where the quantity and quality of arisings justify the development of appropriate handling systems such as on-site baling.

There are significant opportunities to increase plastics packaging recycling within the small and medium enterprises (SME) sector. The implementation of industrial equivalents to domestic ‘kerbside’ or ‘bring centre’ collection systems, servicing particularly industrial and commercial estates, are likely to raise the quantities of plastics waste diverted from these wastestreams.[13]

Polyethylene films

Polyethylene films represent the single most common type of recyclable plastic packaging from the commercial and industrial sector. Film recycling had been well-established for many years prior to regulatory intervention and has grown progressively. The majority of suppliers of waste plastics film are major retailers and distributors, who often have on-site baling and storage facilities. Some businesses also use reverse logistics to deliver film back to central facilities. Tesco, for example, operates a range of Recycling Service Units where film, trays and other packaging is returned for reuse or recycling.

The main types of films being recycled are listed in the market analysis in Figure 4 above. The value of the material is determined by the type of film and its quality. For example, pallet hoods without labels are more valuable than mixed shrink and stretch film with labels or printing.

Crates and trays

There are a number of UK businesses reprocessing returnable tray and crate systems in PP and PE. Table 5 shows the minimum quantities being recycled based on estimates from recyclers. It would be reasonable to expect that growth in this tonnage will correlate closely with the growth in returnable systems use within distribution networks noted earlier.

Table 5 – returnable packaging systems

returnable system	recycled (tonnes/annum)
PP crates	3,000
tote boxes	5,000-10,000
retail distribution trays	5,000
bread baskets	2,000
total	**15,000-20,000**

Source - RECOUP personal communication with plastics processors (2002)

Polypropylene (PP) buckets and pails
PP containers are used in a wide variety of packaging applications and sectors, ranging from catering-sized containers of condiments to paint buckets. Markets for PP recycled from these packaging applications already exist. Unsurprisingly, there are considerable complications to recycling PP containers used to package paints. Although technically feasible, reprocessors would require additional treatment facilities for water contaminated with paint.

Opportunities for recycling of PP pails from the food and dry products industries are more readily identifiable, provided that logistical challenges, such as the collection of sufficient quantities, can be overcome.[14] The use of compatible plastic handles on PP pails, rather than metal handles, would significantly increase the potential for recycling.

Expanded polystyrene (EPS) packaging
Over 15% of EPS from non-domestic packaging waste was recycled in the UK during 2001 (Barnetson, 2002a). The EPS Recycling Group has established a very successful system of take-back schemes with a number of electrical retailers and has extended this to the food packaging sector.

Retailers and suppliers such as Thorn Rentals, Granada, Epson and Dixons Group operate EPS recycling programmes. These usually involve the supplier taking back the EPS packaging from the customer, compacting the material at central depots and selling it on to a recycler. The recovery of EPS in this way carries great financial incentives for suppliers. Collectively Panasonic, Sanyo, Sony and Honda saved more than £500,000 per year in landfill and transport costs through recovery and recycling of the used EPS (EPS Group 1997).

The recycled EPS is manufactured into a range of products including replacement 'hardwood' lumber, simulated slate tiles, plant pots, videos, tape cassettes and loose fill packaging. There is a strong demand for EPS from UK recyclers (Barnetson 2002b) and there are opportunities to increase supply by encouraging food retailers to return EPS packaging such as fish boxes.

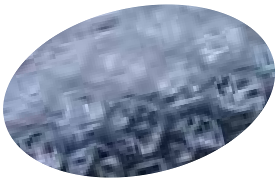
Polystyrene (PS) vending cups
Vending cups account for some 13,000 tonnes of plastics use and are classed as packaging. There is a national scheme for recycling vending cups - the Save a Cup programme. Currently this enables the recycling of 212 million vending cups each year - 850 tonnes of rigid PS. This is recycled into products including desk tidies, paper trays, pencils, rulers and other similar office products.

Currently, the existing collection infrastructure and the economics of a single-stream operation limit the capacity of the scheme. Opportunities exist, however, to link the programme with multi-material recycling schemes.

Thermoformed trays
There has been some recycling of on-shelf trays, for example polyvinyl chloride (PVC) trays from supermarkets, but it has not been possible to identify the market supply or the tonnage recycled. The material is generally clean and readily recyclable. However, the range of polymers (e.g. PVC, PS and PP) used to make visually similar trays presents a challenge in terms of the identification of materials.

Plastic bottles
Plastic bottles found in commercial and industrial waste stem from either converting- and filling-lines waste or customer returns. Large filling and converting companies in both the soft drinks and dairy industry

[11] *We have assumed that process losses from input baled plastics through to conversion to flake/pellet production are 10-15% for material from these sources. This explains the difference between the recyclate use figure (output) and the PRN tonnes issued (input) figure. The guidance of the Environment Agency allows up to 25% yield loss in these processes.*
[12] *We have been unable to verify the breakdown of this figure. Based on process loss level assumptions of 10-15% and assuming the pareto principle applies, this appears plausible.*
[13] *Often businesses are unsure which types of plastic waste, whether and how plastics waste can be recycled. RECOUP is developing a guidance system to help waste management professionals identify the plastics types, using a series of simple inspections and tests. This system will then identify potential recyclers and provide guidelines on maximising material value.*
[14] *RECOUP is currently carrying out a project to establish case studies in this area.*



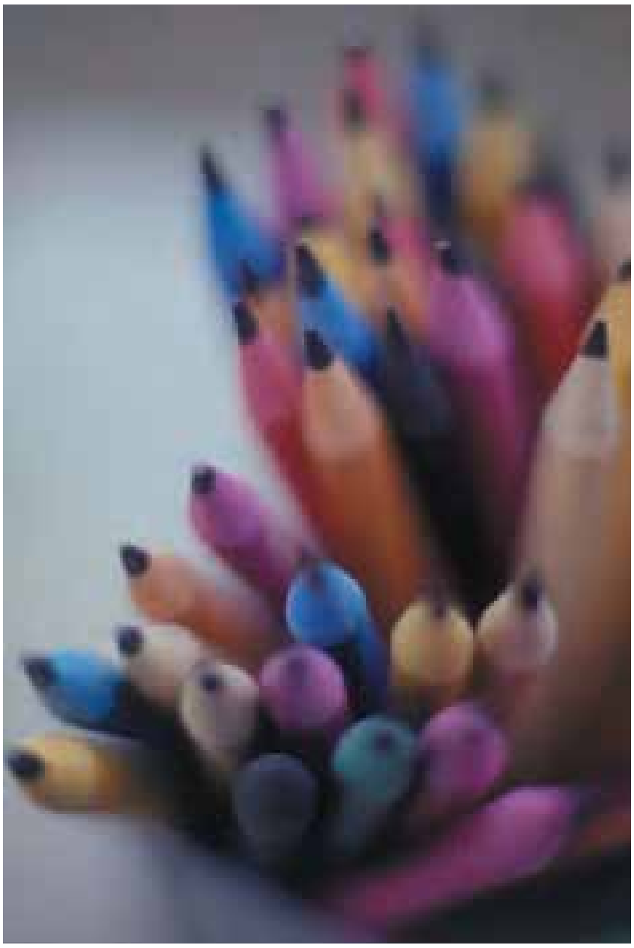
have on-site baling facilities and sell polyethylene terephthalate (PET) and high-density polyethylene (HDPE) bottles to recyclers. RECOUP research suggests filling-line plastic bottle recycling is a little over 3000 tonnes per annum.

Flower pots and seed trays

LBS Repak is an initiative that offers to recycle pots and trays from garden centres and horticultural businesses into new pots and trays. Estimates suggest that the quantity recycled does not exceed 500 tonnes per annum.

Review of EIAs

The findings of EIAs are consistent with those described in the household plastic packaging section above.



Courtesy of Remarkable

The award-winning Remarkable Pencil made using plastic recycled from ESP vending cups

15 *The European Commission COM(1998) 463 final Brussels 22.7.1998, The Competitiveness of the Recycling industries (available from European Commission website at http://europa.eu.int/comm/dg03/directs/dg3c/recycling/recycling.htm) and The recycling industry in the EU: Impediments and prospects (A Report of the Environment Committee of the European Parliament), December 1996 (available at http://europa.eu.int/comm/dg03/directs /dg3c/recycling/recycling.htm)*

Recommendations and priorities for action

including plastic bottles in multi-material kerbside collection systems

Priority should be given to demonstrating how local authorities can include plastic bottle collection in recycling schemes at little or no extra cost and to disseminating this information. Both the packaging industry and central Government should focus on achieving this particular objective to reduce the UK's dependence on landfill and increase recycling-based economic development. The most appropriate approaches should involve a major expansion of information provision for benchmarking and planning purposes combined with technical support through outreach work targeting local government and waste management contractors.

improving existing kerbside collection programmes

New development work should focus on demonstrating how to maximise collection performance within integrated kerbside collection systems. This includes the development of high-quality motivational tools and guidance to local operators. There is evidence of the value of training recycling collection crews as ambassadors for the collection programme, and this should be encouraged and structured programmes developed.

developing incentives for innovation in mixed plastics recycling technology and markets

More emphasis should be placed on developing mixed plastics recycling processes. A number of developments have increased the potential in this area: the progress made in process technology for post-consumer plastics over the last 10 years; the increasing tax incentive to avoid disposal by landfill; and the additional economic incentives that increased recycling targets imply. As collection schemes develop, it will become progressively easier to extend the range of plastics collected if economically and environmentally viable recycling routes exist.

stimulating improved competitiveness of the UK-based reprocessing industry

The UK's growing reliance on export markets for recycling is a concern that should be addressed by central Government. The extremely competitive nature of the UK's compliance system has reduced profit margins and is a major barrier to investment in indigenous reprocessing capacity. A number of EU studies[15] considering ways to improve competitiveness recommend the following steps:

• standardisation to improve the market position of

for the packaging sector

secondary raw materials
- enhancement of market transparency through the creation of exchanges for recyclables and the use of eco-labelling schemes
- promotion of innovation through use of the Fifth European Framework Programme for Research and Development and by complementary policies on quality and training
- simple, and where necessary, harmonised regulation

The Department for the Environment, Food and Rural Affairs (DEFRA) and the Department of Trade and Industry (DTI) and other key stakeholders need to develop a shared understanding of the competitive drivers in the UK reprocessing sector and potential threats to UK compliance with the Producer Responsibility Obligations (Packaging Waste) Regulations 1997. From this, priorities for action in the UK may become clearer.

improving the regulatory framework
Representatives of the plastics recycling supply chain should work with government and the relevant environmental agencies to improve the policy framework for packaging recycling. In particular, the monitoring protocols for accrediting and auditing plastics reprocessors need to be strengthened to ensure continued confidence in the PRN system. In addition, the PRN system has been criticised for failing to create an attractive environment for long-term planning and investment, as PRN prices are driven by a short-term supply and demand balance, which is unevenly phased. It is recommended that reporting of compliance is required quarterly rather than annually. This would reduce speculation and volatility in PRN pricing throughout each year and facilitate longer-term investment planning.

stimulating infrastructure investment
The technologies to efficiently collect, handle and reprocess growing quantities of plastics, especially from packaging sources, are available. One of the barriers to higher levels of recycling is the lack of investment in this new technology, especially in post-consumer kerbside collections and associated downstream activities. government has a role to play in stimulating infrastructure change by offering funds to accelerate this activity and at the same time increasing the comparative cost of waste disposal by significantly increasing landfill tax.

improving data on commercial and industrial inputs and waste arisings
Although some work has been undertaken, there is limited data on waste arisings at a local/regional level in the commercial and industrial sectors. A detailed mapping exercise should be undertaken to identify arisings of plastic packaging waste in the commercial and industrial sectors.

developing practical guidance for waste producers and managers on maximising value from plastics waste
The results of the mapping work referred to above should be disseminated widely both to recycling businesses and to waste management contractors to stimulate the efficient development of new infrastructure and services, especially in the commercial and industrial sectors.

Practical guidance for waste producers, waste contractors and facilities managers on maximising value from plastics waste should be provided. This could be in the form of publications and educational materials. On-line, video and on-site training and technical support would enable the implementation of best practice.

implementing demonstration projects
Projects demonstrating best practice and functioning as case studies should be developed in the following areas:
- collection of EPS fish trays from retailers
- implementation of trials of post-consumer EPS collection from domestic sources
- implementation of least - cost plastic packaging waste management systems for fillers of plastic containers
- multi-material office/facilities collections including vending cups, plastic bottles and recyclables
- business park and SME recycling systems for films, containers and other recyclables

continuing stimulation of value added markets for post-user plastics packaging
There needs to be continued encouragement of supply chains to specify products containing recycled materials. This will be best achieved by a combination of the dissemination of the outcomes of successful case studies and targeted market development work.

Automotive sector

By volume, cars today contain a larger proportion of plastics than any other materials. The specific properties of plastics, which include strength yet light weight, versatility and flexibility, have led to plastics being used to a much greater extent in vehicle manufacture. Due to their light weight, plastics account for an average of only 9.3% (105kg) of the total weight of a vehicle (APME 1999). By comparison, 20 years ago, there was an average of 70kg of plastics used per car. Different types of polymers are used in over 1000 parts of various shapes and sizes, ranging from dashboards and fuel tanks to radiator grilles (APME 1999). The substitution of metals with plastics in vehicles can also lead to significant fuel savings. According to the British Plastics Federation (BPF), 105kg of plastics, used as a replacement for metals, in a car weighing 1,000kg could make possible a fuel saving of up to 7.5%.

Analysis of plastics waste arisings

The average age of an end-of-life vehicle (ELV) entering the UK waste stream is 14 years (APME 1999). Over the period between 1986 and 2000, registrations increased from approximately 1.9 to 2.2 million per year. Assuming an average life-span of 14 years, approximately 1.9 million vehicles have been scrapped during 2000.[16]

In 2000, the average weight of vehicles scrapped was approximately 800 kg (Smith 2002), with plastics accounting for approximately 10% of the overall weight.[17] Safety improvements have contributed to the weight of vehicles and it is estimated that the average weight of new vehicles today is 1100kg. Based on these figures, the weight of plastics waste from ELV is estimated as 150,000 tonnes in 2000 and 244,000 tonnes in 2014.[18]

Legislation and voluntary agreements

End-of-life Vehicles Directive (2000/53/EC)

The End-of-life Vehicles (ELV) Directive (2000/53/EC) came into force in October 2000. The Directive aims to reduce the amount of waste from ELV and sets the following targets for recycling and recovery:

Table 6 – recycling and recovery targets for ELV

year	recovery (% of vehicle weight)	recycling
2006	85%	80%
2015	95%	85%

It should be noted that these targets do not specify which materials are to be recovered and recycled, but may include metal, plastics, rubber and glass.

In addition, the directive

- requires EU member states to ensure that ELV can only be scrapped ('treated') by authorised dismantlers or shredders, who must meet tightened environmental treatment standards
- requires economic operators (this term includes producers, dismantlers and shredders among others) to establish adequate systems for the collection of ELV
- states that last-owners must be able to return their vehicles into these systems free of charge from January 2007
- requires producers (vehicle manufacturers or importers) to pay ‘all or a significant part’ of the costs of takeback and treatment from January 2007 at the latest
- sets rising re-use, recycling and recovery targets for economic operators
- restricts the use of heavy metals in new vehicles from July 2003

Although member states were required to transpose the directive into national law by 21st April 2002, none have yet done so. This is due to the complexity of the directive. The UK government is currently in discussion with industry on the most appropriate implementation options and a consultation paper and draft regulations were published recently.

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[16] *Unfortunately, this number cannot be officially validated as not all companies involved in the process complete the official paperwork (Smith 2002).*

[17] *Weight varies significantly according to model.*

[18] *The estimation provided from the SMMT/CARE group in 1999 was 112,500 tonnes, which is expected to increase to 195,000 tonnes by 2012 (Robson 2002). The estimation calculated from the data supplied by ACORD (ACORD 2001) for 2000 is 192,000 tonnes.*

The Automotive Consortium on Recycling and Disposal (ACORD) Agreement

The ACORD voluntary inter-sector agreement on the treatment of ELV was signed in July 1997 by the following associations

- Society of Motor Manufacturers and Traders
- British Metals Federation
- Motor Vehicle Dismantlers Association
- British Plastics Federation
- British Rubber Manufacturers Association

The member associations committed themselves to improving the recovery of materials to 85% by 2002 and 95% by 2015 (ACORD 2000). However, uncertainty regarding the implementation of the ELV Directive has resulted in a delay in investment in essential treatment facilities and the voluntary targets are now unlikely to be achieved.

Practicalities of recycling

The motor car, despite the complexity of its components and materials, is one of the most effectively recycled products in the UK today. An average of 80% of the weight of each car is already routinely recycled, however this is primarily metal (ACORD 2001).

PP battery cases are commonly dismantled and recycled together with some PP bumpers; the remaining plastics and other materials such as rubber, fabric and glass are usually shredded and sent to landfill (Singh et al 2001). There is limited dismantling and recycling of plastics from ELV and no recycling of shredder residue currently taking place in the UK.

PP accounts for the largest fraction of plastics in vehicles (41%) and there is a trend towards increasing use of it in the production of new vehicles. This is partially due to cost and partially in an attempt to design for recycling by reducing the number of different polymer types used to produce individual parts (Amner 2002). PP battery cases are commonly recycled and some PP bumpers; the remaining plastics from ELV, calculated as approximately 150,000 tonnes for 2000, go to landfill.

Table 7 – material breakdown of a typical vehicle

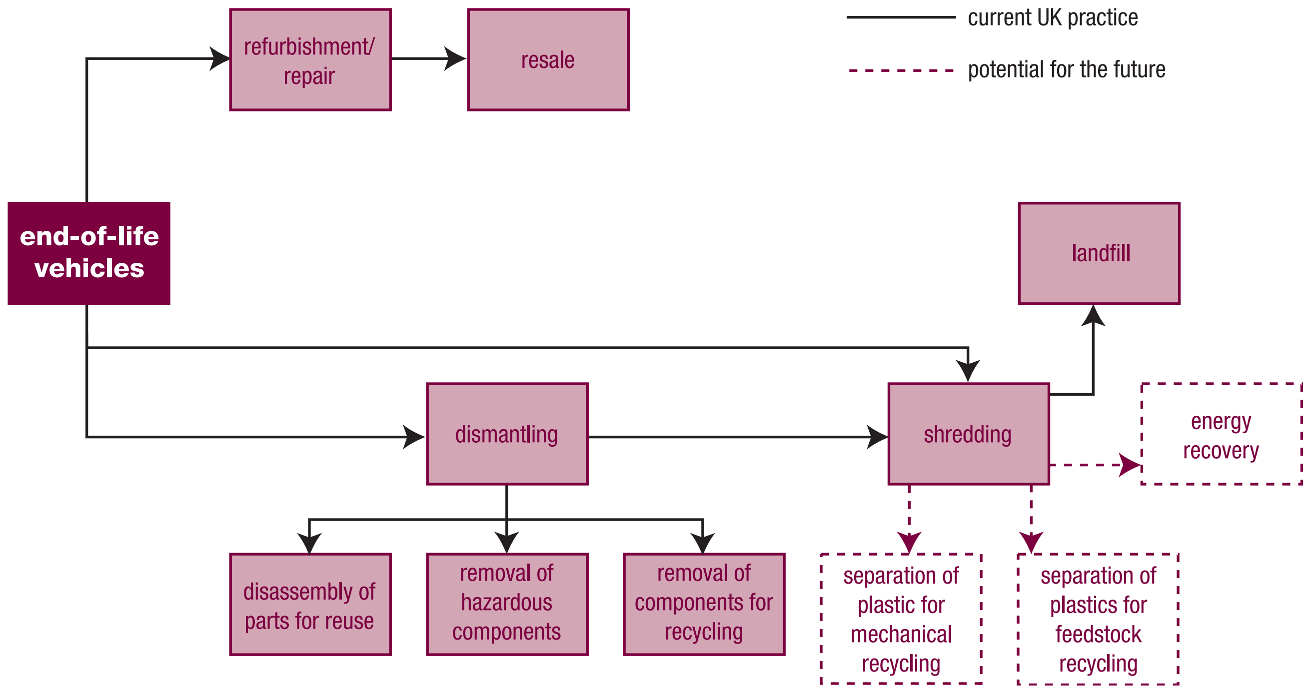
material breakdown	average percentage all cars (1998 - 2000)
ferrous metal	68.3
light non-ferrous	6.3
heavy non-ferrous	1.5
electrical/electronics	0.7
fluids	2.1
plastics	9.1
carpet/NVH	0.4
process polymers	1.1
tyres	3.5
rubber	1.6
glass	2.9
battery	1.1
other	1.5
total	**100**

Source - ACORD (2001)

As noted above, the targets set by the ELV directive for 2006 are not material-specific. Considering the composition of a typical vehicle (table 7), it is evident that there is no specific need to recycle plastics to achieve the 2006 targets. It has been suggested that they could be met more cost-effectively by recycling metal, glass, tyres and fluids (Stokes 2002). However, the recovery and recycling of plastics from ELV may become necessary to achieve the 2015 targets, particularly as the use of plastics in new vehicles increases.

In order to see how this might be achieved it is necessary to understand how ELV are processed (figure 5). There are two points at which plastic can be separated for recycling. The first is at the de-pollution and dismantling stage and the second is after the vehicle has been shredded. However, a number of barriers exist to increasing plastics recycling from ELV sources, which are discussed below.

Figure 5 – current methods of processing end-of-life vehicles



Material identification and separation
Plastics need to be identified and separated into single polymer types if they are to be reprocessed for use in added-value applications. This is a challenging task due to the range of polymers used in vehicles, the design complexity of some components and the high costs associated with the dismantling process. In addition, it is currently difficult to extract single polymer streams from shredder residue.

Reliance on visual markings alone can lead to material contamination, as not all components are marked and some components may be marked incorrectly (Amner 2002). There has been considerable development of technologies to identify and separate plastics, both at the dismantling stage and post shredding. These are described in detail in appendix C.

Contamination can prevent recovered plastics from being used in high-grade, high-value applications. Common contaminants include other polymer types, other materials such as oil, metal, glass and cardboard, dust, moisture, etc. The cost-effectiveness of dismantling of ELV is closely linked to the time this activity requires. Studies have found that manual dismantling of major components enables 60 to 80kg of recyclable plastics material to be separated in the first hour. However, cost-effectiveness decreases the more parts are being separated.[19] This forms a strong disincentive for the complete dismantling of ELV and demonstrates the importance of designing to facilitate dismantling.

Limited end markets
Established end markets exist for certain plastic components from dismantled vehicles, for example PP from battery cases, some bumpers, PVC cable coverings, nylon from airbags. However, there are no commercial, high volume ‘macro solutions’ to plastics recovered from the automotive sector. There is a perception by sections of the user industry that recovered plastic is unsuitable for new products where quality and performance is important (Enviros 2002), whereas in reality many high-quality products can be manufactured from recycled materials. This perception has effectively acted as a barrier to the establishment of end markets for recovered plastics. An associated barrier is that a reliable, high volume

[19] *For example, a study by Schäper (2001) estimated that is takes approximately 45 minutes to dismantle 50 parts weighing a total of 62kg from an Audi TT Coupé. It takes a further 25 minutes to dismantle another 35 parts and only adds an extra 8kg to the total weight. Dismantling a 150 parts takes 140 minutes and brings the total weight of parts dismantled to 78kgs.*

source of material of a specified quality is generally required before companies are prepared to invest in recyclate for use in any significant range of applications. It may be difficult to achieve this given the current infrastructure for the processing of ELV.

It is important for recycled materials to be marketed on the same basis as virgin materials, namely according to cost and fitness for purpose. Manufacturers will have maximum incentive to use recyclates when they are the most economically advantageous option. Suppliers of recycled materials will need to compete on quality and service, providing material quality and supply volume assurance and technical support.

A growing number of car manufacturers, such as Ford, Audi and Vauxhall, are using recycled materials where these meet the required specifications and their cost is comparable with virgin polymer. Ford, for example, have used 30,000 tonnes of recycled plastic globally in 280 different components across their vehicle range (Amner 2002). Audi have used recycled PET bottles in components of the Audi A4 (Scheirs 1998), and Vauxhall have used post-consumer PP in components for the Astra (Nixon 2002). Other major suppliers have examples of similar developments. It is rare for parts to be manufactured using 100% recycled plastic, it is more common to use 25 to 50% recycled plastic blended with virgin. Recycled PET materials, for example, can be used in webbing and carpets in automotive vehicles.

The potential for use of recycled plastics from other sectors in the production of new vehicle parts will be enhanced by the development of common quality standards, as these will help open up cross-sectoral markets for recyclate. The Plastic Reprocessing Validation Exercise (PRoVE) has pioneered the development of generic material specifications for recycled plastics for automotive use, notably talc-filled PP (Amner 2002).

There is also the potential for a certain amount of 'closed-loop' recycling within the automotive sector (Amner 2002), whereby recyclate from automotive plastics waste is used to manufacture new vehicle components. However, a majority of vehicles are now manufactured abroad and would have to be exported for recycling.

Uncertainty over responsibility and financing
Uncertainty surrounding implementation of the ELV Directive has created a barrier to investment in and construction of recycling facilities and associated infrastructure.

The general consensus of experts consulted indicates that the most efficient overall strategy would be to

- dismantle large plastic parts and possibly polyurethane (PUR) seat foam for re-use or mechanical recycling
- separate specific polymer types from shredder residue for mechanical recycling and either landfill the remaining material or use it for energy recovery

Design for sustainability is likely to play an important role in the future through

- the use of simple rather than complex parts in terms of the materials used
- reducing the number of polymer types used in vehicle manufacture
- the introduction of measures to facilitate the identification and re-use of components and materials
- the introduction of measures to promote the use of recycled plastics in new products

When designing for sustainability the entire life-cycle of the vehicle needs to be taken into account, not just the end-of-life disposal/recovery. Studies have concluded that the end-of-life phase of the car consumes only about 1% of the total energy requirements of the life cycle (Coleman 2002). Whilst a decrease in the use of plastics in vehicles may increase overall recycling rates, this is off-set by the fuel savings achieved through the light-weight properties of plastics during the vehicles' life.

Review of EIAs

The following EIA/Life Cycle Assessment (LCA) reports, studying end-of-life vehicles, are currently available:

study	key findings
Coleman T (2002), *Life cycle assessment – disposal of end-of-life vehicles,* Environment Agency	To provide a life-cycle assessment for end-of-life vehicles assessing best practice, environmental options for disposal and examining strategies to meet targets for recovery. The main findings of the study were that the stricter recycling and recovery targets in the draft EC ELV Directive 2000/53/EC and the ACORD plan have the potential to reduce environmental impacts associated with ELV processing and disposal in comparison with 1997 practices. The greatest benefit arising from adoption of the draft EC ELV directive or ACORD plan comes from avoidance of depletion of non-renewable resources.
Jenseit W, Stahl H, Woolny V, Wittlinger R (in preparation) *Eco-efficiency assessment of recovery options for plastic parts from end-of-life vehicles,* Association of Plastics Manufacturers in Europe (APME)	The report considered six different components of a typical car and assessed the recovery options for the plastic element of each. The existing driving force for the recovery of ELV is the recovery of metals. Plastics resulting from the shredding process are currently sent to landfill. Factors considered when assessing recovery options for plastic included the availability of end markets, the quality of plastics recovered and the economics of recovery. For example, mixed plastics are only suitable for use in the production of low quality products, whereas homogenous plastics are suitable for use in the production of high quality products. Additives also affect the potential to use recovered plastic. Dismantling time has a significant effect on recovery, as it is important to gain the greatest environmental benefit for the lowest cost. Recovery options considered in the report included dismantling with mechanical recycling, feedstock recycling and shredding with energy recovery. It was concluded that only limited recovery could be achieved efficiently through dismantling and mechanical recycling and that other recovery methods would need to be used in conjunction with this. The report was due for publication by the end of 2002.
Sullivan J L (1998) *Life Cycle Inventory of a Generic U.S. Family Sedan-Overview of Results* U.S. Automotive Materials Partnership	The Life Cycle Inventory is designed to serve as a benchmark of comparison for environmental performance estimates of new and future vehicles.
Klöpffer W, Le Borgne, R., Feillard, P. (2001), 'End-of-Life of a Polypropylene Bumper Skin', *The International Journal of Life Cycle Assessment* Vol. 6 (3), pp. 167-176.	To apply Life Cycle Assessment methodology to compare various end-of-life scenarios (recycling versus incineration with or without energy recovery) with landfill as a reference for a polypropylene bumper skin The findings of the study indicate that incineration with energy recovery and 90% recycling are the most favourable scenarios.

Recommendations and priorities for action

The ELV Directive was expected to be transposed into UK law by April 2001. However, this has been delayed and government is currently in discussion with industry to determine the most appropriate implementation options. There has been reluctance on the part of producers and reprocessors to invest in collection and sorting infrastructure, and identification and separation technologies whilst these deliberations are on-going. However, the following recommendations provide a focus for the future development work within this sector.

mapping likely profile of arisings of automotive plastics waste in the UK

A more detailed understanding of the profile of plastics waste arisings, including location and quantity, will support infrastructure planning decisions and inform both technology and market development work. It is recommended that a survey of current and potential sources of plastics from vehicles be undertaken to determine the quantities and geographical spread of material available for sorting and reprocessing from dismantling and shredding operations. It may be worthwhile to include plastics waste from electrical and electronic applications in the same survey, as large household equipment is often shredded at the same facilities as ELV.

developing viable shredder residue recovery processes

Development work should focus on maximising the value of plastics in shredder residue. A large-scale programme that links with, supports and builds on international work in shredder residue plastics recycling should also be developed. This should involve evaluating existing technology capable of separating specific polymers from shredder residue and trialing samples of shredder residue from commercial operators to identify suitable technology for the UK and the conditions for viable implementation.

developing best practice guidance for dismantling plastic components

Best practice guidance on the management of plastic components should be developed for dismantlers. This should include costed case studies of plastics recycling through dismantling activities. It should be noted that given the current high costs of dismantling, projects relating to dismantling activities alone are unlikely to generate commercially viable solutions in the absence of ongoing subsidies or economic instruments such as significant increases in disposal costs.

improving information exchange

Producers, dismantlers, shredder operators and reprocessors should be consulted and kept updated on developments and should be encouraged to work in partnership to introduce a suitable infrastructure for the collection and sorting of plastics from ELV.

researching and developing end-markets for recycled plastics from ELV

It is vital to establish end-markets for plastics recovered from ELV, based primarily on the best supplies of plastics from shredder residue. There is considerable potential to consider supplies of PP and other plastics where end-products require low-value feedstock and input quality standards are tolerant of some contamination. There are developments in products/processes for the construction sector that may fit this profile and should be assessed further.

Electrical and electronics sector

In the broadest sense, electrical and electronic equipment refers to any product that relies on batteries and/or electricity for operation, as well as equipment that transports electricity to the product, such as wire and cable. There is a wide range of products defined as electrical and electronics equipment, such as mobile phones, household appliances, electric tools and IT equipment.

Plastics are used in electrical and electronic appliances because they are durable, lightweight, cost-effective, corrosion-resistant and have excellent insulation properties (APC 2000). In 1980, on average, plastics made up 15% by weight of all electrical and electronic equipment. By 2000, this had risen to over 20% (APME 2001).

Analysis of plastics waste arisings

The Industry Council for Electronic Equipment Recycling (ICER) produced a UK Status Report on Waste from Electrical and Electronic Equipment (ICER 2000). This report states that some 915,000 tonnes of post-consumer equipment was discarded during 1998, of which 22% was found to be plastics. Table 8 below provides a breakdown of the waste arising and the tonnage entering recycling processes. ICER, supported by Biffaward, has recently begun major new research establishing up-to-date facts and figures (ICER 2002).

The ICER study reported the following material composition of the above categories of equipment, which made up over 95% by weight of waste electrical and electronic equipment in 1998

- ferrous metals (47%)
- plastics (22%)
- glass (6%)
- non-ferrous metals (4%)

The remaining 21% was made up of other materials, including cardboard, concrete, wood and alloys, as well as complex sub-assemblies, such as circuit boards and motors. This category also included hazardous substances.

Of these materials, metal is currently the only material recovered in large quantities from waste electrical and electronic equipment. Although plastics make up at least 20% of the waste stream, the majority of plastics waste arisings are sent to landfill (ICER 2000).

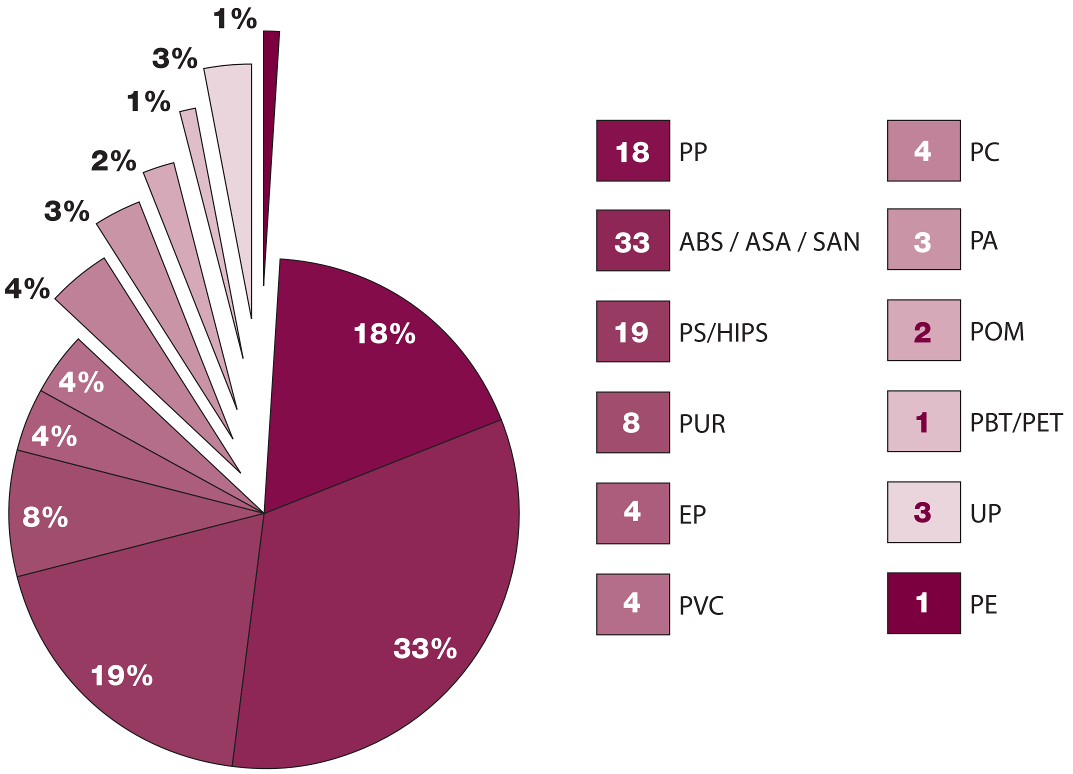
It is estimated that the electrical and electronics industry consumed, in total, 355,000 tonnes of plastic material during 2000. This is based on an analysis undertaken by the BPF of UK consumption and adjusted for import/export movements (Smith 2002). An estimated 200,000 tonnes of plastics entered the wastestream

Table 8 – electrical and electronic waste arisings and breakdown of quantities recycled, 2000

category	waste arising		waste recycled		
	tonnes	% of total waste arising	tonnes	% of total waste recycled	% of total waste arising
large household appliances	392,000	43	345,000	77	38
IT equipment	357,000	39	95,000	21	10
radio, TV, audio equipment	72,000	8	3,000	<1	<1
small household appliances	30,000	3	250	<1	<1
electrical and electronic tools	28,000	3	500	<1	<1
gas discharge lamps	12,000	1	100	<1	<1
toys	8,000	<1	0	0	0
monitoring and control equipment	8,000	<1	0	0	0
telecommunication equipment	8,000	<1	4,000	<1	<1
total	**915,000**	**100**	**447,850**	**100**	**49**

Source - ICER (2000)

Figure 6 – polymer types used in electrical and electronic equipment



Source - APME (2001)

during 1998. With a year-on-year market sector growth of between 3 to 5%, post-consumer plastics are estimated to be approximately 220,000 tonnes in 2000 (Smith 2002) and are expected to continue to rise.

The wide range of equipment and polymer types (figure 6) used in electrical and electronic equipment makes recovering plastics from this equipment a potentially challenging task.

Of these styrenes (ABS, ASA, SAN, PS, HIPS) and PP are the most common, accounting for approximately 70% of plastics used in electrical and electronic equipment in Western Europe in 2000 (APME 2001). By weight, 90% of waste electrical and electronic equipment is made up of large household appliances, IT equipment and brown goods. These types of equipment and polymers therefore hold the greatest potential for recovery and recycling (table 9).

Table 9 – equipment and polymer types targeted for recycling

application	main polymer types targeted for recycling	notes
fridges / freezers	styrenes	• taken to Environment Agency licensed plants for the removal of Ozone Depleting Substances • large plastic parts such as shelving removed prior to shredding • remainder of plastic shredded
other large household appliances	polyolefins (PO)	• refurbished for reuse or taken to a dismantler/ shredder operator
IT equipment and brown goods	styrenes	• commonly shredded together with end-of-life vehicles, producing a PP rich shredder residue • refurbished for reuse or taken to a dismantler/ shredder operator

Source - Data supplied by RECOUP (2002)

Currently, there is very limited recycling of post-consumer plastics from waste electrical and electronic equipment in the UK. It has not been possible to establish any significant post-consumer tonnage recycled. There is development work on recycling of styrenes from fridges and phone casings. A number of UK plastics recyclers, for example Luxus, indicate their ability to handle particular items such as TV casings. However this is based on clear input specifications. Recycling of PVC from cable scrap is the most common plastics recycling activity in this sector.

Although ICER reports a growing network of waste electrical and electronic equipment dismantlers, these companies do not have outlets for their plastics and currently materials are stockpiled and/or landfilled. There is some evidence, based on similar activities in the US, that there are export markets in the Far East for plastics from waste electrical and electronic equipment. However, these do not appear to be used by UK-based recyclers.

Legislation and voluntary agreements

Waste Electrical and Electronic Equipment Directive

In October 2002, the European Parliament and the European Council of Ministers completed the conciliation process for the Waste Electrical and Electronic Equipment (WEEE) Directive. There are a number of further stages that need to be completed before the final version of the directive is placed on the EU statute books (Downs 2002). Member states will be required to implement the Directive within 18 months of this (Lunnon 2002). It appears likely that the transposition deadline will be September 2004, with the financial aspects of producer responsibility coming into force by September 2005.

The purpose of this directive is to reduce the amount of waste electrical and electronic equipment requiring disposal. It aims to increase re-use, recycling and other forms of recovery of such wastes and to minimise their environmental impact. The broad objectives of the directive are

- separate collection of waste electrical and electronic equipment
- treatment according to specified standards
- targets for recovery and recycling (table 10) to be met within forty-six months of the directive coming into force
- producer pays from collection onwards
- retailers to offer free take-back
- consumers to return waste electrical and electronic equipment free of charge

Table 10 – WEEE draft directive recycling and recovery targets

category	recovery	reuse/recycling
large household appliances	80%	75%
IT & telecommunications equipment	75%	65%
small household appliances lighting equipment electrical and electronic tools toys, leisure & sports equipment monitoring & control instruments automatic dispenser	70%	50%
gas discharge lamps		80%

Restriction of Hazardous Substances Directive

In addition to the WEEE directive, the European Parliament and the European Council of Ministers completed the conciliation process for the Restriction of Hazardous Substances (RoHS) Directive in October 2002 (Downs 2002). Member states will be required to implement it within 18 months of its coming into force (Lunnon 2002). Complementing the WEEE Directive, the RoHS Directive seeks to reduce the environmental impact of waste electrical and electronic equipment by restricting the use of certain hazardous substances during manufacture. The RoHS directive covers all products in the WEEE directive except medical equipment and monitoring and control equipment. It bans the use of lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls and polybrominated diphenyl ether (EC 2000a) by July 2006 (Downs 2002).

Electrical and Electronic Equipment Directive

The Electrical and Electronic Equipment (EEE) directive (EC 2001) was put forward as a working paper in February 2001 by Directorate General Enterprise (ICER 2002). The directive seeks to apply design for environmental sustainability to electrical and electronic products across the life-cycle. Industry across Europe has been contributing to a business impact assessment, the outcome of which will enable the Commission to decide whether to put forward an official proposal for a directive and how to improve the current draft (ICER 2002).

Environmental Protection (Controls on Ozone-Depleting Substances) Regulations 2002 (SI 2002 No. 528)
The regulations provide controls for the use of ozone-depleting substances in the following areas

- production and use
- trade
- emission

The regulations requires end-of-life equipment containing ozone depleting substances, such as fridges and freezers, to be treated at Environment Agency licensed plants for the safe removal and disposal of the ozone depleting substances.

Practicalities of recycling

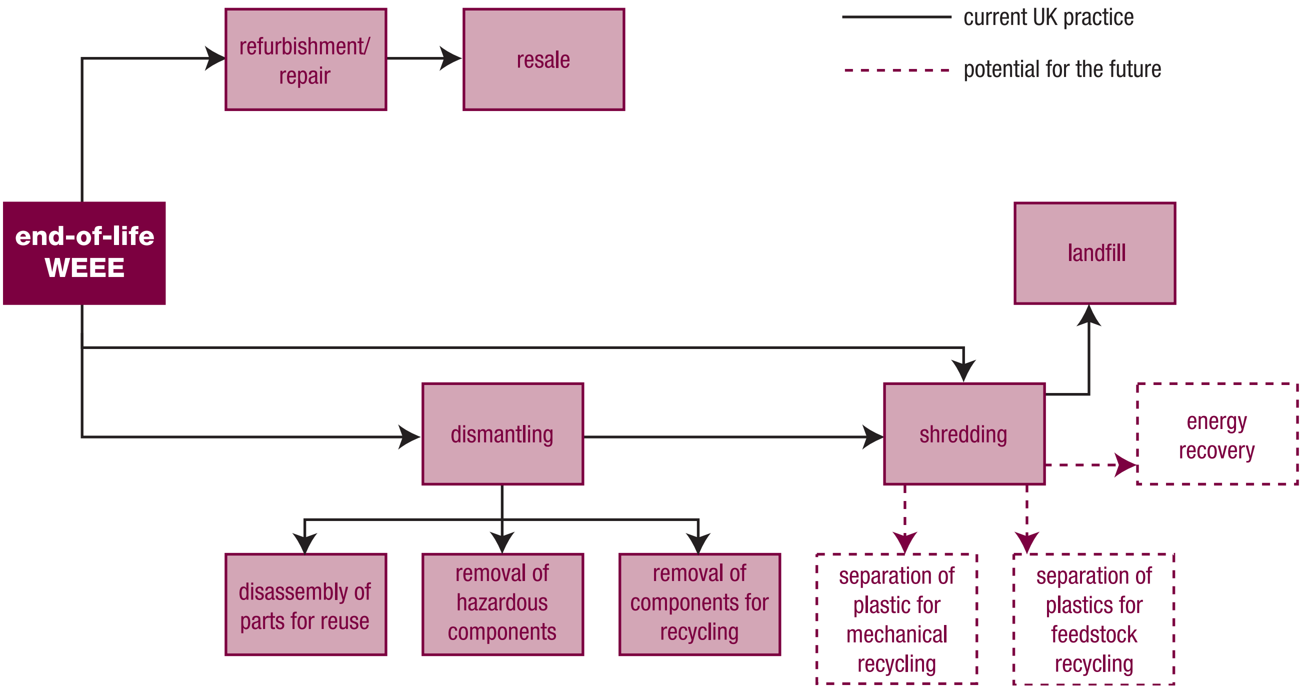
In order to meet the targets set by the WEEE Directive it has been suggested that in excess of 50% of the plastics content of waste electrical and electronic equipment will need to be mechanically recycled (Burstall 2002).[22] Potentially, this means recycling over 100,000 tonnes of plastics.

The reuse of electrical and electronic equipment should receive high priority, as a large quantity is suitable for refurbishment and redistribution. A recent report by DARP Environmental Ltd (2002a), investigates the re-marketing of white goods.[23] A guide to the re-use of computers, which includes a directory of refurbishers, is available from the DTI (DTI 2000). With regards to recycling, there are two points at which plastics can be separated. The first is during the dismantling process and the second is after equipment has been shredded (figure 7).

A number of barriers have been identified, which need to be overcome to increase the recycling of plastics from waste electrical and electronic equipment.

Material identification and separation
Plastics need to be identified and separated into single polymer types if they are to be reprocessed for use in high added-value applications. This is a challenging task due to the many different types of plastic used in waste electrical and electronic applications, the complexity of some equipment and the high costs associated with the dismantling process.

Figure 7 – current methods of processing end-of-life electrical and electronic equipment



[22] *The calculation is based on taking the average recycling targets in the WEEE directive and assessing the amounts of ferrous, non-ferrous and other materials and their achievable yields. The finding is that to achieve the overall recycling target, at least 50% of all plastic and all glass needs to be recycled (Burstall 2002).*
[23] *The report is available for download from the DARP website at www.darpenvironmental.com.*

Contamination can prevent recovered plastics from being used in high added-value applications. Common contaminants include other polymer types, other materials such as metal, glass, cardboard, dust, moisture and so on. Adequate collection arrangements and design for recycling will help reduce contamination.

However, businesses providing technologies and operational facilities to separate polymers to market standards have the potential to address this barrier. There has been considerable development of technologies to identify and separate plastics both at the dismantling stage and post shredding (see Appendix C). A study undertaken by MBA Polymers and the APC found that identifying plastics on a whole part basis using benchtop or automated spectroscopic units and manual or automated sorting is less cost-effective than plastic flake sorting (Arola et al 1999). The greatest opportunity therefore lies in the automated sorting of shredder residue.

Use of hazardous substances

Flame retardants are used in waste electrical and electronic applications to meet fire safety regulations (APME 2000). Some brominated flame-retardants form dioxins and furans when subjected to heat during the recycling process. Of particular concern are polybrominated diphenylethers (PBDEs) and polybrominated biphenyls (PBBs) (ICER 2000). Flame-retardants also affect flow properties of recovered plastics making them more difficult to reprocess (Enviros 2002). The overall proportion of flame-retardant plastics contained in electrical and electronic equipment, however, does not exceed 12% of overall plastics (APME 2000). The WEEE directive will require flame-retarded plastics to be separated during dismantling (Lunnon 2002). Some technologies allow brominated flame-retardants to be separated using an automated sorting process after shredding (Biddle 2002).

Other substances found in older equipment include cadmium and CFCs, found in plastic foam inside old fridges. There is a legal requirement (SI 2002 No. 528) to remove ozone-depleting substances prior to disposal and specialised recovery plants are now in operation in the UK (EA 2002).

As previously stated, the RoHS directive will prohibit the use of certain hazardous substances by July 2006. While this will eliminate the problem of having to manage these substances in the future, it adds to the current challenge of developing end-markets for material from older equipment.

Limited end markets

Currently there are limited commercial markets for plastics recovered from waste electrical and electronic equipment. ICER (2000) claims that 'one of the keys to improving the cost/value balance lies in finding markets for recycled plastics.' There is a general perception by specifiers and manufacturers that recovered plastics are of low-grade and low value (Enviros 2002). This misconception has acted as a barrier to the establishment of end markets for recovered plastics.

It is important for recycled materials to be marketed on the same basis as virgin materials, namely according to cost and fitness for purpose. Manufacturers will have maximum incentive to use recyclates when they are the most economically advantageous option. Suppliers of recycled materials will need to compete on quality and service, providing material quality and supply volume assurance and technical support. Detailed material performance certification could be provided to assure manufacturers of the quality of recyclate.

Mixed plastics can be recycled and used to produce low-value products, such as wood and concrete substitutes; they are not currently suitable for high-value or closed loop applications. There is, however, an opportunity for further development and diversification of applications produced using mixed plastics.

Plastics containing substances banned under the RoHS directive cannot be used to produce components for use in new electrical and electronic equipment to be put on

the market after July 2006. This means that alternative end-markets will need to be found.

As the WEEE directive will require flame-retardant plastics to be separated out during dismantling, in theory shredder residue should not contain these substances. Plastics containing these substances could be used in low-value applications not associated with electrical and electronic equipment, but more research is needed in this area.

A further barrier to the establishment of end-markets is that a reliable, high-volume source of material of a specified quality is generally required before companies are prepared to invest in it for use in applications. Given the wide variety of equipment and polymer types found in waste electrical and electronic equipment, this may prove challenging.

There is a growing number of routes for collection of waste electrical and electronic equipment, involving both specialist refurbishment companies and recyclers. To achieve the targets set by the WEEE directive, there will need to be an increase in consumer collections of WEEE including plastics. However, the primary drivers for new collection systems are not targeted specifically at plastics waste.

The plastics recycling sector does not need to replicate existing supply infrastructure. Existing commercial recyclers are looking for outlets for the plastics they currently generate as a by-product of their operations. This offers dedicated plastics recyclers or specialist technology providers the potential to readily source commercially viable volumes of recyclable plastics. Recyclers could enhance their income through charging a gate fee for plastics from waste electrical and electronic equipment. If this fee is lower than prevailing alternative disposal costs, this will create an incentive to divert plastics waste from the waste stream.

In addition, virgin engineering thermoplastics commonly used in electrical equipment are often high-value, specialised polymers. Plastics recovered from waste electrical and electronic equipment, therefore, have the potential to attract relatively high market values if reprocessed to the required standards (Enviros 2002). This could act as an incentive for the investment in reprocessing facilities and the marketing of recycled plastics.

Unclear responsibility and financing
Uncertainty surrounding implementation of the WEEE Directive has created a barrier to investment in recycling facilities and associated infrastructure.

As in the automotive sector, the general consensus of experts indicates that the most efficient overall strategy would be to dismantle large plastic parts for re-use or mechanical recycling, separate specific polymer types from shredder residue for mechanical recycling and either landfill the remaining material, or use it for energy recovery.

Design for sustainability is likely to play an important role in the future, through:

- simplification of the material composition of parts
- reducing the number of polymer types used in vehicle manufacture
- minimising the use of hazardous substances
- the introduction of measures to facilitate the identification and re-use of components and materials
- the introduction of measures to promote the use of recycled plastics in new products

Active disassembly using “smart materials” could also greatly increase the potential for recycling of waste electrical and electronic equipment. Automatic disassembly is achieved through the incorporation of smart material devices into a host application. A number of consumer electronic products from Sony, Nokia and Motorola are currently being disassembled using this technique (Jones et al 2002).

Review of EIAs

The following EIA and LCA reports assessing waste electrical and electronic equipment are available:

study	key findings
PriceWaterhouseCoopers (2002), *Environmental Life Cycle Assessment and Financial Life Cycle Analysis of the WEEE directive and its implications for the UK,* DTI	The study aimed to provide updated estimates of the expected environmental and financial costs and benefits to the UK of the collection, pre-treatment, recycling and recovery of a range of electrical and electronic products based on the latest version of the WEEE directive for all environmental indicators, the introduction of the WEEE directive has a positive effect for most products, due mainly to an increase in refurbishment and recycling of materials. The analysis shows that the current situation is only cost-effective for personal computers and that the introduction of the WEEE directive worsens the situation by increasing costs. It should be noted, however, that despite an overall negative figure, profitable activities take place within the disposal chain (e.g. shredding, refurbishing, and recycling).
Mayne 2002, (in preparation) *Eco-efficiency of routes for selected WEEE products containing plastics, TNO Report R2001/454,* Association of Plastics Manufacturers in Europe (APME)	To provide an assessment of routes for selected WEEE products containing plastics. The report considered three typical WEEE products: one large (fridge), one medium (TV) and one small (mobile phone). The existing driving force for the recovery of each product was examined. Although fridges are collected in order to remove CFCs, TVs to remove cathode-ray tubes and mobile phones to recover precious metals, plastics are generally sent to landfill. Recovery options considered in the report included dismantling with mechanical recycling, feedstock recycling and shredding with energy recovery. It was concluded that only limited recovery could be achieved efficiently through dismantling and mechanical recycling and that other recovery methods would need to be used in conjunction with this.

Recommendations and priorities for action

Similar to the situation in the automotive sector, investment activities in plastics recycling are currently discouraged by the uncertainty over the implementation of the forthcoming legislation. The clarification of statutory responsibilities arising from the WEEE directive will enable producers and reprocessors to identify the most appropriate investment and infrastructure development opportunities. The following recommendations identify the priorities for action within this sector.

mapping available supplies of WEEE plastics
This could be achieved by conducting a survey of current and potential sources of plastics from WEEE to determine the quantities and geographical spread of material available for sorting and reprocessing by dismantlers and shredder operators. This information will provide key data required to identify where secondary plastics handling processes may be viable. As previously mentioned, surveys of automotive and large waste electrical and electronic equipment could be combined as these are often shredded in the same facilities.

evaluating dismantling practices of WEEE plastics
Individual specialist refurbishers and dismantlers of waste electrical and electronic equipment are unlikely to have the throughput of material required to make it economically feasible to invest in the identification and sorting equipment required to separate plastics efficiently. A potential model is that such businesses supply dismantled plastics components to specialist plastics reclamation plants for identification and reprocessing. The feasibility of such a model should be evaluated.

evaluating the infrastructure for shredder residue plastics
Many experts in the recycling of waste electrical and electronic equipment agree that as technology develops, separating plastics after shredding will be the preferred option. The separation performance and cost effectiveness of existing technologies capable of separating specific polymers from shredder residue should be evaluated. This work should be undertaken in partnership with one or more of the larger shredder operators, as they are most likely to have a sufficient throughput of plastics material to make the process economically feasible. EMR is already researching the separation of plastics from shredder residue (Robson 2002) and US-based MBA Polymers are undertaking large trials on materials from the UK (Biddle 2002).

stimulating capital investment in appropriate technologies
Grants or other economic instruments can be used to bring forward early commercial investment in appropriate plastics recycling technologies from this sector. The extent of requirements for this approach should be considered following the evaluation and mapping work identified earlier.

developing end markets for WEEE-sourced plastics
It is vital to establish viable end markets for plastics recovered from waste electrical and electronic equipment to achieve statutory targets. This should prioritise dismantled styrenics, PP, sorted shredder residue and markets for plastics containing hazardous substances

designing for recycling
There needs to be increased engagement of the electrical and electronic equipment supply chain in designing for recycling and the use of recycled materials. These considerations should be incorporated within a wider 'Integrated Product Policy' approach.

Examples of such action could include
- development of a low-cost training package on how products can be designed to be more readily recyclable, for example through material selection, marking and ease of dismantling
- development of generic standards for recycled material acceptable to major customers in the sector

The development of many electrical and electronic products is at an international level. Major changes in practices in the supply chain will require European or international agreements and be based on cost-led arguments, rather than an appeal to 'green sensibilities'.

finding common solutions
Wider supply chain collaboration and communication between producers, refurbishers, dismantlers, shredder operators and reprocessors is required to stimulate common solutions across the supply chain.

Greater cross-sectoral communication, for example dissemination of case studies of effective supply chain solutions, and a stakeholder dialogue process may be of value in aligning understanding and expectations. The most appropriate way to take this forward initially might be through a project forum where responsibilities, development needs and financial parameters can be discussed.

Building and construction sector

The building and construction sector is the second largest plastics user after the packaging sector and is an important growing market for plastics (APME 1998a). Compared to other materials used in the building and construction industry, the percentage of plastics used in this sector is relatively small (less than 1% by weight). However, they form part of a wide variety of applications. Approximately, 0.8 million tonnes of plastics are used per year, much of which does not enter the waste stream for many decades.

PVC is by far the most common plastic used in the building and construction sector, accounting for approximately 60% of all plastics used. Other plastics used include PU, EPS, HDPE, LDPE and PS (APME 1998a). Common uses include pipes and ducts, insulation, floor and wall coverings, windows, profiles, lining and fitted furniture (APME 1998a).

A large proportion of plastics used in the construction industry has an intended life of many decades. Over the past 25 years there has been a trend towards increased use of plastics in the building industry and in Western Europe it is predicted that plastics use will increase to almost 8 million tonnes by 2010 (APME 1998b). Given this increased use of plastics, it is likely that large quantities of plastic waste will arise during future demolitions.

During 2000, approximately 800,000 tonnes of plastics were used within the building and construction sector (Smith 2002). A wide range of component products and total systems were produced from a number of different polymers. The majority of bulky items were both manufactured and sold within the UK to maintain operational efficiency. In the case of the smaller items, much of these were manufactured in the UK and distributed on a European or worldwide basis. A superficial examination supports the view that imports and exports are largely in balance (Smith 2002).

Analysis of plastics waste arisings

Structural products

With a share of approximately 60% of plastics used in the construction sector, PVC is by far the most commonly used material and accounted for 500,000 tonnes during 2000 (Smith 2002). HDPE is the second most commonly used material (13%) and accounts for a further 105,000 tonnes (Smith 2002). An overall breakdown of materials used, including the remaining 27%, is provided below (table 11).

Table 11 – polymer types used in the building and construction sector

polymer type	quantity (tonnes)	use
PVC	500, 000	rainwater systems non-pressure drainage systems window profiles doors and door frames claddings/soffits/bargeboard skirtings/architraves telecom/service ducting
HDPE	105,000	waterproof membranes pressure system for gas/water supply conduits non-pressure drainage
PUR	45,000	insulation
PP	35,000	small-bore pipes/components
EPS	24,000	wall insulation
ABS	21,000	pipes/sheeting
PC	14,000	sheeting/glazing
PMMA	14,000	shower trays/sanitary ware
PA	13,000	ancillaries
UPR	29,000	sanitary ware/cladding/ roof tiles
total	**800,000**	

Source - Smith (2002)

The vast majority of these construction products have an intended life of many decades. For example, over 60% of PVC applications have a lifetime in excess of 40 years (Cousins 2002). It is estimated that 100,000 tonnes of PVC plus a significant tonnage of HDPE is buried below ground and, in the normal course of events, is unlikely to be removed for disposal, as the cost of this would far outweigh any perceived benefit. Table 12 shows the tonnage of plastic that is not recoverable/potentially recoverable from the building and construction sector. A further 25,000 tonnes of PVC is contained within building structures and unlikely to be removed unless the property is demolished (Smith 2002).

Other plastics components include external items, such as rainwater pipes and cladding, and items such as sanitary ware. Currently no statistics for these items exist. Assuming that less than 10% of this total tonnage is likely to be removed, for example in kitchen or bathroom replacement, no more than around 50,000 tonnes of material will enter the waste stream per year.

Table 12 - quantity of potentially recoverable plastics in building and construction sector

material	quantity (tonnes)
material not recoverable[24]	225,000
material potentially recoverable	575,000
total material used	**800,000**

Source - Smith (2002)

Non-structural products
A further 250,000 tonnes of plastics materials are used per year by the construction industry to produce:

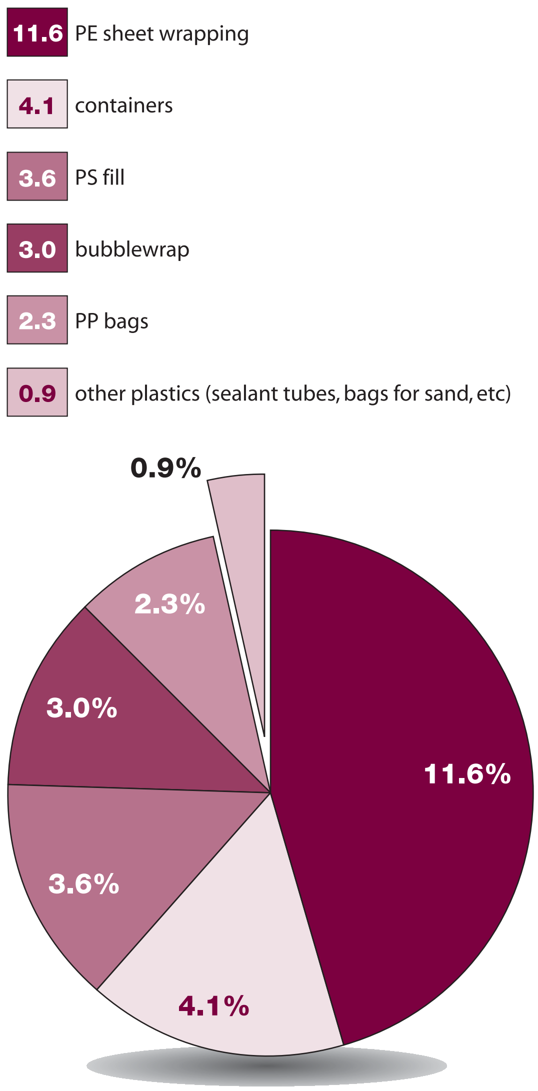
- floor, wall and ceiling coverings
- blinds and shutters

These products are largely made from PVC and have a limited lifespan.

Packaging
Packaging plays an important role in protecting and identifying products. Most products used on construction sites are placed on, wrapped in, or held together by packaging. Plastics make up approximately 25% by weight of packaging waste on construction sites (figure 8), with the remainder being mainly timber, paper and cardboard (Anderson et al 2002).

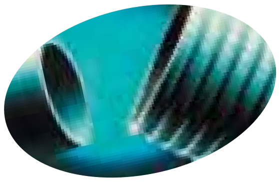
Packaging waste arisings change during the construction process, with the greatest percentage of plastics packaging volume being produced when a project is close to 80% completion (Anderson et al 2002). PE sheet wrapping makes up over 11% of plastics packaging waste from construction sites, and it is estimated that 17,168 tonnes are available for collection per year (Anderson et al 2002)

Figure 8 - constituents of plastic packaging waste in construction (%)



Source - Anderson et al (2002)

[24] The majority of this 225,000 tonnes comprises of PVC and PE pipes buried in the ground. It must at this time be assumed that the environmental cost of removing these products, far exceeds any environmental gain.



Legislation and voluntary agreements

There is currently no legislation directly relating to the recycling of plastics from the building and construction sector. However, the Producer Responsibility Obligation (Packaging Waste) Regulations 1997, discussed above, will apply to packaging waste arising from this sector.

Vinyl 2010 – The Voluntary Commitment of the PVC Industry

The Voluntary Commitment of the PVC Industry, signed in March 2000, has been developed to address comments received during extensive public and political consultation. As a result, an updated version called Vinyl 2010 – the Voluntary Commitment of the PVC Industry was signed in October 2001 (Vinyl 2010).

With respect to end-of-life products, four sector associations have committed to mechanically recycle at least 50% of collectable waste by 2005 (2008 for flooring)

- plastics pipes and fitting sector, represented by The European Plastics Pipes and Fittings Association (TEPPFA)
- window frame sector, represented by European PVC Window Profile and Related Building Products Association (EPPA)
- flooring sector, represented by EuPC PVC Flooring Sector Group (EPFLOOR)
- roofing membranes sector, represented by European Single Ply Waterproofing Association (ESWA)

Practicalities of recycling

The majority of plastics waste from the UK building and construction sector is currently landfilled and only very little is recycled.[25] However, the imposition of the landfill tax in the UK means that landfilling of construction waste is rapidly ceasing to be a commercially viable option (Douglas et al 2000).

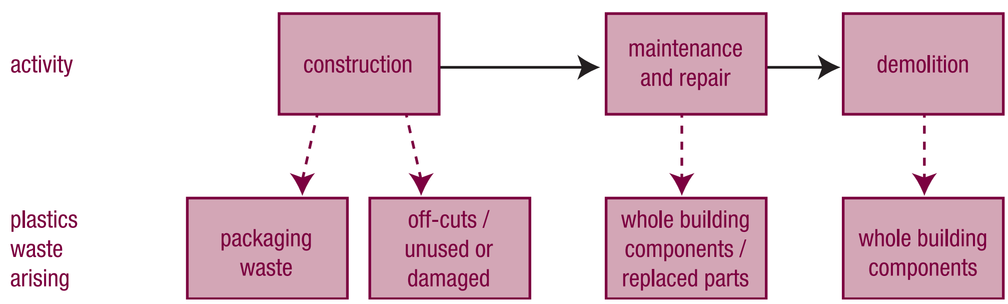
To determine strategies for the recycling of plastic from the building and construction sector it is necessary to understand the types of waste generated and the stage at which they are generated (figure 9).

As can be seen there are four distinct sources of waste generated by the building and construction sector - packaging, off-cuts and unused or damaged material, parts that have been replaced and whole building components. These sources of waste arise at different phases of construction and demolition, as shown below.

Culture of waste disposal

There is little evidence of businesses attempting to recover plastic materials during either construction or demolition. The complex nature of many construction projects, often involving a wide variety of subcontractors, responsibilities and changing locations, presents logistical and cultural challenges. Arguably there is a culture of disposal where waste is simply 'skipped' and moved off site. Without demonstrating practical, financially viable systems of operation this approach will be difficult to change. Many smaller construction firms are unaware of their environmental responsibilities; according to research commissioned by the Environment Agency, 74% of smaller construction

Figure 9 – plastics waste from construction and demolition



[25] *Figures for Western Europe show that during 1995 less than 5% of plastic waste from the building and construction sector was mechanically recycled.*

businesses surveyed did not believe that they carried out activities that could harm the environment (Edie Newsroom 2002).

Material identification and separation

Plastics need to be identified and separated into single polymer types if they are to be reprocessed for use in high-grade, high-value applications. In theory, this should not be a significant barrier to recycling plastics waste at the construction phase, as the construction manager should know exactly what materials are brought onto a site and should therefore be able to manage waste flows with some confidence (Symonds 1999). Identifying and separating plastics from demolition waste is likely to prove more challenging. The BPF are planning to undertake an analysis of demolition waste in the near future (Davis 2002).

Contamination

Contamination can prevent recovered plastics from being used in high-grade, high-value applications. Common contaminants include other polymer types and other materials such as metal, glass, cardboard, dust and moisture. Waste materials from new construction are usually clean and relatively uncontaminated, whereas demolition wastes tends to be contaminated and mixed with other materials (Douglas et al 2000).

Lack of guidance and collection infrastructure

Limited guidance relating to the recovery and disposal of plastics from the building and construction sector, coupled with the lack of adequate collection infrastructure, creates a major barrier to recycling. Some guidance is available, for example the *Waste Minimisation and Recycling Consortium - Design Manual* (1998) published by the Construction Industry Research and Information Association (CIRIA). The contents concentrate on three key aspects: waste minimisation through the reduction of resource consumption, reduction of waste generation at construction and demolition sites and improvement of materials reclamation.

End markets

The construction sector represents an opportunity for the development of end markets for recycled products. There is a range of products containing recycled plastics suitable for the construction and related industries such as HDPE drainage pipe, window profiles, acoustic shielding, pathway systems, hollow core floor slabs, geomembranes and insulation materials. In addition there is a range of composite products that are under development that combine recycled plastics with glass fibre, concrete or wood.[26]

There is also the potential for closed-loop recycling within the building and construction sector. Closed-loop recycling for PVC is already operated in the Netherlands, where discarded PVC pipes are separated out and shredded to a granulate form. The granulate is heat-treated and used for the production of non-pressure sewerage pipe (APME 2000).

In the UK, the Building Research Establishment (BRE), supported by WRAP, is currently undertaking a project aimed at increasing markets for recycled construction products, particularly through assistance with certification and product approvals to allow products to be promoted as fit for purpose (BRE 2002).

If end markets are to be developed further, reprocessors need to be able to guarantee a reliable and adequate supply of material. Ensuring appropriate collection infrastructure is in place would help ensure that this can be achieved.

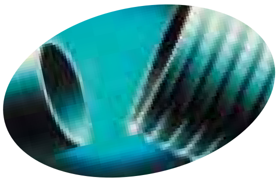
In certain cases there are standards, other than performance, that limit the use of recycled materials such as the requirement to use virgin polymer. These are a potential barrier to recyclate use in some applications in this sector.

Value of recovered material

The most viable materials for recovery are unused/damaged PVC and PVC off-cuts from the construction phase and polyethylene sheet wrapping. If handled correctly, these materials are relatively easy to separate and keep clean, thereby increasing potential market value. Special clauses can be inserted in tenders and contracts requiring contractors to recycle specific materials during construction. Specifying requirements for recycling at this stage removes the potential for added costs later on.

The BPF are currently running a number of small trials on demolition/refurbishment work with old PVC windows, but at present the value of the recovered material is less

[26] *Examples of many of these products can be found on the RECOUP website (www.RECOUP.org) in the "End Products" section, or on the eco-construction website (www.ecoconstruction.org), which contains guidance on issues such as planning, selecting or specifying materials and case studies.*



than the cost of recycling it. However, steps are being taken to address this (Jervis 2002).

Design for environmental sustainability
There is growing emphasis on ‘sustainable construction’. Sustainable building design and international standards such as ISO 14001 to facilitate waste minimisation, recycling and increased use of environmentally sustainable products will play an important part in improving recycling of plastics and other waste from the building and construction sector.

A strategy to increase plastics waste recycling within the building and construction sector should include the following steps

Design phase
- design for selected demolition and use of recycled materials
- specification based on performance only

Construction phase
- encourage implementation of a well designed and managed waste minimisation systems
- target PVC off-cuts/unused or damaged material for mechanical recycling
- target polyethylene sheet wrapping for mechanical recycling

Demolition phase
- selective demolition
  - separation and disposal of hazardous materials
  - separation of specific building components such as PVC window frames for reuse/recycling

Review of EIAs

To date it does not appear that any EIAs or LCAs have been undertaken with respects to plastics waste from the building and construction sector. However, both DEFRA and the European Commission (EC) have produced a number of relevant studies on PVC, the main polymer used in the construction sector[27]

study	key findings
DEFRA (2002) *Life Cycle Assessment of Polyvinyl Chloride and Alternatives: Summary Report for Consultation*	This study aims to inform policy development regarding the manufacture, use and end-of-life management of PVC. The report considered a selection of applications and alternative materials. It was found that in the case of collation trays the PVC tray system generally performs marginally better and for flooring it is the linoleum system that exhibits the marginal general performance advantage. In the case of rainwater pipes and window profiles, the differences are more pronounced however, with the PVC pipe system performing better than the aluminium pipe system and wood profile system performing better than the PVC profile system.
EC (2000a) *Environmental Issues of PVC*[28]	
EC (2000b), *Mechanical Recycling of PVC Wastes*	
EC (2000c), *Chemical Recycling of Plastics Waste (PVC and Other Resins)*	
EC (2000d) *The Influence of PVC on the Quantity and Hazardousness of Flue Gas Cleaning Residues from Incineration*	
EC (2000e) *The Behaviour of PVC in Landfill*	

Recommendations and priorities for action

developing and distributing best practice guidelines
Development of best practice guidance is required to identify the best on-site management options for major plastic items to enable recycling. This could be in the form of case studies with supporting economic arguments. Guidance on waste minimisation and recycling in construction is available, but there appears to be a lack of information relating specifically to plastics waste.

developing end-markets for recycled plastics in the construction sector
Focused work is required to stimulate and commercialise new uses of recycled plastics, particularly recycled pipes and profiles, in this sector. In addition, there are opportunities for the use of recycled plastics in composite products where plastic has not been a traditional material of choice.

developing design for selective demolition
It is recommended that further research be undertaken to assess the following:

- types of plastic component (e.g. PVC window frames) that can be easily dismantled and separated for recycling during demolition
- quantity of material likely to be available for collection and recycling from the demolition sector
- reprocessing facilities for plastics from demolition and their potential specialist requirements

Deutsche Gesellschaft für Kunststoff-Recycling mbH

Window profiles from recycled PVC

[27] *A large number of studies dealing with issues relating to PVC are available, only the most recent are listed here.*
[28] *This is a draft green paper on the environmental issues of PVC based upon the below studies. This is available from the European Union*

Agricultural sector

There are approximately 250,000 agricultural enterprises in the UK. The use of plastics has grown in the agricultural sector and covers a range of applications. Plastics are used in products such as packaging, permanent/semi-permanent buildings, crop covers, irrigation systems and tools and equipment. Little material is currently recycled or recovered. A significant tonnage is either buried or burned after use.

Analysis of plastics waste arisings

UK agricultural enterprises generate the following plastics waste arisings (Table 13)

Legislation and voluntary agreements

Although there currently are no obligations to recycle materials from these sources, the government intends to extend existing waste management controls to include waste from agriculture in the implementation of the EC Framework Directive on Waste. This will introduce a waste management licensing system, a legal duty of care and a registration system for businesses transporting waste. Waste disposal on farms will no longer be possible without a waste management licence or exemption. Since the costs associated with applying for and holding a licence are very high, the only viable option

Table 13 – estimates of agricultural waste arisings (tonnes), 1998[29]

agricultural waste arisings (tonnes)					
	England	**Wales**	**Scotland**	**Northern Ireland**	**total**
packaging					
agrochemical	1720	30	276	374	2400
fertiliser bags	8748	984	1654	815	12200
seed bags	840	15	134	12	1000
animal feed bags	6419	1283	2019	1680	11400
animal health	444	105	124	76	750
oil containers	501	47	84	38	669
miscellaneous	2063	331	1166	240	3800
total packaging	**20734**	**2794**	**5457**	**3235**	**32219**
non-packaging plastics films					
silage plastics	12425	5016	5029	2530	25000
greenhouse/tunnel film	242	5	6	5	500
mulch/crop cover	3738	30	657	76	4500
total film	**16405**	**5051**	**5692**	**2611**	**30000**
other					
silage wrap cores	703	339	327	138	1506
other horticulture	5617	114	143	127	6000
bale twine/net wrap	7934	821	1683	662	11100
tree guards	6694	532	4492	182	11900
total other	**20948**	**1806**	**6645**	**1109**	**30508**
total plastics	**58087**	**9651**	**17794**	**6955**	**92727**

Source - Marcus Hodges Environment Ltd (2001)

[29] *In some cases the quantity of plastics reported in this section will also have been reflected in other sections of this report - e.g. packaging. Information is included to reflect the discrete nature of waste arisings from this stream and the relatively good data available.*

for many wastestreams will be to transfer the waste to a contractor for disposal, or recovery at a licensed facility (Environment Agency 2001).

Certain farm plastics, such as feed bags, fall under the provisions of Packaging Directive. Silage films and crop covers are not classed as packaging.

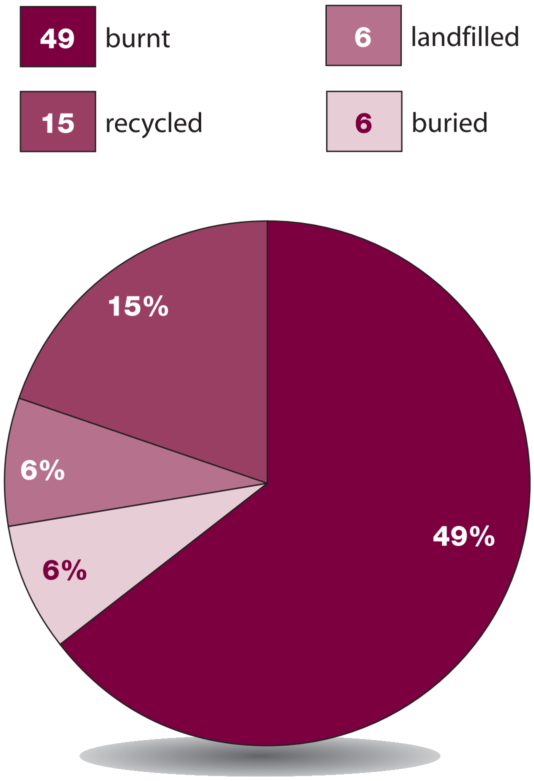
In the early 1990s, the film manufacturing industry, recognising that many farmers had an end use disposal problem, set up a national scheme to recover 'farm films' for recycling. This voluntary scheme was financed by a £100/t levy on each tonne of agricultural film sold to cover the incremental cost of collecting and reprocessing this material. This voluntary agreement collapsed because two overseas suppliers gained a competitive advantage through evading this charge.

Practicalities of recycling

Efforts to recycle plastics from this sector have predominantly focused on films. However, the quantity of waste film produced per enterprise is relatively low and heavy contamination with residual soil or silage is likely in the case of silage plastics films, mulch and crop covers. Each tonne of silage plastics collected typically has a proportion of 57% contamination by weight (Davies 2002). Crop covers can have even higher levels of soil contamination.

Research by the ADAS consultancy group indicates the following waste management practices for silage wrap (Davies 2002)

Figure 10 - waste management practices for silage wrap



Source - Davies (2002)

There is currently one recycler of farm films in the UK, British Polyethylene Industries (BPI) and three grant-subsidised schemes collecting farm films exist in Wales, Cumbria and Scotland. Schemes are not financially viable unless farmers are charged for the service or there is some other form of subsidy.

Pesticide container recovery schemes currently operate in Belgium, France, Germany and the Netherlands. These are financed by producer levies. However, it should be noted that in all cases, except the Netherlands, the collected containers are incinerated with energy recovery rather than recycled. The Crop Protection Association (formerly called British Agrochemicals Association) has undertaken some work in this area and is actively involved in the issue of container management in the UK; they also represent the UK industry in discussions at European level.

Review of EIAs

The Environment Agency co-ordinated a LCA study, using their WISARD analysis tool, into options for managing waste silage plastic. This indicated that recycling silage film at the BPI plant is environmentally preferable to both landfill and incineration with energy recovery. The study also concluded that the environmental benefits of recycling could be increased significantly if the level of contamination of the plastic is reduced at source and if the distance to the reprocessing facility is decreased. These factors would also reduce the financial cost (Marcus Hodges Environment Ltd 2001).

Recommendations and priorities for action

clarifying and strengthening of producer responsibility

A voluntary approach has proved unworkable in the past and it is therefore likely that Government will need to apply producer responsibility principles to the sector to achieve a move away from landfill. The Government has recently set up an agricultural waste stakeholder group which should provide an appropriate forum for this discussion.

developing collection infrastructure

Developing cost-effective waste collection arrangements is crucial for the facilitation of recycling. This should be supported by research and development work to determine optimum logistics arrangements.

developing best practice guidance

The development of a code of practice and guidance on managing farm wastes, backed by practical 'best practice' evidence, would enable farming enterprises to identify alternative management options for plastics waste.

promoting a change in attitudes towards waste disposal

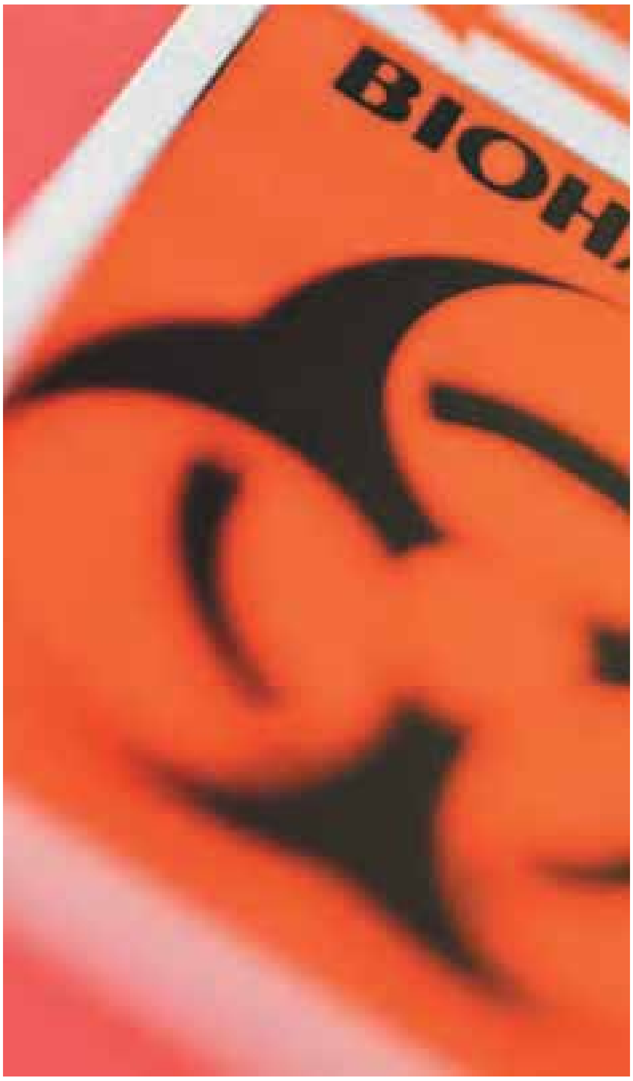
A key to achieving higher recycling rates of agricultural plastics waste is a change in the attitudes to waste disposal such as a reduction of the proportion of plastics waste being burnt or buried. This cultural change could be achieved in part through communication of issues and expectations to all stakeholders and in part through effective enforcement of new waste management requirements.

developing end-markets for mixed and contaminated plastics such as agricultural films

It is recommended that work is undertaken into developing end-markets for mixed and contaminated plastics such as agricultural films. Some progress has already been made in this area, for example Plasmega is operating a research and development facility capable of producing low-grade products for the construction industry.

Medical sector

The use of plastics within the medical sector varies from highly sophisticated applications such as prosthetics to commonly used items like drip bottles and instrument trays. The majority of more demanding applications use specially formulated materials and are generally long-life items not commonly found in the waste stream. The more widely used items are seen as readily disposable and may be used only once. Most of these will be used and discarded within one year of purchase. In addition, plastics waste arises in electronic equipment, such as PCs and medical monitoring equipment.



Analysis of plastics waste arisings

Quantitative data on plastics use within the sector is limited. Valuplast data suggests that 95,000 tonnes of polymer are used in the production of medical applications. An accurate breakdown by polymer type is currently not available.

It is estimated that 10,000 tonnes of the total plastics used is PS (Smith 2002). PVC is also commonly used in a range of medical applications and is expected to be a significant contributor to the overall total.

It is estimated that in 1999 there were approximately 155,000 tonnes of clinical waste generated in the UK (Waste Management Paper 25, HMSO). From work carried out in the Midlands by MEL Research, it was estimated that there is a ratio of 2:1 for clinical waste (yellow bags) and domestic waste (black bags). However much of the waste in the yellow bags was in fact domestic type waste. This being the case, it was estimated that approximately 43% of the waste generated in hospitals was clinical, which would suggest that there is around 205,000 tonnes of 'domestic' waste (Capitec 2000). On this basis there is likely to be in excess of 20,000 tonnes of non-clinical plastics currently being disposed of by sector.

Legislation and voluntary agreements

There are no specific recycling requirements covering medical products. Most medical products are excluded from the WEEE Directive although targets may be considered at a future date.

Any plastics recycling scheme implemented within the healthcare sector will be required to comply with the Clinical Waste Regulations 1992, in addition to other waste management legislation.

Practicalities of recycling

For many years, the National Health Service (NHS) benefited from Crown Immunity and consigned unknown quantities of waste to on-site incineration. With the end of this immunity, clinical waste management costs increased to a rate of £300/tonne. Faced with these high costs and the 1997 Audit Commission report *Getting Sorted*, which was highly critical of the NHS, a large programme was undertaken to develop a comprehensive waste strategy. One outcome of this is the establishment of a Waste Strategy Group within the NHS Purchasing and Supply Agency (NHS 2002), which has drawn up a number of guidelines to promote best practice in waste management. *Healthcare Waste Minimisation - A Compendium of Good Practice*[30] was published in 2000 (Capitec 2000).

Many NHS Trusts perform some material separation, but this is usually restricted to glass, metal and paper

[30] *This drew from responses to a questionnaire sent to all NHS Trusts sponsored by The BOC Foundation.*

(Priestman 2002). All NHS Trusts have been urged to appoint a waste manager or equivalent, and to develop and implement waste minimisation programmes. However, this is seen as an additional cost with respect to resources and time. Many trusts sub-contract waste collection and cleaning, which would involve training for these staff.

As pharmaceutical delivery systems become more sophisticated there are additional issues to consider. For example, as there is a trend towards 'smart' dispenser systems that may contain small circuits, these may fall under the WEEE directive.

The potential for the use of recycled materials in the medical sector is limited, as standards are restrictive in many applications and health and safety concerns form an overriding priority. There may be areas where changes in procurement practices could increase the purchase of products containing recycled plastics, but these areas are more likely to relate to facilities issues rather than medical products themselves.

Review of EIAs

It has not been possible to identify any EIAs relating to plastics medical waste. Some examples of the benefits of reducing waste, and hence cost, are given in the case studies in *Healthcare Waste Minimisation – A Compendium of Good Practice* (Capitec 2000).

Recommendations and priorities for action

Work in this area is of relatively low priority due to the low tonnage of waste plastics arisings within the medical/healthcare system, the additional complexities associated with clinical waste and the restrictions on recyclate use in medical applications. However, there are some potential activities that would be of value.

establishing quantity of recyclable plastics in hospital waste
Improved data is needed on the quantity and types of plastics supplied to the medical appliance industry and the percentage of plastics within the non-clinical waste fraction of hospitals. This would allow for a more detailed assessment of waste reduction and recycling opportunities.

supporting existing waste management initiatives within the NHS
Partnerships with NHS Trusts should be established through the Purchasing and Supply Agency to identify how waste minimisation and plastics recycling initiatives can be introduced or expanded.

A small number of pilot projects to source plastics from hospital waste streams would allow the development of case studies and best practice guidelines. Information arising from such projects should be widely disseminated, including procedures for meeting ISO14001 requirements.

identifying end-markets use options
Identify opportunities for use of recyclates in the healthcare sector and encourage environmental considerations to be taken into account in purchasing policy.

Furniture and housewares sector

Many everyday household items are manufactured from polymers as they are durable whilst being lightweight and offering a variety of colour and design options. Within the market place for furniture there was a world-wide demand for over 750,000 tonnes of virgin PP alone in 2000 (TNO Sofres 2002). Within the UK, the largest sector demand is for garden furniture with over 70% of UK households owning some form of plastic garden furniture.

More recently, items such as containers for recyclables are being produced and there is an increased demand for wheeled bins, composters and water butts, where plastics are preferred to other materials.

Analysis of plastics waste arisings

Data on plastics waste arisings in this sector are limited. Table 14 indicates the amounts of polymer used in with totals including UK manufacture plus imports (Smith 2002).

Table 14 – polymer types used in the furniture and housewares sector (tonnes)

	PP	PS	HDPE PVC	ABS/PE	total
furniture	38,000	7,000	n/a	n/a	295,000
housewares	61,000	n/a	22,000	n/a	>83,000

Source - Smith (2002)

Legislation and voluntary agreements

There currently are no specific regulatory provisions relating to the handling of plastic furniture and housewares waste.

Practicalities of recycling

A proportion of recycled material is already used in this sector, where high levels of fillers and pigments are required to provide stability against UV light degradation. New opportunities for other items such as decking, benches and other garden products are starting to be exploited. There are a range of suppliers of such products using recycled plastics from polyolefins and PS and it is estimated that over 20,000 tonnes of recycled plastics per annum are used in these applications within the UK (RECOUP 2002).

There are a number of social enterprise schemes across the UK, which collect furniture for re-use or recycling. Although the majority of this furniture is non-plastic, there is an existing infrastructure for collection. This may provide opportunities to promote re-use of certain plastic items, although opportunities are probably modest. It is recognised that the volumes available and the complexity of requirements make a recycling solution unlikely if plastic furniture is not appropriate for re-use. Individual sites would have to dismantle and granulate materials, and larger items would require cutting prior to granulation.

A number of wheeled bin suppliers now offer wheeled bin recycling schemes. In the UK, Plastic Omnium Urban Systems offer a refurbishment and recycling service and also supply a wheeled bin range that is manufactured using post-consumer recycled plastics.

In the longer term, facilities may be provided at civic amenity sites to enable recycling of large plastic items such as furniture. However, currently the lack of drivers, the complexity and the low potential quantities arising make this a low priority wastestream for recycling.

Review of EIAs

There does not appear to be any information available on the recycling of furniture and housewares, although there are interesting LCAs comparing the use of recycled plastic lumber with treated timbers. These indicate the benefits of using recycled plastics lumber due to the long life, low maintenance and reduction in environmental damage associated with the use of wood-treatment chemicals (Nosker 2001).

Recommendations and priorities for action

encouraging use of recyclate
Due to the low quantities of recyclable plastics arising in this sector, main environmental gains can be made through stimulating the use of recyclate in the production of furniture and housewares, rather than actively pursuing recycling programmes.

establishing available quantities of recyclable plastics
In order to make a more detailed assessment of the opportunities for recycling in this sector, it would be valuable to obtain more data on the material breakdown to identify viable quantities of plastics for recycling.

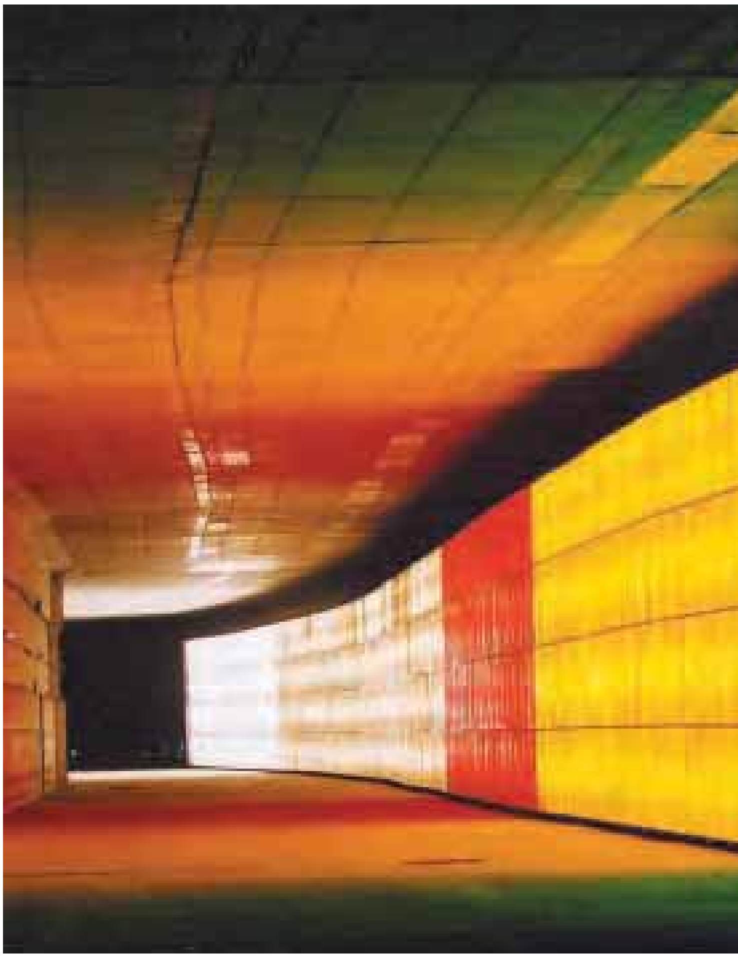
Conclusions

This report provides an initial analysis of the opportunities to reduce landfilling of plastics and stimulate plastics recycling in the UK. The report describes the use of plastics in different sectors of the economy, the current issues relating to plastics waste management and key regulatory drivers within each sector. The analysis has identified data gaps, which need addressing in future work.

The research shows that both the opportunities for, and the challenges to, increasing the recycling of plastics vary considerably between sectors and applications.

There are many opportunities to increase the recycling of plastic packaging from domestic sources, primarily through plastic bottle collection. In this sector, the main barrier to increased recycling is the lack of an adequate collection infrastructure. However, systems based on integrated, multi-material kerbside collections are likely to generate good quality materials for the reprocessing sector at little or no additional cost to landfill-based disposal. The need for capital investment and a legislative framework that encourages all local authorities currently form the main barriers to achieving this. Recycling of plastic packaging from the commercial and industrial sectors is already well established and around half of this material is currently recycled. However, there are likely to be diminishing returns in this sector especially with an expected increase in returnables-based distribution systems. In this sector the main barrier arises from the lack of an adequate collection infrastructure.

In automotive and electronic applications the challenges relate to the cost-effective separation of plastics types in significant quantities, and to the difficulty of handling engineering thermoplastics and thermosets containing a range of additives. Future statutory requirements relating to the recycling of plastics from waste electronic and electrical equipment and end-of-life vehicle sources are currently unclear. In the case of the ELV directive, it can be argued that there is no requirement to recycle plastics from ELV scrap as the directive includes no material-specific recycling targets and compliance could be achieved through recycling ELV materials other than plastics. In the case of the WEEE directive, it is more likely that plastics will have to be recycled, although the targets are also non-material specific. Even if around half of waste electronic and electrical equipment plastics were recycled under the terms of the WEEE directive, this might only amount to around 100,000 tonnes. The potential environmental impacts of such recycling and the cost involved remain unclear.



Courtesy of Deutsche Gesellschaft für Kunststoff-Recycling mbH

From waste to art: a 140 metre long light wall by artists Bär + Knell created from plastics packaging waste

In the medical, furniture and housewares sectors there are a range of challenges which, considering the relatively low quantities of waste plastics generated by these sectors, suggest that efforts focussed on other sectors will produce the greatest return for society in the foreseeable future.

Overall, as shown in various environmental impact assessments, the resources required in recycling systems, including collecting, transporting and processing waste plastics into recyclate, are typically significantly lower than the resources required to produce virgin polymers. The substitution of virgin polymer with recycled plastics will also lead to greater resource savings than efficiency improvements in virgin polymer production alone.

The collection and processing infrastructure for waste plastics

The issues relating to collection and handling greatly depend on whether the primary aim of the collection is the recovery of plastics waste as opposed to other materials. The collection infrastructure for plastic packaging recycling can to some extent be designed specifically to maximise the value of the plastics, for example by preventing contamination. The infrastructure for sourcing plastics from ELV, on the other hand, is driven primarily by the most efficient methods for metals recycling.

The packaging sector is the only sector where collection infrastructure is the specific limiting factor. In the case of ELV and, to some extent, WEEE the collection systems are in place and the barrier to recycling relates primarily to the separation of the recyclate and the marketing of derived products.

The most significant opportunity to maximise the recyclability of waste plastics is through the development of separation technology. Commercially viable systems for the separation of 'large' plastic items such as bottles already exist. For other sectors, in particular WEEE and ELV, the greatest potential lies in developing commercial systems for high-speed, high-quality separation of different polymer flakes arising from shredding operations.

Plastics reprocessing technology
The technology for mechanical recycling of plastics is well-established and it is likely that there will be continued development in the efficiency of traditional mechanical recycling processes. Mechanically recycled materials can already be found in highly specified applications such as food-grade packaging and automotive components.
The main opportunity for developing mechanical recycling lies in the processing of mixed plastics into commercial products. Although viable processes do not appear to exist currently, the progress of many researchers and entrepreneurs in this relatively new area is encouraging. Examples of this include Plasmega and Plascrete, who have developed products for the construction industry, which replace concrete and aggregate. Feedstock recycling technologies are being developed with improved economic efficiency.

The commercial viability of plastics reprocessing will increase not only as a result of continuing R&D investment, but also as disposal costs increase. Plastics reprocessing does not have to be profitable per se; it must simply be a better option than the least expensive alternative disposal route. Higher landfill charges and incinerator gate fees, resulting from tax escalators and higher environmental compliance costs, will increase the value of avoiding final disposal.

The same is true for feedstock recycling processes. Although beyond the scope of this report, it should be noted that feedstock recycling is technically feasible. The main barriers to its development relate to process economics and supply volumes. The comparative cost of feedstock recycling is likely to continue to fall as the cost of landfill and incineration increase, making it more commercially viable in the future.

End markets for recyclate
A review of end market market development issues is beyond the scope of this report. However, it is important to recognise the importance of stimulating the growth of value-added secondary markets for plastics recyclate. Demand for recycled plastics will increase when there is a reliable supply of quality recyclates. These need to be priced competitively in comparison to virgin materials to enable manufacturers to improve profitability by switching to recyclates.

It is essential to distinguish between end markets that have real commercial potential and those that offer only marginal opportunities for increased recyclate use. If recyclate use is to enter mainstream manufacturing, it is essential for recycled materials to be promoted on the same basis as virgin materials – according to cost and fitness for purpose – and not primarily because of their ‘green’ credentials. Manufacturers and specifiers will have maximum incentive to use recyclates when they are the most economically advantageous option. This competitive advantage of the use of recyclate must be highlighted. Robust case studies and the analysis of supply/value chains and future trends will be extremely valuable to support the business case for recyclate use.

This requires a crucial shift in thinking: suppliers need to consider recycled polymers as alternative materials with defined properties rather than inferior versions of virgin polymer. Recyclate suppliers need to mirror the service, quality assurance and marketing capacity of the virgin polymer industry. This should be a key thrust of future market development activities[31] and could be achieved through supporting targeted market research, training, standards development and specific product/material marketing campaigns. Organisations such as WRAP are ideally placed to carry out this work.

The term 'recycled' now has such broad connotations that it fails to represent accurately its potential benefit to customers. Suppliers therefore need to consider stating the benefits of recycled materials in a precise manner, for example in terms of the reduction in resources used. The statement 'this product is made from plastic material which uses 50% less energy and reduces emissions by 30%' demonstrates a more specific and tangible advantage than 'contains recycled plastics'. The packaging industry has for many years generated increasingly sophisticated life-cycle models and eco-profiles to evaluate and justify the use of particular virgin materials. The extension of this methodology to recycled materials is essential to the successful increase in recyclate use.

The way forward

Sufficient progress has been made in the last ten years to demonstrate the potential for further development in plastics recycling. The greatest challenges relate not to technology or markets, but to deciding priorities for recycling on economic and environmental grounds. A 'targets-based' approach is a fairly blunt mechanism to drive environmental efficiency; however, it probably represents a necessary starting point.

It is recommended that stakeholders embrace a more sophisticated analysis of the relative environmental impacts of products throughout their whole life-cycles. This will provide the foundation for more mature and constructive dialogue between government, producers and consumers of all products, not only plastics. Such an approach will assist both plastics producers and their customers to assess and minimise the environmental impacts of products and will result in more sustainable resource use by society as a whole.

Priorities for action

The following recommendations and priorities for action highlight the most significant short-term opportunities for increasing of plastics recycling in the sectors considered in this study

- increase post-consumer plastic bottle recycling through the inclusion of plastics bottles in integrated multi-material kerbside collection schemes
- maximise the recycling of plastics packaging from the commercial and industrial waste stream
- develop technologies for the efficient mechanical recycling of plastics from shredder residue
- develop a range of end-markets for recovered plastics and promote public sector procurement of recycled plastics products
- increase the cost of disposing of plastics waste, potentially through increasing the landfill/disposal tax
- ensure that the environmental and economic trade-offs of recycling certain types or quantities of plastics are properly understood by policy makers

[31] *It should be noted that many virgin materials suppliers are also engaged in recyclate production.*

Appendices

Appendix A

UK plastics consumption

Total UK plastics consumption by polymer type

The British Plastics Federation and the Packaging and Industrial Films Association have for a number of years compiled and updated data on the usage by the UK manufacturing industry of all thermoplastic and thermoset material by polymer type. A digest of this information for 2000 is shown below.

material	UK industry manufacture (kt)
thermoplastics	
PVC	777
PP	764
PS	260
EPS	57
HDPE	544
LDPE	1002
ABS	89
PC	38
PBT	9
PET	235
PA	46
PMMA	40
POM	16
PUR	55
PC/ABS	4
sub total	**3936**
thermosets	
UPR	80
EPOXY	33
PHENOLIC	81
sub total	**194**
total	**4130**

Source - Valuplast from British Plastics Federation & PIFA (2001)

UK polymer consumption by market sector

The bulk polymers have been further analysed to identify their respective market sector usage in 2000 (in kilo tonnes). These are shown in the following tables. Similar information on the other polymers may be obtained from the British Plastics Federation.

PVC	kt	%
construction	467	60
packaging	85	11
electrical	67	9
automotive	15	2
others	143	18
total	**777**	**100**

PP	kt	%
packaging	288	38
textiles	167	22
automotive	65	9
housewares	61	8
furniture	38	5
building	32	4
appliances	27	3
others	86	11
total	**764**	**100**

PS	kt	%
packaging	114	43
electrical goods	48	19
durables	-	-
sheet/profile	26	10
toys/leisure/fashion	15	6
medical	10	4
furniture/housewares	7	3
others (durables)	40	15
total	**260**	**100**

EPS	kt	%
packaging	31	54
building	22	38
others	4	7
total	**57**	**100**

HDPE	kt	%
packaging	315	58
construction	98	18
housewares	22	4
automotive	11	2
others	98	18
total	**544**	**100**

LDPE	kt	%
packaging	707	71
agriculture/building	122	12
electrical	32	3
others	141	14
total	**1002**	**100**

PET	kt	%
blow-moulded	217	92.5
engineering	2	0.5
others	16	7.0
total	**235**	**100**

ABS	kt	%
electrical	73	31
automotive	33	14
extrusions	21	9
pipes	19	8
tools/DIY	16	7
packaging	7	3
others	66	28
total	**235**	**100**

Source - RECOUP (2002)

Appendix B

Summary of identification, separation and recycling technologies

technology	commercially available	common uses	developments
FT-IR, FT-NIR, FT-Raman, and x-ray: this technology identifies plastic by electromagnetic absorption and reflectance measurements. After identification, some method must be used to separate the material.	yes	identification of plastic bottles by polymer type, and/or colour	new sensor technology for separation on the flake level has been developed
Photo-acoustics: Similar to IR, but a green light is used and acoustic emission is measured.	unknown	n/a	still in research stage (1996)
mechanical plastic separation technologies:			
Float-sink method using supercritical fluids: mixed waste is placed in a sealed pressure vessel with CO2 or a mixture of CO2 and SF6. The pressure inside the vessel is varied so as to vary the density of the fluid over the range of the mixed waste. The operator thus has the ability to float different materials in stages, removing the floating material before proceeding to the next density.	unknown	n/a	still in research stage (1994)
Float-sink using other fluids	unknown	n/a	still in research stage (1996)
Air classification: conventional air classification uses a steady, rising current of air to separate lighter particles from heavier ones.	yes	removal of polyurethane foam component of shredder residue	air classifier using a pulsed airflow to overcome the problem of a less dense, larger particle being mistaken to be equivalent to a smaller, more dense one
Hydrocycloning: similar to air classification, except that the fluid medium is a liquid, not a gas.	yes		
Electrostatic separation: separation based on the fact that different materials lose electrostatic charge at different rates.	yes	used to separate plastic from metal, e.g. cable scrap	plastic from plastic separation has now been developed

technology	commercially available	common uses	developments
Magnetic separation: ferrous metals may be separated via a simple magnet mounted over a moving conveyor belt. Non-ferrous metals are separated by rapidly spinning magnetic pulleys.	yes	used to separate both ferrous and non-ferrous metals from the light fraction of shredder residue	
Paint/soating removal: water-based process	yes	paint/coating removal	
Selective solvent extraction: SR is first sifted through a screen and then treated using acetone, xylene and ethylene dichloride.	unknown	separation of specific polymers from shredder residue.	still in research stage (1996)
Melt temperatures: separation of polymers based on melt temperature.	unknown	n/a	still in research stage (1996)
Dielectric characteristics: separation of polymers based on dielectric characteristics.	unknown	n/a	still in research stage (1996)
Separation in an oxygen-free vacuum oven: material is placed in a sealed separation device. Nitrogen is used to drive any oxygen from the system and a vacuum is applied. The device heats the contents, separating copper and plastic.	yes	cable scrap	
chemical recycling processes:			
Pyrolysis: mixed plastics are decomposed into energy sources or monomers by ultrahigh temperature in the absence of oxygen.	yes		
Glycolysis: a process that breaks down PET into short-chain oligomers	yes		

technology	commercially available	common uses	developments
Hydrolysis: polyurethanes, polyesters and polyamides can be treated by hydrolysis.	yes		
Methanolysis: polyesters can be treated by methanolysis.	yes		
Waste-to-energy conversion: mixed plastics are used as a fuel for combustion.	yes	energy recovery from mixed plastic waste	

Source - Hendrix et al (1996)

Appendix C

Recent developments in identification and separation technologies

Plastics in the automotive sector
Virtually all of the material in today's vehicles can be recycled; the challenge facing engineers is making this recycling process cost-effective. Different types of plastic-from-plastic and plastic-from-metal separation technologies exist that allow economically feasible recycling (Hendrix et al 1996, appendix B). It is probable that a combination of technologies would be required to successfully identify, separate and recycle plastics from ELV.

Two systems developed on behalf of Ford have been designed to identify plastics from vehicles at the dismantling stage; these are the Tribopen and Polyana (http://www.walkersystems.de). The Tribopen works by measuring the tribo-electric (static) charge generated when its head is rubbed briefly against the plastic part to be sorted. It is a portable, handheld device that is used to separate two predefined materials. The Polyana identifies polymers using FT-IR spectroscopy and can be used to sort all types of plastic, irrespective of the materials colour, so long as the plastics are on its database. The system can also identify whether the material is pure, a blend of two plastics, or plastic containing fillers. Similar technologies are being developed in other countries.

Technologies specifically designed to separate plastics from shredder residue have been developed, or are being researched by -

- GALLOO PLASTICS, (GALLOO METALS subsidiary), Belgium-French shredder operator
- SALYP, Belgium
- The University of Delft, The Netherlands
- MBA Polymers, USA
- The University of Brighton, UK

Emphasis has been placed on the extraction of polypropylene, as this comprises the largest fraction of automotive and WEEE plastics, often shredded in the same facilities.

GALLOO PLASTICS is operating a 10,000 tonnes per annum (tpa) capacity plant in northern France, with a doubling of capacity under construction. The investment was supported by the French Environment Agency (Picot 2002). There must be a critical mass in respect of the amount of recovered plastics for the process to be economically viable. At most only 20% of the material going through the separation process is recovered, but as the process operating costs are low, the fact that a large quantity of shredder residue has to go through the process is not critical (Picot 2002). The commercial feasibility is, however, dependent upon the market price of the recovered polypropylene and the cost of alternative disposal, such as landfill.

SALYP has reached an agreement with the Chinese government to build a facility to separate mixed plastics from shredders that process auto bodies, appliances and electronics in China. The China ELV Centre will recycle post-consumer computers in Beijing as a demonstration project, with the aim of introducing a network of regional and local ELV Centres. After an evaluation period, automotive bodies, white goods and the residue from other shredded objects will be processed at the centre (RT Online News 2002).

The University of Delft in the Netherlands has developed a wet jigging technology, enabling the separation of plastics from shredder residue. The system has the advantage that the plastics are not contaminated by salt, which is used in other density systems. A pilot plant has been constructed capable of processing 400 kg/hour (Dabekaussen 2002).

MBA Polymers specialise in the separation of specific polymer types and grades (e.g. injection and extrusion grades) from shredded mixed plastic produced by the electrical and electronics sector (Biddle 2002). It is possible this technology could also be used to separate shredded plastics from ELV.

Research at the University of Brighton demonstrated that polyolefins could be separated from shredder residue by a float-sink process. It was also shown that polypropylene recovered manually from shredder residue can be reprocessed into viable products with good mechanical properties. This has not yet, however, been achieved at industrial levels (Singh et al 2001).

Plastics in the electrical and electronic sector
Different types of plastic-from-plastic and plastic-from-metal separation technologies exist that may lead to economically feasible recycling (Hendrix et al 1996, appendix B). It is probable that a combination of technologies would be required to successfully identify, separate and recycle plastics from WEEE.

The two identification systems, Tribopen and Polyana, developed by Ford to aid in the identification of plastics at the dismantling stage, are also useable in the context of WEEE.
DARP Environmental, funded by the DTI's Smart Award scheme, is developing a series of processes that they claim will be able to turn WEEE into marketable materials. On their website (http://www.darp3.co.uk) they state that they will be

able to demonstrate a full-scale commercial plant that will recycle all waste electrical goods in 2004 (DARP Environmental Ltd 2002b).

As in the automotive sector, emphasis has been placed on the extraction of polypropylene, as this comprises the largest fraction of WEEE, often shredded in the same facilities. The technologies designed to sort plastics from shredder residue mentioned in the above section are applicable to WEEE plastics.

Plastics in the building and construction sector
Mechanical recycling is common in the UK, but a technology has also been developed specifically for the recycling of PVC. Known as Vinyloop the process is equivalent to mechanical recycling so far as current legislation is concerned and deserves mention here due to the prevalence of PVC in the construction industry.

The Vinyloop process allows the regeneration of the PVC compound contained in composite structures that is impossible to recuperate using traditional methods. From a technological point of view, the process allows composites containing levels of PVC as low as a couple of percent to be processed, however, in the current state of development, an annual average PVC content of 85% is recommended.

Materials that can be treated by the Vinyloop process fall into the following five major categories: cables, automobiles, flooring, tarpaulins and rigid products.

The process includes 6 main steps

- pre-treatment of the PVC residues
- selective dissolution in a mixture of solvents
- separation of the insoluble residues
- precipitation of the regenerated PVC compound
- drying and conditioning
- recovery and recycling of the solvent for reuse

A compound of precipitated PVC is produced, that in many cases can be re-used in its original application. The only industrial plant currently in operation is located in Ferrara in the north of Italy. The plants nominal annual capacity is 10,000 tonnes of raw material of an 85% extractable compound weight, which represents 8,500 tonnes of regenerated PVC compound (http://www.vinyloop.com).

The UK PVC industry, under the remit of the BPF Vinyls Group, is investigating the viability of establishing a recycling facility for PVC-rich waste that is either heavily contaminated or of widely varying quality. The facility is expected to include the Vinyloop recycling process.
The National Centre for Business and Sustainability is contributing to this work by carrying out a project to identify the amounts and sources of waste available in the UK for recycling through the Vinyloop process (http://www.thencbs.co.uk/index_environmental.html).

Appendix D

Plastics mass balance UK

A report produced by Bowman Process Technology

Introduction

This report forms part of the Biffaward Programme on Sustainable Resource Use and aims to map the movement of plastic materials through the UK economy. Data for this report was collected by Valuplast Ltd. The project was managed by Waste Watch.

This report seeks to quantify the mass flows of plastic materials between the various industrial and consumption sectors. Where possible the composition of flows is retained to provide information on the different polymer types finding their way to final disposal and crossing between sectors.

It is beyond the scope of this present work to assess mass balance data for other process flows such as emissions or energy consumption.

Embodied plastics are not always identified by type so the input to industry sectors is sometimes used to provide estimates. Where this is the case, appropriate notes are provided.

Composition is a term used throughout this document to refer to the breakdown of the total plastic flows identified into individual plastic types. Material quantities are stated in either metric tonnes (t) or thousands of metric tonnes (kt). All information applies to the year 2000.

Methodology

Plastics are found in a wide variety of products whether as a principle component, in the form of packaging or both. Every sector in the economy includes in its flows a significant proportion of plastic materials. It can therefore be difficult to trace the quantities and composition in detail.

The most readily available data for plastic refers to the final disposal of plastics waste. A large proportion of this is packaging waste in the domestic stream, but also includes durable household goods containing plastics.

The packaging wastestream shows the lowest degree of accumulation in any sector and products can be expected to pass through the supply chain rapidly. It is assumed therefore that there is no accumulation of plastic packaging in any sector. This assumption cannot be made for other plastic products. However, accumulation figures can only be established when the following information is available:

- detailed stock information at the start and end of a period under consideration
- quantities and compositions of plastic materials entering and leaving the sector
- product life-cycle data

The movement of plastics through the economy has additional flows associated with energy-use in conversion and manufacture, the use of additives for specific products and various other process flows. However, this study is concerned with the main plastic component of products and a more detailed analysis is not possible due to limited data availability.

The approach to the problem involved the following stages:

- decide on a flow structure that is representative of the plastic flows through the UK economy

- identify points in the structure where data is available and review the structure as necessary

- assign the collated quantity and composition data to streams

- derive information regarding individual sectors

Streams are symbolised by lines that represent movement of material through the economy and are largely associated with distribution, import, export or other transport. Nodes are the focus of stream movements and can be related to industrial and consumption centres, disposal methods, etc. Unless otherwise stated the data used was obtained from Post Use Recycling of Plastics (Valuplast Ltd 2002) (Reference [1]). Source points in the document are noted below.

Model Structure

A generic structure was prepared but it was found necessary to adapt this for some of the sectors analysed particularly where more detailed data was available. The structure provides a model for the flow of plastics through the UK economy with an allowance for import and export of primary materials, products and components.

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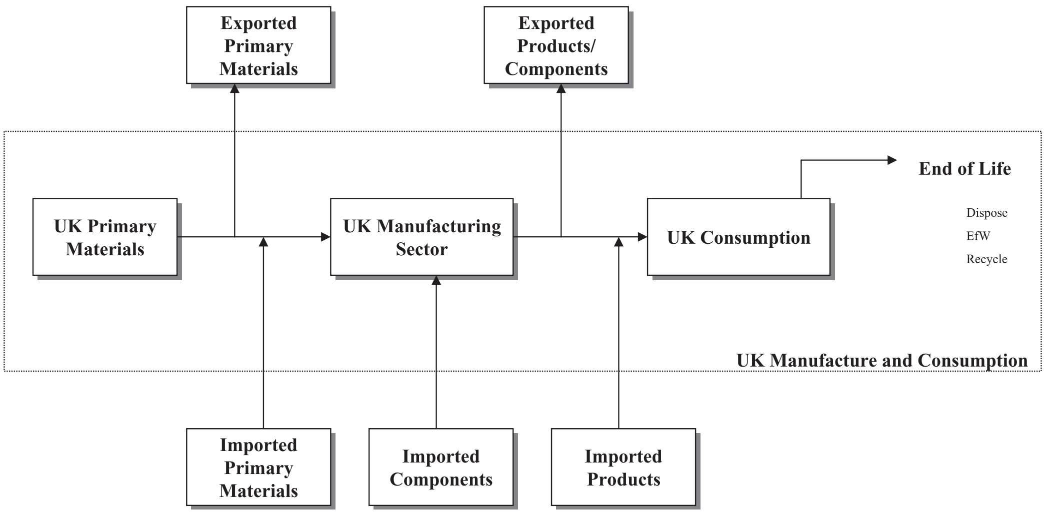
1 *The term composition is used throughout this document to refer to the breakdown of the total flows of plastics categorised by individual types of plastics.*

2 *For example antioxidants, compatibilisers, plasticisers, fillers etc.*

Figure 1 - generic mass balance structure



There is limited information available for the consumption of primary plastics by all UK sectors, which is represented in Figure 2.

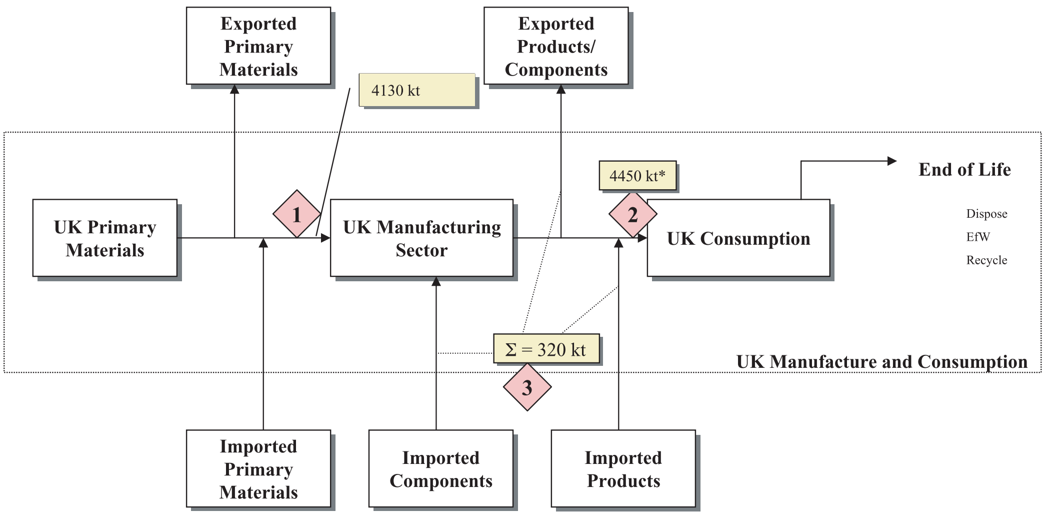
The data shows that 4,130,000t of plastics were consumed by the UK economy in 2000. After deducting the import and export of products and components containing plastics, there is a net import of 320,000t of plastic. This results in 4,450,000t of plastics being used by what may be considered a UK consumption sector. When specific applications are considered streams on the structure are numbered for reference purposes wherever there is data availability. The structures are presented below for each sector that was sufficiently defined by the data.

In order to identify streams uniquely, the sector/type of use is identified by a prefix followed by the stream number indicated on the flow diagrams. For example stream 5 in the packaging structure is referred to as P-05, stream 2 in the construction structure would be C-02 etc.
The sector prefixes are as follows:

Table 1 - sector stream prefixes

type of use/sector	prefix
agricultural	A
building and construction	C
electrical and electronics	E
vehicles parts/accessories	MC
packaging	P

Figure 2 - structure for plastic consumption by all sectors



Plastics in the packaging sector

The structure has been modified to show the relationships between the converters, packer/fillers and the wholesale/retail sections of the economy.

Figure 3 shows the quantities of primary plastic materials and their general use and current disposal routes. The structure has been expanded in Figure 4 to show the relationships during the consumption stage greater detail.

Data available on the composition of streams vary widely. In some cases only the quantity of material can be provided, in others a breakdown of the overall quantity of individual polymer types has been from the data and in another category it has been possible to estimate composition from knowledge of the material and industries involved. This applies to all sectors and details of estimations of composition made that were not explicitly provided in *Plastics in the UK economy* (Reference [1]) are listed in the Appendix. Table 3 shows the stream references for plastic packaging together with the mass flow and whether or not composition data is known.

Figure 3 - structure of plastic packaging sector - primary plastics

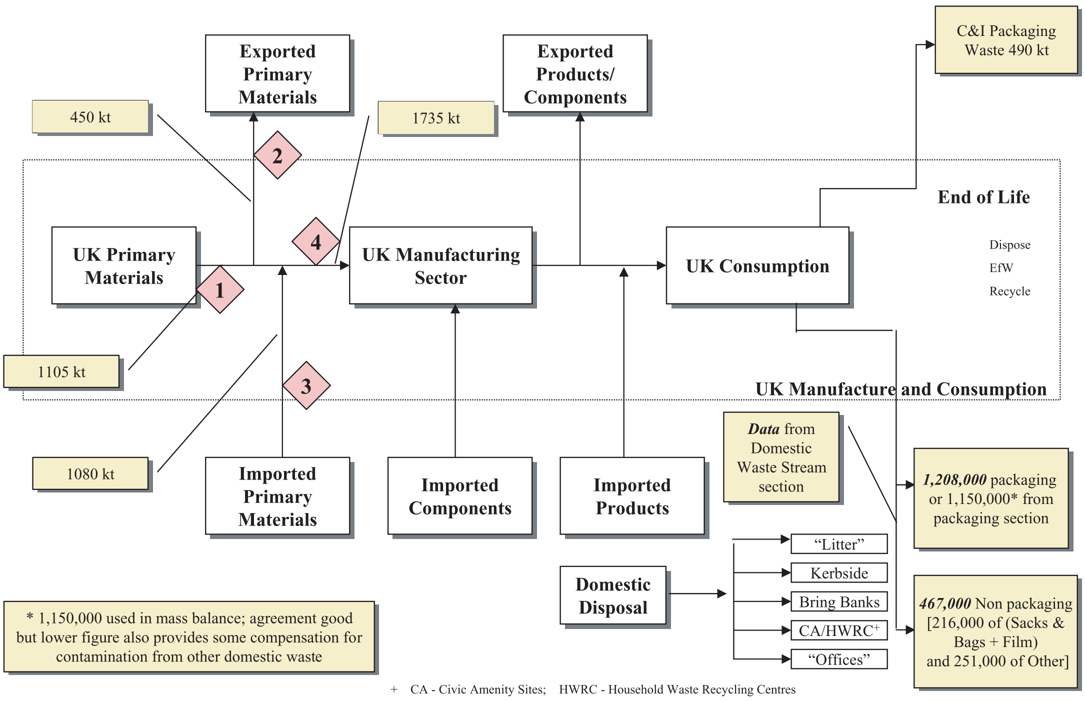


Figure 4 - structure of plastics packaging from converters through to consumption

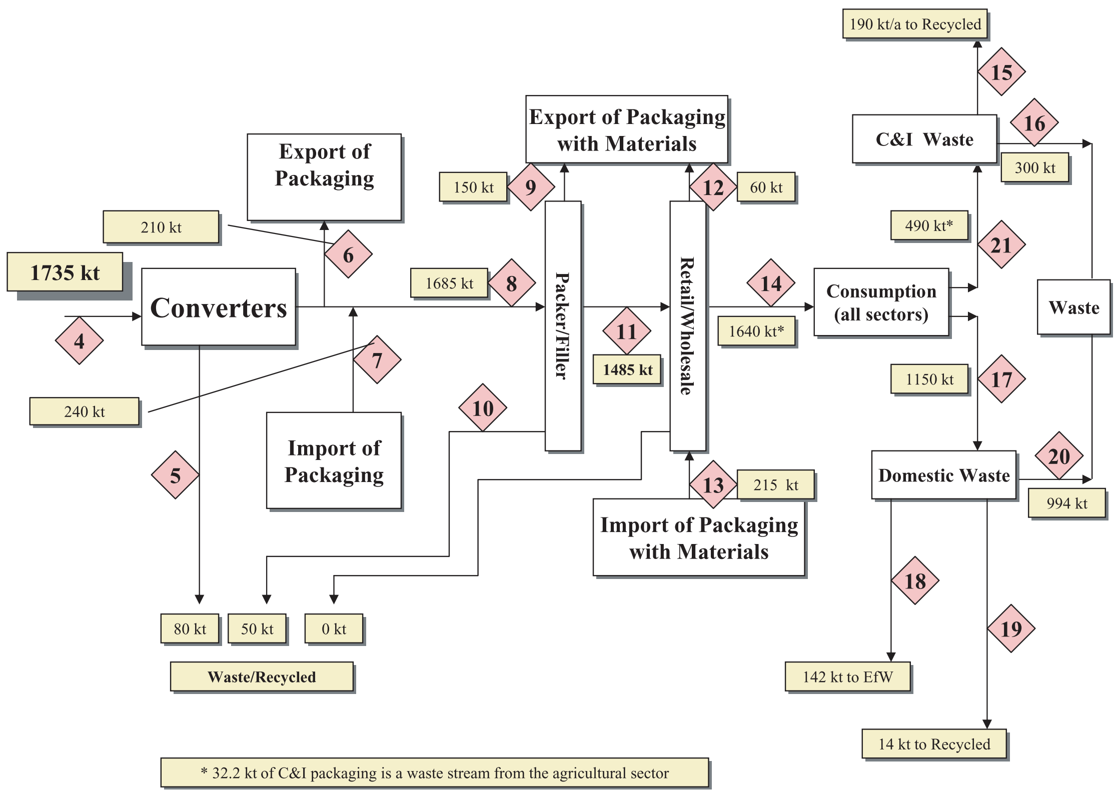
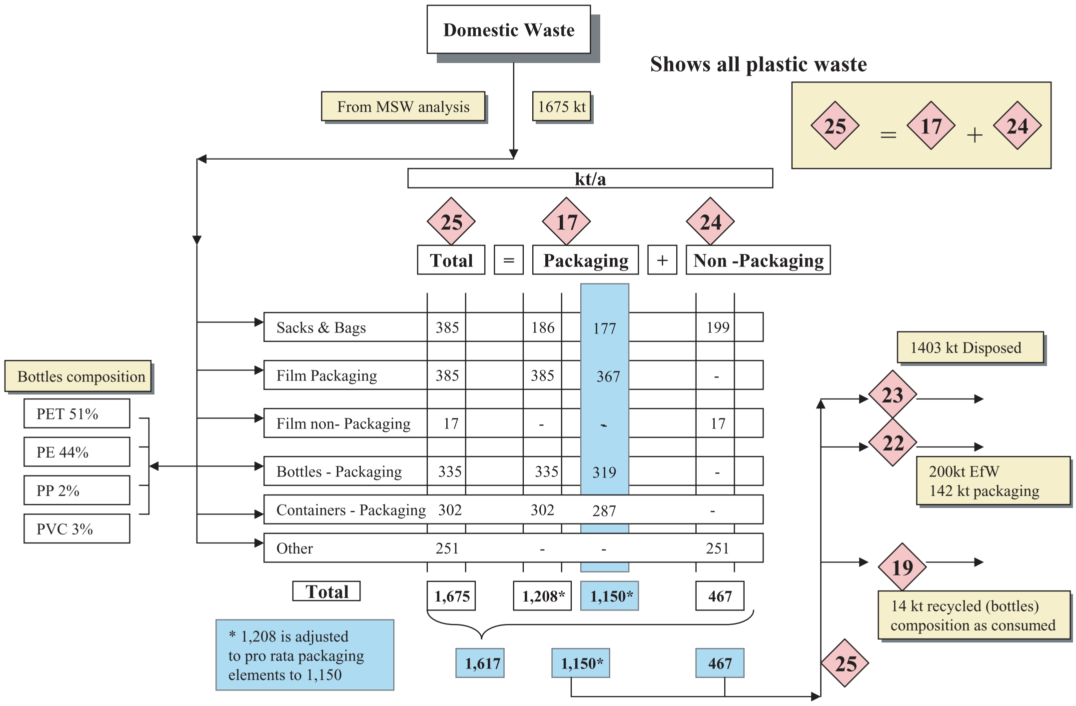


Table 2 - summary of plastic packaging streams, 2000
(see Notes for comments)

stream reference	consumption/use kt	composition (y/n)	references / notes
P-01	1105	-	
P-02	450	-	
P-03	1080	-	
P-04	1735	Y	[1] & Note 2
P-05	80	Y	[1] & Note 2
P-06	210	Y	[1] & Note 2
P-07	240	-	
P-08	1685	-	
P-09	150	-	
P-10	50	-	
P-11	1485	-	
P-12	60	-	
P-13	215	-	
P-14	1640	Y	[1]
P-15	190	-	
P-16	300	-	
P-17	1150	-	Note 27
P-18	142	-	
P-19	14	Y	[1] & Note 11
P-20	936	-	
P-21	490	-	
P-22	200	-	
P-23	1403	-	
P-24	467	-	
P-25	1617	-	

Figure 5 - structure of plastics packaging from converters through to consumption



Streams P-22 to P-25 include packaging and non-packaging plastics materials and comprise the plastic waste from households in the UK. Figure 5 shows this with a breakdown of the packaging content.

Plastics in the building and construction sector

The basic structure has been used for this sector but a detailed breakdown of structural and non-structural materials has been added.

Figure 6 - plastics in the building and construction sector

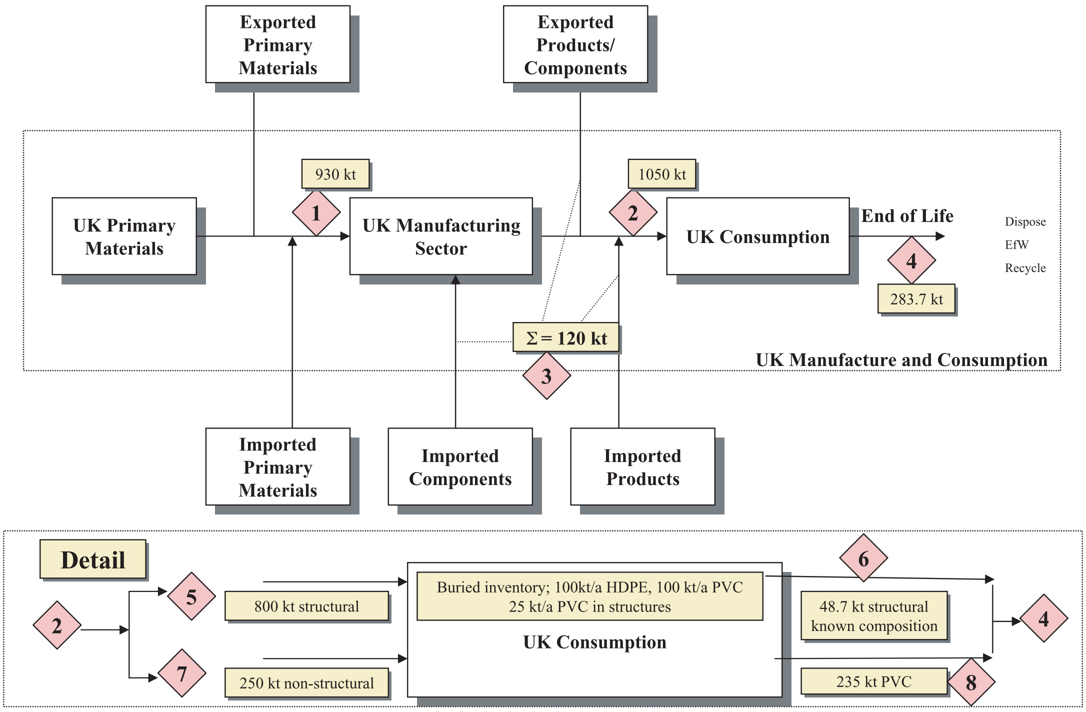


Table 3 - summary of plastic streams in the building and construction sector, 2000
(see Notes for comments)

stream reference	consumption/use kt	composition (y/n)	references/ notes
C-01	930	-	
C-02	1050	Y	[1]
C-03	120	-	
C-04	283.7	Y	[1]
C-05	800	Y	[1]
C-06	48.7	Y	[1]
C-07	250	Y	[1]
C-08	235	Y	[1]

Plastics in the electrical and electronics sector

The basic structure has been used for this sector. Composition data are not available.

Figure 7 - plastics in the electrical and electronics sector

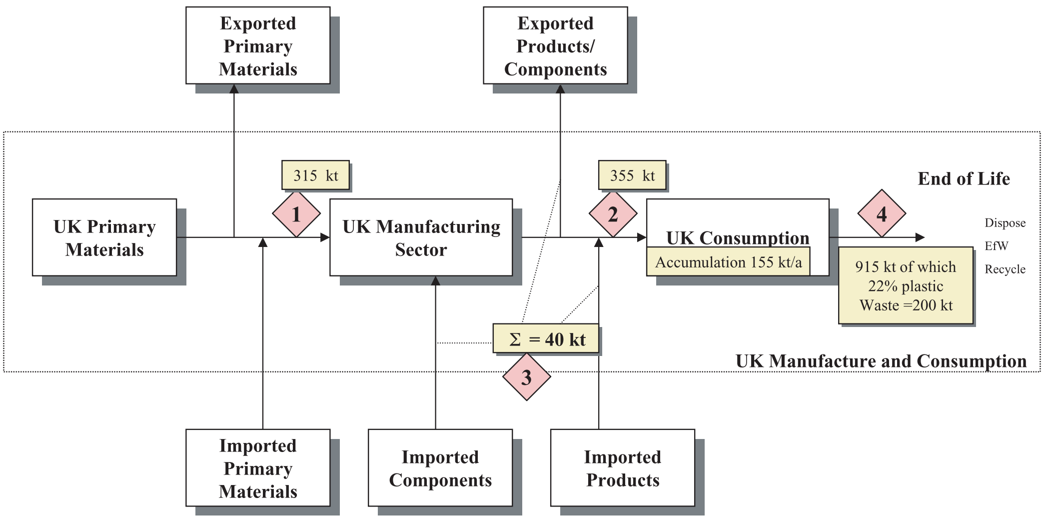


Table 4 - summary of plastic streams relating to electrical/electronic sector, 2000
(see Notes for comments)

stream reference	consumption/use kt	composition (y/n)	references/ notes
E-01	315	-	
E-02	355	-	
E-03	40	-	
E-04	200	-	

Plastics in the automotive sector

Information is available for new vehicle registrations and average vehicle life. The plastics content of the average car is also known and can be used to provide some composition information, particularly at for ELV.

Figure 8 - plastics in the automotive sector

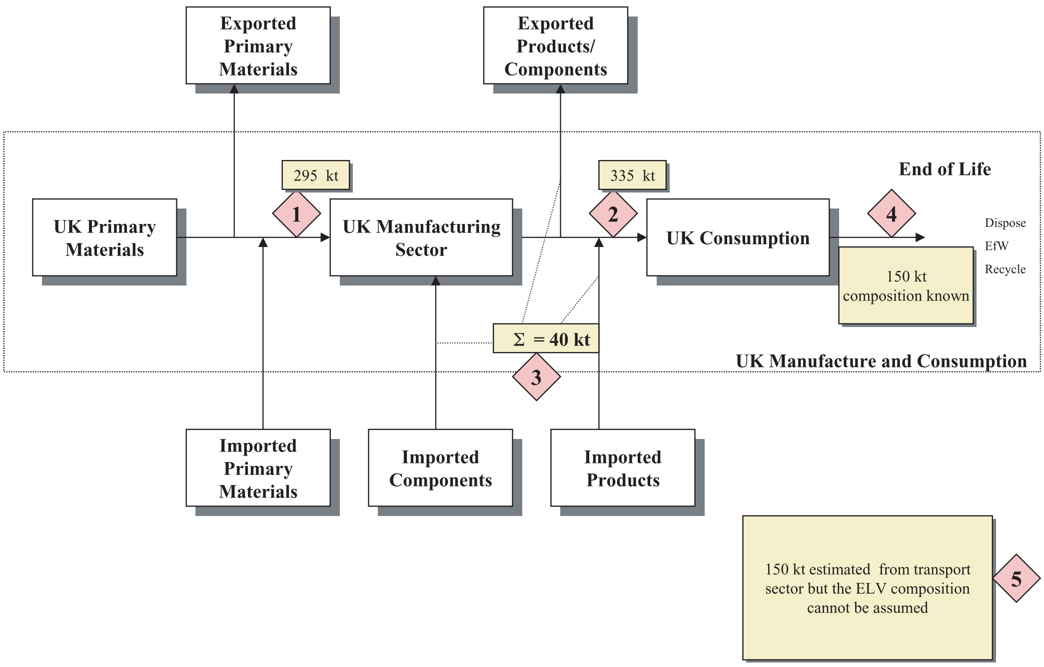


Table 5 - summary of plastic streams in the automotive sector, 2000
(see Notes for comments)

stream reference	consumption/use kt	composition (y/n)	references/ notes
MC-01	295	-	
MC-02	335	Y	[1]
MC-03	40	-	
MC-04	150	Y	[1]

Plastics in the agricultural sector

The agricultural use of plastics is illustrated in Figure 9. It is notable that the waste arisings identified are significantly lower than sector consumption. Further research will be needed to identify the disposal routes of materials unaccounted for.

Figure 9 - plastics in the electrical and electronics sector

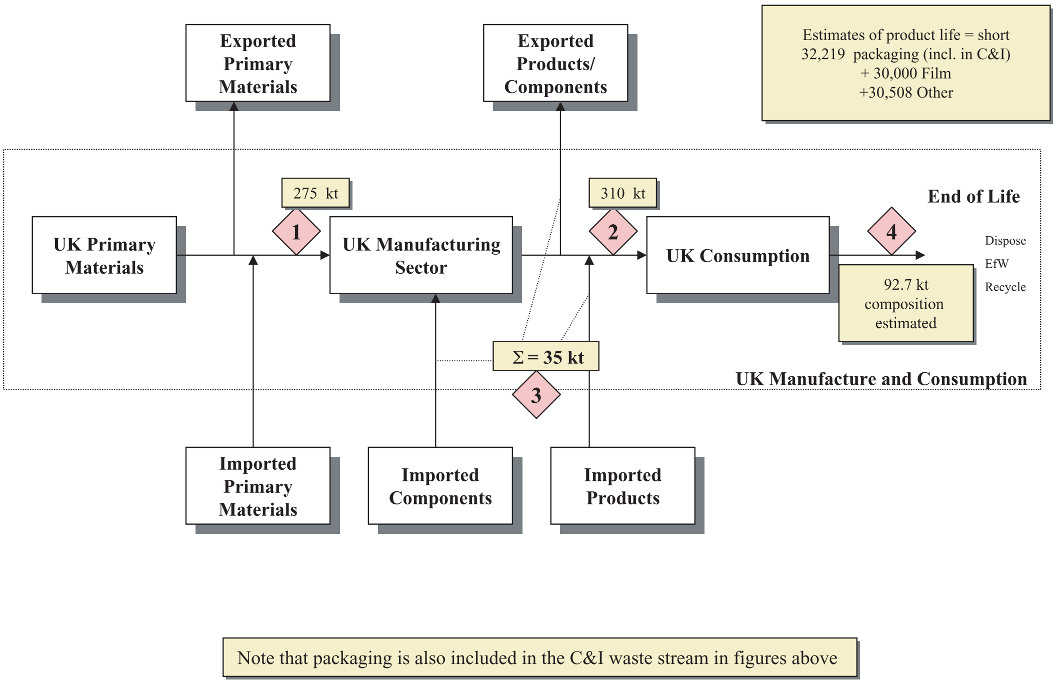


Table 6 - summary of plastic streams relating to electrical/electronic sector, 2000
(see Notes for comments)

stream reference	consumption/use kt	composition (y/n)	references/ notes
A-01	275	-	
A-02	310	-	
A-03	35	-	
A-04	92.7	Y	[1] & Note 26

Sector, material and product codes

Industrial sector codes were obtained from the UK Standard Industrial Classification of Economic Activities UK (National Statistics Office) (Reference [4]). The source and destination sector for each stream was identified and the appropriate codes applied. This facilitates the inclusion of the data in the UK Mass Balance database.

Material and product codes were obtained from the Intrastat Classification Nomenclature 2001 (HM Customs and Excise) (Reference [5]).

Having assigned codes to the range of plastic types considered, to the industrial sectors and to product consumption sectors, the data for each stream identified in the balance structure is assigned. By sketching an envelope over any section of the flow diagram the flows in and out of the envelope will be available by considering all streams that cross the envelope boundary. Certain selections may not be accessible to analysis, because information is not always available. However, the figures in Section 3 can be used to readily determine where information is available.

A number of problems were encountered in relating product codes and industrial sectors. This is due to the highly diverse uses for plastics and their inclusion in many different assemblies. A good example of this is the building and construction sector. An SIC code can be selected that covers the manufacture of builders' ware of plastics (within 25.23). The CN codes for these materials do not conveniently sit within a grouping that is sufficiently precise to exclude many non-builders ware products. Such anomalies will need to be resolved.

Two materials were found not to have specific codes. These were polybutylene terephthalate (PBT) and polyphenylene sulphide (PPS). PBT is chemically related to PET and the code for PET is 3907 60 (including 3907 60 20 and 3907 60 80). There are no assigned codes until 3907 91 for other (unsaturated) polyesters. Series of codes under 3907 70 and 3907 80 are presumed to be available. It is suggested that 3907 70 be assigned as a CN code for PBT. PPS is more difficult because there is no clearly related compound listed. Code assignment for PPS needs to be resolved and the assignment for PBT confirmed.

Data availability

Plastics in the UK economy has established figures for the usage and disposal of plastic materials for a variety of points throughout the UK economy. The collection and collation of such data is a difficult task not least because the shortage of readily available data sources. The document can provide a positive contribution in identifying data gaps and appropriately channelling resources. It is hoped that the graphic approach used in this document will assist with the identification of these areas.

This report is based on data provided by earlier stages of the project. The effort required to obtain such data provides is indicative of the costs necessary to repeat the exercise. Regular collection and collation will be important if the mass balance approach is to endure. The extension and automation of the process would also be a significant advance. It is recommended that methods of achieving this be investigated.

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[6] Linstead, C and P Ekins, *Mass Balance UK - Mapping UK resource and Material Flows,* Royal Society for Nature Conservation, 2001

Notes

1. **Production of primary plastic materials in the UK**
No overall or specific production figures have been inserted. There is some data but it is not available for all polymers and the UK polymer industry is currently undergoing considerable change.

2. **Converters**
The manufacture of plastic packaging goods - 1735kt were used (of both UK and Import origin). 80kt were recycled. Consequently the 'used' figure is 1655kt. Composition of waste/recycled streams are assumed the same as input material. The composition is based on a knowledge of the quantities of bulk polymers used in the sector (References [1] & [2])

3. **Packaging plastics (not embodied) to all UK sectors**
Total flux in to 'All Sectors' is interpreted to be import of plastic packaging materials and is Stream P-07 + P-13. Export is P-06 + P-09 + P-12 , i.e. net +35kt Import. Produced/Extracted is the UK manufacture of packaging materials (1655kt).
50kt is lost from packer fillers and it is assumed that only 50% of this is suitable for recycling. The other 50% goes to final disposal.
Final disposal is therefore 50% of P-10 plus P-20 and all of P-16 (i.e. 25+994+300 = 1319kte).
Recycled is therefore 50% of P-10 plus all of P-15, P-18 and P-19 (i.e. 25+190+142+14=371kt). Note that EfW of plastic packaging is considered to be recycling.

4. **Packaging plastics (not embodied) to the manufacture of plastic packaging goods**
1655kt of packaging produced in UK, and leaves as total flux out. % Composition is as supplied material.

5. **UK consumption of embodied plastics**
Consumption by UK industry of all polymers is available by polymer. This gives the balance from (Import - Export + Production). Import and export figures by polymer type are not normally available.
Only net import/export balances are available so no data for composition or quantity of plastics for imports and exports is available.

6. **All embodied plastics to UK manufacturing**
Similarly only net import/export data available for embodied plastics to all manufacturing sectors. We do not know if material is embodied or not when it enters the sector as an import as only net import information is available.

7. **Not embodied packaging plastics and UK manufacturing**
Looks at packaging plastic (not-embodied) entering packer/fillers (= all manufacturing) and is stream P-08. 50kt is a waste stream of which 50% is recycled and 50% is to disposal. Net quantity is embodied in various packaged products. Composition is not known.

8. **Embodied packaging plastics and UK manufacturing**
Flux out of the manufacturing sector is taken to be the sum of P-09 (exported packaging, with packaged materials) and P-11 the packaging associated with packaged goods passed on to the retail/wholesale sector.

9. **Embodied packaging plastics and UK wholesale and retail**
Total plastic packaging into retail/wholesale. Total flux in is that received from UK packer/fillers (P-11 at 1485kt) and that imported (P-13 at 215kt). Total flux out is P-12 and P-14.

10. **Packaging plastics and UK households**
Total flux in is stream P-17. Final disposal is stream P-20. Recycled is the sum of streams P-18 and P-19.

11. **Packaging plastics and UK households - bottles**
The quantity of the different polymer bottles that are present in household waste have been estimated. [This is based on the assumption that the composition of the recycled bottles stream is the same as the consumption. stream]. These are embodied plastics i.e. in bottles and other goods as product.
The amount of bottle recycling is equal to the sum of the bottles recycled (stream P-19; Recoup information but referenced from[1]) and the bottles recycled through EfW (within stream P-22). The plastic material to EfW was 200kte and bottles represent 319/1617 of the total stream (assumes no bottle removal from those collections that are destined for EfW; 71% assumption/ agreement would not be valid if the material was depleted of packaging content). Therefore bottles were 39.46kt to EfW in 2000. Total bottle recycling was this plus 14kt, i.e. 53.46kt.
Container recycling is only through EfW. There are 287kt of containers in 1617kt of waste. Therefore 287/1617 times 200kt are sent to EfW = 35.5kt.
For sacks and bags recycling, we assume very low levels of film recycling to allow estimation of the quantities. Again pro rata the quantities in domestic waste to estimate the sacks and bags that enter EfW. That is 177/1617 times 200 are sent to EfW = 22kt in 2000.

12. All primary polymers for the manufacture of builders' ware of plastics
930kt of plastic primary materials were used in 2000 to supply this sector. We enter a figure in the embodied column if we assume that no supplied material to the sector is wasted or recycled.

13. Specific primary polymers for the manufacture of builders' ware of plastics
We have no information on the composition of primary plastic supplied to this sector.

14. Builders' ware of plastic produced in this manufacturing sector
930kt of builders' ware of plastic manufactured.

15. Builders' ware of plastic to all consuming sectors
Only the balance of import/export is known (120kt, stream C-03). But stream C-02 is defined in volume and composition.
No builders' ware produced or extracted in consumption sectors. Disposal is defined by stream C-04. In addition there is a buried inventory of 100kt/a of HDPE, 100kt/a of PVC and 25kt/a of PVC "embodied" in structures.

16. Builders' ware of plastic to all consuming sectors - plastic type composition
Data is available on the composition of plastic entering the consumption sectors for builders' ware of plastics and on the disposal tonnes and composition (Reference [1]).

17. All plastics used in the manufacture of electrical and optical equipment
315kt of primary plastic materials were used by this UK manufacturing sector in 2000. The composition is unknown.

18. Specific plastics used in the manufacture of electrical and optical equipment
There is no composition data for this sector. The breakdown available expresses the quantities by appliance type not by material content.

19. Electrical equipment supplied to all sectors
355kt of plastics are estimated to be components of the electrical/electronic equipment supplied to consumers in the UK in 2000. There was disposal of 915kt of waste electrical and electronic goods in 2000. 22% of this were plastics, i.e. 200kt.

20. Electrical equipment supplied to households
There is no data that we can use to estimate the household consumption or disposal figure independent of the total.

21. All plastics to the manufacture of parts and accessories for motor vehicles and their engines
295kt of primary plastic material was supplied to the UK motor car parts and accessories sector in 2000. The composition is unknown. Low wastage rates are assumed - estimating that 295kt of plastic was embodied into car parts and accessories.

22. Specific plastics to the manufacture of parts and accessories for motor vehicles and their engines
Composition of plastic materials supplied to/used in the UK motor vehicles parts sector are not available.

23. All plastics embodied in motor vehicle consumption by all sectors
The plastic content of this category of vehicle and associated components entering service in 2000 was 335kt. The end of life content was 150kt. Indicates an accumulation in stock. The plastic type breakdown is also available. Although the quantity of vehicle components recycled and disposed of are not known it can be assumed that recycling of plastic content is low. Therefore it is estimated that 150kt of plastic content in vehicles from this sector were disposed of in 2000.

24. Specific plastics embodied in motor vehicle consumption by all sectors
Composition data is available for the plastic content of vehicles. The above is applied for each plastic resin in the sector. Current plastic content is assumed to apply to all ELV.

25. All plastics consumed in the agricultural/ horticultural sector
310kt of plastic product content was supplied to the UK agricultural and horticultural sector in 2000. 92.7kt is recognised at end of life for these materials in 2000. Recycling is assumed to be very low allowing an estimate of 92.7kt disposal to be made. The sector requires additional analysis and tracing to identify the fate of the balances - in part assumed to be embodied in various plant and equipment and at other sector establishments.

26. All plastics consumed in the agricultural/ horticultural sector

Some assumptions have been made about the composition of material disposed of by this sector and based on the table presented on page 30 of the Post Use Plastics Recycling - Best Practice Guide. It is assumed that 90% of the material is in the form of various polyethylenes, 5% is PVC and 5% polypropylene.
Flux in by plastic type cannot be specified. It is assumed that recycled quantities are small and can be ignored

27. Domestic plastics waste

The quantity of plastic packaging in domestic waste has been derived from a two sources.
1,208kt was calculated from Local Authority data (obtained from reference [1] and scaled up to UK wide figures from information per household p.13)
1,105kt from the plastics packaging section in Reference [1] - originating from considerations by the Valuplast Data Group.

The packaging plastic data for the domestic stream for each plastic material has been adjusted pro rata to agree in total terms with the 1,105kt figure. The figures were in reasonable agreement in any case but the lower figure was chosen because research has shown that information from waste analysis overestimates quantities slightly due to contamination of the measured material by other wastes.

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