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Recycling agricultural waste plastic

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The Agricultural Waste Stakeholders' Forum was established in Autumn 2002 with representatives from Government, the Environment Agency, farming organisations, waste management companies and farm input suppliers. The aim is to identify and tackle the issues associated with the planned extension of waste management controls to agriculture, and to work in partnership to help develop solutions and practical systems to meet farmers needs.

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Recycling Agricultural Waste Plastic

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EXECUTIVE SUMMARY

The need for this research follows the intention of Government to implement the Agricultural Waste Regulations, as stated in the Waste Strategy 2000. Thus waste plastics from agricultural and horticultural holdings will become controlled waste. It has been previously estimated that 90,000 tonnes (t) of this type of waste are generated in the UK[1, 2]. Currently there are not sufficient recycling schemes in operation to ensure that this waste is disposed of using the best practicable environmental option.

This report investigates the potential for recycling waste plastic from agricultural and horticultural enterprises in England and Wales. The project has quantified and qualified waste plastics arisings, and identified potential recyclers and their requirements.

An economic model for a collection scheme for England and Wales has been developed. The model describes one of a number of permutations. In order to provide data for the model, a limited number of farms were visited to evaluate and measure the arisings of the common plastic waste streams. The eighteen farms chosen for this survey represented the main types of farms as defined in the Defra (Department for Environment Food and Rural Affairs) June Census. The first objective was to develop a model which could be used to assess different collection scheme scenarios.

The second objective of this project was to investigate the potential for recycling waste plastic from agricultural and horticultural enterprises in England and Wales and, in particular, to:

- identify the amounts and types of waste plastics produced from different agricultural and horticultural enterprises in England and Wales;
- identify potential recyclers and the issues that affect their ability to accept the waste, including external market factors;
- identify optimum locations for the local and regional collection of farm plastics;
- estimate the cost of a national collection scheme for farm plastics.

It is estimated that approximately 1% of agricultural waste plastic is currently being recycled. Several reasons for this low recycling rate have been identified. Recyclers capable of taking this type of plastic have been identified and the regional concentrations of plastic mapped.

Current literature on agricultural and horticultural waste plastic and the plastics recycling industry has been reviewed. The variation in regional concentrations of plastic waste produced on agricultural and horticultural units in England and Wales has been defined by undertaking farm visits and applying existing census data. Data

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[1] Biffaward (2003). *Agricultural Waste Mass Balance: Opportunities for Recycling and Producing Energy from Waste Technologies.*
[2] Environment Agency (2001). *Towards Sustainable Agricultural Waste Management.* Environment Agency R&D Technical Report P1-339. Environment Agency, Bristol.

has been collected from farms representing seven different farm types. Samples have been taken for weight analysis during the farm visits. Polyethylene (PE), in its various forms, and Polypropylene (PP) are the main polymers produced on farms and were therefore the main focus of this work.

Waste arisings for each polymer have been expressed in terms of unit weight per hectare of crop and unit weight per livestock unit. Defra June 2000 Census data was used to map waste arisings for each polymer – by county in England and by region in Wales.

A list of potential recyclers has been obtained using published information from industry associations. Research was undertaken using a questionnaire that was developed to highlight those recyclers showing the greatest interest in agricultural waste plastics. A number of recyclers have been visited in order to gather more information. One significant outcome from this study has been to raise awareness among recyclers of the range of waste types being generated by agricultural and horticultural enterprises.

A collection network for waste agricultural and horticultural plastics in England and Wales has been proposed, and the costs of its operation calculated. Regional differences and the effect of external grant aid have been calculated. Three components of the collection scheme were taken into account:

- farm to hub or collection centre;
- hub to collection centre;
- collection centre to recycler.

Collection centres are larger sites than hubs, with greater handling capacities and better developed sorting and processing facilities. Hubs are, in effect, mini collection centres with the capacity to bale plastics, making transport more cost-effective. Appropriate locations for new collection centres were proposed, taking into account the location of existing collection centres and the concentration of waste produced. Hubs were then located in areas where farmers would need to travel more than fifty kilometres to reach the collection centres, as it was believed that this would be the maximum distance farmers would be prepared to travel. The same issues of collection would apply to collection services, as travelling long distances to collect low-density materials would not be attractive.

The assumptions used in the model were as follows:

• Percentage of waste arising to be collected	80%
• Average weight of plastic carried on a trailer pulled by a truck	2,000 kg
• Average weight of plastic carried on a lorry	5,000 kg
• Annual cut-off volume, below which it is not worth running a lorry	1,000 tonnes
• Split of total tonnage transported by trailer to a collection centre	10%
• Split of total tonnage transported by lorry to a collection centre	90%
• Average distance between pick-ups, once the collection vehicle has left the collection centre	5 km

- Pick-ups from each farm per year 1
- Transport of materials will be pre-organised by a third party and not individual farmers themselves

A summary of the main findings is given below:

- Calculations based on the methodology described above show that the total amount of waste plastics generated per year is 101,400 tonnes (86,900 tonnes in England and 14,500 tonnes in Wales). This is made up of the following polymer types: PP – 16,300 tonnes; LDPE – 29,100 tonnes; LLDPE – 54,400 tonnes; HDPE – 1,600 tonnes. (See section 3.2.1 for definitions of polymer types.) These figures broadly agree with estimates from other reports.

- Forty-seven potential recyclers have been identified, four of which are already taking agricultural or horticultural plastics. Most recyclers expressed a preference for baled, clean plastic that can be sourced throughout the year. The majority of recyclers only deal with a small number of polymer types. Only one recycler would be willing to take High Density Polyethylene (HDPE) originating from pesticide containers.

- The model uses existing collection centres and proposes new hubs and collection centres. For the purposes of developing a workable model, the authors have chosen an average distance travelled from hubs to collection centres of 83 km, from collection centres to PP recyclers of 63 km and collection centres to PE recyclers of 95 km.

- The average cost of collecting waste from farms and transferring to a recycler has been calculated to be £48 per tonne. There is a regional variation of £40-£67 per tonne. This is mainly attributed to the differences in the density of arisings between the regions. These are costs, not prices, and take no account of the need for a commercial operation to create a profit. The calculations include the costs of a baler to compact materials but not of cleaning operations to reduce contamination.

- Mechanical recovery systems require a pre-cleaning process, typically washing and shredding, prior to processing. Current collection schemes pay for this as a gate fee. The cost of such a gate fee would be £30-£45 per tonne of contaminated material. This must be added to the collection cost above in order to arrive at the total cost of recycling. While outline set-up costs for washing and shredding plants have been given later in this report, detailed costing has not been attempted as such costs are entirely site-specific.

- There is a clear need to persuade recyclers to take agricultural plastics in order for a national recycling scheme to work. Only five of the recyclers contacted presently accept agricultural waste plastic. The rest (more than 40) expressed some interest. These recyclers must therefore start to recycle agricultural plastic to ensure that sufficient tonnages are recycled and that transport distances are economically viable.

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1. INTRODUCTION

When the proposed Agricultural Waste Regulations come into force, plastic wastes from agriculture and horticulture will be classified as ‘controlled wastes’ and will be subject to certain control measures. The open burning of plastic wastes on farms, currently the favoured disposal method, will no longer be permitted. At the same time there are increasing legislative and environmental pressures to discourage the landfilling of wastes. The economic pressure of rising landfill charges will also encourage farmers and growers to find alternative methods of disposal. Indeed, many farmers have expressed a desire for an effective recycling scheme to be set up.

A limited number of collection schemes are already in existence. However new collection schemes will be required to cope with the volumes of plastic waste from agricultural and horticultural holdings that will be generated as a result of the new Regulations.

The Environment Agency funded this study on behalf of the Agricultural Waste Stakeholder Forum. It investigates the potential for farmers and growers, in England and Wales, to participate in agricultural plastic recycling schemes.

2. PROJECT OBJECTIVES

The objectives of this project are to investigate the potential for recycling waste plastic from agricultural and horticultural enterprises in England and Wales – in particular to:

- identify the amounts and types of waste plastics produced from different agricultural and horticultural enterprises in England and Wales;
- identify potential recyclers and the issues that affect their ability to accept the waste, including external market factors;
- identify optimum locations for the local and regional collection of farm plastics;
- estimate the cost of a national collection scheme for farm plastics.

3. COLLECTING BACKGROUND INFORMATION

3.1 Introduction

Background research included current literature on agricultural waste plastics arisings, on existing agricultural waste plastics disposal routes, and on the plastics recycling industry. The literature review illustrates areas where further research is required. These areas will be described in more detail throughout the report.

This section considers current research and published information on agricultural waste plastics. It will then summarise background information on the plastics recycling industry.

3.2 Agricultural waste plastics

There are approximately 240,000 agricultural holdings in the UK.[3] Agricultural waste plastic represents 5% of total plastic consumption in the UK.[4] The total quantity of non-natural waste on farms is estimated to be in the order of 500,000 tonnes per year. Plastics have been identified as one of the most significant wastes from agriculture[5], forming a major proportion of the total waste produced. More than 90% of holdings generate waste plastic packaging and more than 80% generate one or more of silage plastics, net wrap or bale twine.[6] It is estimated that the quantity of plastic packaging waste produced on UK farms is approximately 33,000 tonnes/year[7]. The total quantity of non-packaging non-contaminated plastic waste is estimated to be 60,000 tonnes/year in the UK.[8] Silage and horticultural films (50,000 tonnes and 23,000 tonnes respectively) represent more than half of the non-packaging plastic. The actual weight of these waste streams is high due to high levels of contamination from soil, water and other debris.

3.2.1 Types of plastic found on farms

The types of waste streams found on holdings do not vary significantly across England and Wales.[9] A comprehensive list of the sources of agricultural plastic waste is provided in Appendix 1. A mass balance of agricultural plastics is illustrated in Figure 3.1.

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[3] Statistics from 1999. Environment Agency (2001) *Towards Sustainable Agricultural Waste Management.* Environment Agency R&D Technical Report P1-339. Environment Agency, Bristol.
[4] AMA Research (2003) *Plastics Recycling Market -UK 2003*, Cheltenham.
[5] Environment Agency (2000) *Towards Sustainable Agricultural Waste Management*. Bristol.
[6] Environment Agency (2003) *Agricultural Waste Survey 2003.* Environment Agency, Bristol
[7] Biffaward (2003) *Agricultural Waste Mass Balance: Opportunities for recycling and producing energy from waste technologies.*
[8] 1998 data. Environment Agency (2001) *Towards Sustainable Agricultural Waste Management.* Environment Agency R&D Technical Report P1-339. Environment Agency, Bristol.
[9] Environment Agency (2003) *Agricultural Waste Survey 2003.* Environment Agency, Bristol

Figure 3.1: Inputs and outputs of plastics on different types of holdings[10].
(Quantities used and wastes arising depend on farm type and size.)

INPUTS
- Agrochemicals
- Fertilisers
- Seeds
- Animal health products
- Animal feed
- Silage/horticultural films
- Other horticultural plastics
- Bale twine and bale wrap
- Miscellaneous products

→

FARM TYPE
- Dairy
- Cattle & Sheep
- Cereals
- General cropping
- Pigs and Poultry
- Horticulture
- Mixed

→

WASTE OR USED PLASTICS
Packaging plastics
Non-packaging plastics:
- Silage films
- Horticultural films
- Bale twine & wrap
- Cores
- Tree guards
- Other plastics

The main farm enterprises producing plastic waste are dairy farming and horticulture. Most of the plastic in agricultural applications is polyethylene film, or sheet for silage and crop cover. Seed and fertiliser bags represent 80% of packaging waste. [11]

The main plastic polymers used in agriculture are:

- Polyethylene (PE), this includes:
  - Low Density Polyethylene (LDPE)
  - Linear Low Density Polyethylene (LLDPE)
  - High Density Polyethylene (HDPE)
- Polypropylene (PP)
- Expanded Polystyrene (EPS).

To identify plastics materials, the American Society of Plastics Industry (ASPI) has developed a coding system. This system includes all the types of plastic used in agriculture. This coding system is illustrated in Appendix 2.

3.2.2 Methods of waste disposal

The Agricultural Waste Survey carried out by the Environment Agency in 2003 showed that 90% of the holdings surveyed were disposing of at least one plastic waste stream using one or more practices that is likely to be illegal following the introduction of Agricultural Waste Regulations.[12] For example, packaging and silage plastics are most likely to be disposed of by burning. Stockpiling on farms has

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[10] Figure adapted from Environment Agency (2001) *Towards Sustainable Agricultural Waste Management.* Environment Agency R&D Technical Report P1-339. Environment Agency, Bristol.
[11] AMA Research (2003) *Plastics Recycling Market -UK 2003*. Cheltenham.
[12] Environment Agency (2003) *Agricultural Waste Survey 2003.* Environment Agency, Bristol

increased during the last few years due to pressures to stop burning.[13] Some waste is re-used on farm; other waste is placed in household dustbins, returned to distributors or merchants, or transferred to a specialised waste contractor.

There is evidence that there is a considerable demand for waste plastic collection schemes. 92% of the Environment Agency's Waste Survey respondents stated that they would participate in an on-going waste collection scheme for waste such as silage plastics, if the cost were not prohibitive.

3.2.3 Factors affecting waste production and recycling on farms

There are many issues that must be considered when looking at recycling agricultural waste plastic:

- The nature and diversity of agricultural production systems. Different farm activities create different agricultural waste streams, as will be demonstrated in Section 4.[14]
- The amount of plastic waste produced on different farms. [15]
- The location and density of specific farming activities. For example, dairy, beef, sheep, pig and poultry and arable regions with a high density of a particular activity are most likely to have high concentrations of waste in localised areas. High production densities in horticulture and field vegetables are also local rather than regional. [16]
- The seasonal variations in waste arisings.
- The level of contamination and the potential for its reduction.
- Current and impending legislation.
- Farmer awareness.

These issues will be considered later in this report to identify trends in plastic waste production. This will enable the setting up of appropriate and effective recycling chains.

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[13] Environment Agency (2001) *Towards Sustainable Agricultural Waste Management.* Environment Agency R&D Technical Report P1-339. Environment Agency, Bristol.
[14] Biffaward (2003) Options for agricultural waste collections A Study to help identify sustainable options for the future, Biffaward, October 2003.
[15] Biffaward (2003) Options for agricultural waste collections A Study to help identify sustainable options for the future, Biffaward, October 2003.
[16] Biffaward (2003) *Agricultural Waste Mass Balance: Opportunities for Recycling and Producing Energy from Waste Technologies. C-Tech Innovation Ltd, 2002*

3.2.4 Current data models for agricultural plastic waste streams

A model has been devised to provide quantitative and qualitative data on agricultural waste and associated resource management.[17] Using this model, several agricultural plastic wastes were identified as high priority waste streams – for example, agrochemical packaging and silage plastic (with and without contamination). There were, however, assumptions made in the model and some data may be out of date or incomplete.

3.3 The plastic recycling industry

It was estimated that in 2003 only about one percent of agricultural plastic waste was recycled: the majority of this was PE film from silage wrap.[18] There is a large plastic recycling capacity in England and Wales. The plastic recycling market in the UK is estimated at 350,000 tonnes per annum. However, only ten percent of total available plastic waste is currently recycled.[19] For example, in the North West, there are a total of seventeen companies that provide a recycling capacity of approximately 156,000 tonnes. However, only 64% of this region's total capacity was utilised in 2002.[20] A number of the region's recycling companies had expansions planned during and post 2003. These would double the capacity for plastic recycling in the region. Similar trends are expected throughout the country (this is further illustrated in Section 5).

3.3.1 Characteristics of the plastics recycling industry

The plastic recycling industry is still in its infancy and is characterised by a relatively small number of companies. The six largest recycling companies recycle more than 30% of plastics.[21] Plastic recyclers are found throughout England and Wales but are not spread out evenly at a local level. For example, the accredited re-processors for plastics in the North West are mainly concentrated in the Mersey belt and in Lancashire – 60% of the plastic recycled there is imported from other regions[22].

The cost of new processing plants is very high. Therefore, recyclers would invest in new machinery only where the supply of recyclate is guaranteed and the full recovery of costs is possible.

[17] Environment Agency (2001) *Towards Sustainable Agricultural Waste Management.* Environment Agency R&D Technical Report P1-339. Environment Agency, Bristol.
[18] AMA Research (2003) *Plastics Recycling Market - UK 2003*. Cheltenham
[19] AMA Research (2003) *Plastics Recycling Market - UK 2003*. Cheltenham.
[20] ADAS Consulting Ltd (2003). Pre-Feasibility Study: Recycling of Waste Plastic from Rural Industries in the North West.
[21] AMA Research (2003) *Plastics Recycling Market - UK 2003*. Cheltenham.
[22] Rowe, L (2002) *Survey of Accredited Recyclers in the Northwest.* Environment Agency.

There are two types of recycling process:

Mechanical recycling requires plastics to be sorted by polymer type. It takes advantage of the fact that most plastics soften on heating and can be recycled into new plastic products.

Feedstock recycling breaks polymers into their constituent monomers. These can then be used as intermediate building blocks for a wide range of new industrial intermediates.

3.3.2 Polymers currently recycled

Previous studies have shown that polyethylene (PE) is the most common type of recycled polymer, accounting for 62% of the market by volume. However, although 25,000 tonnes of PE film are used annually for silage sheet and bale wrap, only ten percent is recycled.[23] Polypropylene is the second most common recyclate, representing 22% of the market, followed by polystyrene accounting for 11%.[24]

3.3.3 End markets for recycled products

There are many end uses for recycled plastics. These include refuse sacks, crates, construction products and temporary traffic control products. [25] There are also many potential end-uses in the agricultural sector, for example silage sheets, irrigation systems and slurry pits.[26] Plastic wood can be used instead of conventional wood for fencing and storage, as it has a longer lifespan and few maintenance requirements. One recycling company is working on a long-term project to develop a recycled drainage channel. This would require 4,000-5,000 tonnes of contaminated plastic feedstock made from agricultural and rigid packaging. The horticultural industry also uses recycled PP, HDPE and High Impact Polystyrene. Indeed, most pots and trays are made from recycled material and the industry consumes approximately 4% of all the recycled plastic used in the UK.

Many end uses of recycled plastics are currently of low value. This, it is suggested, is because a quality control culture and subjective perception in the marketplace[27] (especially with recycling contaminated plastic waste streams) result in a lack of market stability for the collected material. However, a pre-feasibility study carried out by ADAS[28] indicated that enterprising recyclers are able to identify new markets for recycled agricultural plastics. Demand for plastic feedstock is therefore on the increase. Section 7 will analyse those factors that affect the market for recycled products.

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[23] AMA Research (2003) *Plastics Recycling Market - UK 2003*. Cheltenham.
[24] AMA Research (2003) *Plastics Recycling Market - UK 2003*. Cheltenham.
[25] Survey of application markets for recycled plastics.
[26] AMA Research (2003) *Plastics Recycling Market - UK 2003*. Cheltenham.
[27] WRAP (2003) *Standards and Specifications Affecting Plastics Recycling in the UK*. WRAP, Banbury.
[28] ADAS Consulting Ltd (2003). Pre-Feasibility Study: Recycling of Waste Plastic from Rural Industries in the North West ADAS.

3.3.4 Barriers to recycling schemes

Outlined below are some of the barriers to effective recycling schemes:

- Seasonal variation in waste from farms – re-processors require a consistent and regular supply of feedstock. This issue will be covered in more detail in Section 7.
- The bulky nature of plastic waste (especially packaging and silage plastic) requires special equipment and vehicles for recycling. See Section 10.
- Contamination from soil or foreign material can be in excess of 50%, by weight, for some waste products. This barrier will be considered more extensively in Section 7.
- The quantities of agricultural wastes produced are small compared with other industries. Of the three million tonnes of plastic waste produced each year in the UK,[29] only 92,000 tonnes are from agriculture.[30] Agricultural and horticultural plastic therefore only represent 3% of the total waste plastic in the UK. See Section 7.
- Existing and emerging markets are currently dominated by other raw materials. There is a lack of sustained competitive pricing between virgin polymer and recyclate. See Section 7.
- Current and impending legislation can create barriers – such as the potential administrative burden from waste carrier registration, waste management licensing legislation and Packaging Recovery Notes.[31] .
- The technology and skill base of the UK plastic recycling industry could be better. This issue will be dealt with in Section 11, where opportunities for further research have been highlighted.
- Costs. The total costs of collection, pre-treatment and transport are greater than the current disposal cost of the material. General costings are considered in Section 3.3.5 below.

3.3.5 Costs associated with recycling plastics

The total costs incurred in collection, pre-treatment and recycling to granulated feedstock for mixed plastic waste have traditionally been high compared with other methods of disposal. This is illustrated in Table 3.1 below.[32] Please note that this study was carried out several years ago and the actual figures may now have changed (for example the cost of landfill).

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[29] Department of the Environment, Transport and the Regions (DETR) (2000*) Waste Strategy 2000 for England and Wales: part two.* DETR, London.
[30] Environment Agency (2001) *Towards Sustainable Agricultural Waste Management.* Environment Agency R&D Technical Report P1-339. Environment Agency, Bristol.
[31] For example, The Producer Responsibility Obligations (packaging Waste) Regulations Statutory Instrument 1997, No.648. See www.legislation.hmso.gov.uk
[32] *Plastics in the Environment* report. Environment Agency, March 2001.

Table 3.1: Cost of collection, pre-treatment and recycling for mixed plastic wastes for various processes.

Process	Estimated cost (£/t)
Feedstock recycling	330
Municipal waste incinerator	214
Cement kiln	181-221
Landfill (municipal solid waste)	165

A pre-feasibility study in the North West[33] showed that the costs of collection and re-processing could be between £50-75/tonne for distances of less than 50 miles from farms. An economic analysis for a collection and recycling scheme is found in Section 10.

3.4 Conclusion

Previous studies have acknowledged the need for a national agricultural plastics collection scheme. However, in-depth modelling of proposed schemes and economic analysis have not been undertaken.

It is also apparent from the literature reviewed that there is a need for a more accurate approach to estimating the quantities of principle polymers occurring. The existing data is starting to become dated and it is acknowledged that these current estimates are based on a significant number of assumptions.

There are no previous studies that link agricultural waste production and the plastic recycling industry. In particular, no information was found which established a chain for waste generated at the farm level to the end user or recycler.

It is believed that the results of this study will provide a broader knowledge base for agricultural plastics recycling and will contribute to a practical solution in the form of a workable collection scheme model.

[33] ADAS Consulting Ltd (2003). Pre-Feasibility Study: Recycling of Waste Plastic from Rural Industries in the North West.

4. WASTE PLASTIC ARISINGS ON FARMS

4.1 Introduction

One aim of this study was to define the variation in regional concentrations of plastic waste produced on agricultural and horticultural units in England and Wales. The methodology used incorporated estimates of the amounts produced from various enterprises. These estimates[34] were then multiplied by the area of each holding, using data from the "ADAS, one kilometre Agricultural Data for year 2000" (derived from Defra Agricultural June 2000 Census[35]) to obtain figures for agricultural plastic waste by county.

In order to apply the Census data, waste arisings were converted into unit weight per hectare and unit weight per livestock animal. As there is little published information available in these units for individual waste streams, this was supplemented by data obtained during farm visits.

4.2 Farm visits

Farms visited were classified according to their main activities in order to illustrate the most significant amounts of plastic waste produced by farm type:

1. arable farms
2. dairy farms
3. vegetable producers
4. beef/sheep farms in the uplands
5. beef/sheep farms in the lowlands
6. pig farms
7. protected cropping.

In order to obtain accurate values for each waste stream by activity, the farms that were visited usually only had one farming activity. In cases where more than one farming activity was carried out, only data from the predominant activity was analysed in detail. Trends for the subsidiary activities were however noted and taken into account in subsequent calculations.

Between one and three different holdings for each of the listed farm types were visited. Different types of locations throughout England and Wales were chosen in order to deduce whether geography had an effect on plastics types and amounts produced. In total, eighteen farm visits were made during April 2004.

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[34] These estimates were derived from a number of reference sources, including *The Survey of Fertiliser Practice* (2002). All assumptions used to calculate the unit weights of the different agricultural plastics are described in Appendix 4.
[35] This was the most recent accurate data at the time of writing, due to the outbreak of foot and mouth in subsequent years.

Poultry producers were not visited due to bio-security implications. Neither were fruit farmers surveyed, as information was already available from a previous ADAS survey (see Section 4.4.1 and Appendix 4).
Farmers and growers were asked questions relating to cropping and livestock numbers, and on types of plastic waste arising each year. Further discussion was necessary to evaluate the amounts of each waste stream, and whether these were disposed of or re-used on farm. For each holding the amounts of the following types of plastic waste were determined:

- agrochemical (pesticide) containers
- other bottles/ containers
- shrink wrap from packaging
- feed bags
- fertiliser bags
- seed bags
- silage bale wrap and clamp cover
- net wrap and string for silage bales
- net wrap and string from straw and hay
- horticultural mulch
- polyethylene pots, polystyrene trays, etc from horticultural units
- polystyrene trays.

Farmers were also asked about their current disposal methods, their attitude to recycling, participation in current recycling schemes, and procedures for reducing contamination of the waste. The questionnaire template used for all farms is included in Appendix 3.

Where appropriate, samples were taken for weight determination. Some samples were subsequently shown to a selection of recyclers, as will be described in Section 5.

4.3 Results from farm visits

4.3.1 Amounts of plastic wastes produced

Table 4.1 below summarises the cropping and livestock information for each farm. Table 4.2 illustrates estimates of the annual production of all the plastic waste streams found on the farms. Only wastes present in significant amounts have been recorded. The average unit weights of plastic wastes, as weighed from samples taken from the farms, are shown in Table 4.3. Material weighed was selected to represent the typical level of contamination normally found.

Table 4.1: Cropping and livestock found on holdings surveyed during April 2004.

Farm	Farm type	Crop no cover (ha)	Crop covered (ha)	Livestock dairy	Livestock 1-2 year	Livestock <1 year	Sheep	Sows	Bacon	Poultry
A	Arable	2,320	0	0	150	0	600	0	0	0
B	Arable	154	0	0	0	0	0	0	0	0
C	Arable	187	0.1	0	0	0	0	0	0	0
D	Arable	400	0	0	0	0	0	0	0	0
E	Arable/veg	1,878	56	0	0	0	1,200 & 1,100 lambs	0	0	0
F	Beef lowland	148	0	0	60	20	470	0	0	0
G	Beef lowland	607	0	0	40	0	1,300	0	0	0
H	Beef lowland	109	0	0	130	0	550 &100 hogs	0	0	0
I	Beef upland	247	0	100	240	0	700	0	0	0
J	Beef upland	73	0	0	25	40	600	0	0	0
K	Dairy	142		100	89	40	40	0	0	0
L	Dairy	81	0	134	33	7	0	0	0	0
M	Dairy	107	0	110	0	0	0	0	0	0
N	Protected cropping	0	10	0	0	0	0	0	0	0
0	Pigs	66	0	0	0	0	0	200	3,000	0
P	Pigs	33	0	0	0	0	0	0	3,000	0
Q	Veg	712	219	0	0	0	0	0	0	0
R	Veg	493	34	0	0	0	0	0	0	

Table 4.2: Annual plastic arisings for holdings surveyed during April 2004.

Farm	Pesticide bottles (tonnes)	Other bottles (tonnes)	Feed bags (tonnes)	Fertiliser small bags (tonnes)	Fertiliser inner bags (tonnes)	Fertiliser outer bags (tonnes)	Seed bags (tonnes)	Silage film (tonnes)	Clamp cover (tonnes)	Silage Net wrap (tonnes)	Straw/hay Net wrap (tonnes)	Bale twine (tonnes)	Horticultural white plastic (tonnes)	Horticultural black plastic (tonnes)	Horticultural fleece (tonnes)	PE trays (tonnes)	PS pots(tonnes)	EPS trays (tonnes)
A	0. 635		0.046		0.968	1.292	0.312	0.9	0.127	0.132	0.49	0.25						
B	0.097				0.118	0.144	0.066											
C	0.152	0.008			0.087	0.118	0.04								0.017			
D	0.138	0.008			0.162	0.216	0.22											
E	0.275				0.675	0.9	0.44		0.043			1.25		24				
F	0.028	0.001	0.005		0.063	0.084	0.022	0.6		0.198	0.154	0.025						
G	0.083		0.048		0.36	0.48	0.11	0.9		0.134	0.535	0.078						
H	0.002	0.016	0.091		0.033	0.046	0.001	0.591	0.1		0.207							
I					0.036	0.048		0.15	0.04			0.113						
J			0.046		0.018	0.024		0.45	0.111			0.012						
K			0.04		0.037	0.054	0.013		0.678			0.116						
L	0.008	0.048	0.006		0.034	0.054	0.004	0.156	0.137		0.089	0.05						
M		0.112			0.005	0.006		0.300	0.108		???	0.031						
N	0.013			0.05										1.652		0.003	0.4	70
O					0.036	0.048					0.034	0.035						
P		0.008	0.389															
Q	0.57				0.27	0.36							36	90	1.673			
R		0.035			0.338	0.45	0.008					0.875		14.1				

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Table 4.3: Weights of individual waste plastics products.

Waste product	Polymer type	Weight (kg)
Fertiliser bag (50 kg)	LDPE	0.175
Fertiliser bag (500 kg) – inner	LDPE	0.45
Fertiliser bag (500 kg) – outer	PP	0. 62
Seed bags (600 kg)	PP	2.2 *
Feed bags (25 kg)	PE	0.16
Bale twine around small bales (thin – 3 mm diameter)	PP	0.018
Bale twine around large quadrant bales and around silage bales (thick – 5 mm diameter)	PP	0.2
Net wrap (around round silage bale)	PP	0.2
Net wrap (around large round straw bale)	PP	0.225
Sheep drench packs (5 litre)	HDPE	0.32
1 litre can	HDPE	0.102
5 litre can	HDPE	0.275
10 litre can	HDPE	0.5
20 litre can	HDPE	1.33
20 kg disinfectant tub	PP	1.1
20 litre dairy bleach & circulation cleaner	PP	0.885
25 litre oil cans	PP	2.2
Mineral feed tubs – 14 kg	PP	0.4
Silage bale wrap – round bale	LLDPE	1.5
Silage bale wrap – rectangular bale	LLDPE	2.1
Silage clamp cover	LDPE	0.1 (kg/m^2)
Horticultural black plastic mulch	LDPE	0.07 (kg/m^2)
Horticultural fleece	LDPE	0.025 (kg/m^2)
Plastic around 25 kg woodchip bales	LDPE	0.148
Polystyrene trays	EPS	0.07

*This includes nylon straps and ties

4.3.2 Other relevant information gathered during farm visits

Analysis of the questionnaires completed during farm visits revealed that the preferred method of plastic waste disposal was burning on farm. A few farms buried some types of plastics or included these in the household bin. Many farms have chosen the landfill route for certain waste streams. Some farmers have, in the past, sent samples to various recyclers but had only received negative feedback on their suitability for recycling.

Several farmers that were visited were already involved in plastic collection schemes. A few farmers participated in the Gloucestershire Collection Scheme (see Section 8). One farmer gave his waste silage plastic to the Wales collection scheme (see Section 8). However, most farms surveyed had not participated in any recycling scheme to date, including earlier voluntary schemes that have since collapsed.

Although most farmers supported the introduction of a collection/recycling scheme, opinions were mixed as to whether they would pay for these. The general consensus was that farmers would pay for a recycling scheme only if it would cost less or a similar amount to landfill costs. A frequent concern was storing waste plastics on the farms between collections, as most plastic wastes are bulky and attract pests such as rodents. Farmers indicated that collections would be necessary on a regular basis to prevent these problems.

On one dairy and beef farm, all pesticides were applied by the supplier (Technicrop Ltd). This farm therefore only paid for the chemicals applied to crops and not for the packaging. This procedure is a type of plastic take-back scheme.

The majority of farmers were concerned about the implications of the new Agricultural Waste Regulations. Many believed that the Regulations would not be supported by the infrastructure to deal with plastic waste disposal legally. Some farmers were disappointed that they had not received more information on the Regulations or advice on the best practical environmental options for dealing with waste streams.

4.4 Estimates of national arisings for different types of plastic waste

One aim of this study was to estimate the arisings of various plastic wastes in weight/ha or weight per livestock unit. This estimate is based on the surveys carried out, and from ADAS knowledge of farming systems.

Assumptions were made for the enterprises and waste streams considered. These assumptions are described in more detail in Appendix 4.

Table 4.4 on the following page summarises the estimates of weights of plastic waste streams calculated for each enterprise.

Table 4.4: Weights of plastic waste streams per ha or livestock unit per annum.

Waste stream	Unit weight
Outer liner of 500 kg fertiliser bag	0.645 kg/ ha (tillage)
	0.5 kg/ ha (dairy grass)
	0.186 kg/ ha (other grass excluding rough grass)
	Nil (rough grass)
Inner liner of 500 kg fertiliser bag	0.468 kg/ ha (tillage)
	0.36 kg/ ha (dairy grass)
	0.135 kg/ ha (other grass excluding rough grass)
	Nil (rough grass)
Seed bags	0.2 kg/ha
Silage plastic (including both wrap and clamp cover) for cattle	9.7 kg/ dairy cow
	9.7 kg/cattle older than two years
	7.7 kg/cattle between the age of one and two years
	3.9 kg/ cattle below the age of one year
Net wrap and string for cattle	1.25 kg/ dairy cow
	1.25 kg/cattle older than two years
	1 kg/cattle between the age of one and two years
	0.5 kg/ cattle below the age of one year
Total silage plastic (including both wrap and clamp cover) for sheep	0.795 kg per lowland sheep
	0.534 kg per upland sheep
Silage net wrap and string for sheep	0.16 g per lowland sheep
	0.1 kg per upland sheep
String and net wrap for straw and hay	1 kg per lowland cattle
	0.5 kg per upland animal
Agrochemical containers	0.4 kg/animal
Horticultural mulch	1010 kg/ha (early potatoes)
	1020 kg/ha (field vegetables)
	1940 kg/ha (soft fruit)

4.5 Waste plastic arisings in England and Wales

Using data from Table 4.4 and Defra Census data, the annual amounts of the significant waste types have been estimated in Table 4.5 below.

Table 4.5: Annual production of different waste streams in England and Wales.

Waste product	Polymer type	England (t)	Wales (t)	England & Wales (t)
Fertiliser bags – outer liners	PP	3,793	305	4,098
Seed bags	PP	786	13	799
String / net wrap for straw / hay	PP	3,074	635	3,709
Silage net wrap / string	PP	6,128	1,528	7,656
SUB TOTAL		**13,781**	**2,481**	**16,262**
Fertiliser bags – liners	LDPE	3,586	396	3,981
Feed bags	LDPE	914	573	1,487
Horticulture mulch – for early potatoes	LDPE	550	0	550
Horticulture mulch – for field vegetables	LDPE	14,280	0	14,280
Horticulture mulch – For soft fruit	LDPE	8,794	0	8,794
SUB TOTAL		**28,124**	**968**	**29,092**
Silage plastic (wrap & clamp)	LLDPE & LDPE	43,404	11,012	54,416
SUB TOTAL		**43,404**	**11,012**	**54,416**
Agrochemical containers	HDPE	1,572	26	1,599
SUB TOTAL		**1,572**	**26**	**1,599**
TOTAL ALL POLYMERS		**86,881**	**14,488**	**101,369**

5. THE POTENTIAL RECYCLING MARKET

5.1 Introduction

Certain types of agricultural plastic waste are more attractive to recyclers due to the value of the recyclate; others are contaminated or have been in contact with hazardous materials – they are therefore less appealing.

For the purposes of this study, it was essential to identify plastic recyclers based in England and Wales who would be interested in the polymers and waste streams from farming enterprises. Research was undertaken to gather data on all plastic recyclers dealing with PE, PP and EPS in England and Wales. A database was developed using information obtained from various websites and the BPF (British Plastics Federation) recycling directory.[36] Initial contact was made with PE, PP and EPS recyclers by telephone. Information collected included: contact name at the recycling plant; location and postcode of the recycling plant; type of polymer treated; form in which plastic is required; recycling plant capacity; contamination specifications; anticipated expansion of production in the next five years.

Using these criteria, a selection was made of recyclers demonstrating the greatest interest and potential to deal with agricultural plastic waste. Initial site visits to several of these recyclers were conducted in order to gather more information on their requirements for accepting plastic wastes.

5.2 Potential recyclers

Table 5.1 below shows those recyclers who expressed some interest in one or more of the plastic wastes from agriculture and horticulture. Where a triple tick (✓✓✓) is placed against a polymer type, this indicates that the recycler is already accepting such materials.[37] Where a double tick (✓✓) is placed against a polymer type, this indicates that the particular recycler expressed a strong interest in these materials. Those recyclers expressing a strong interest made it clear that they would be willing take agricultural plastic following testing procedures and a reassurance that plastics were "non-contaminated". A single tick (✓) represents a company expressing some limited interest.

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[36] BPF (2003) Directory of UK Companies involved in the Recycling of Plastics, PRD03.
[37] Please note that these were accepting agricultural plastics at the time of writing of the report. Due to the nature of this industry (see Section 3), the situation may change in the future.

Table 5.1: Plastic recyclers in England and Wales that showed an interest in agricultural plastics.

Company	County	LDPE	HDPE	PP	EPS/ PS
1	Derbyshire			✓✓	
2	Lancashire			✓✓	
3	Merseyside			✓	
4	Cheshire			✓	
5	Flintshire			✓	
6	Surrey			✓✓	
7	North Yorkshire			✓✓✓	
8	Gwent	✓✓			
9	Suffolk	✓	✓		
10	Greater Manchester			✓	
11	Bedfordshire			✓	
12	Warwickshire			✓	
13	Greater London	✓✓	✓✓	✓✓	
14	North Yorkshire	✓✓✓	✓✓✓	✓✓✓	✓✓✓
15	Merseyside			✓✓	
16	West Sussex				✓
17	Unspecified		✓✓		
18	Lancashire			✓	
19	Lancashire			✓	
20	Leicestershire			✓✓	
21	Merseyside	✓	✓		
22	West Yorkshire	✓	✓	✓✓	
23	Leicestershire	✓	✓		
24	Greater Manchester	✓✓	✓✓	✓✓	
25	Essex				✓
26	West Yorkshire		✓	✓✓	✓
27	Cheshire			✓	
28	West Yorkshire				✓
29	Lancashire			✓	
30	Gloucestershire	✓✓	✓✓	✓✓	
31	Gloucestershire	✓✓	✓✓	✓✓	✓✓
32	Lancashire	✓✓	✓✓	✓✓	✓✓
33	Surrey	✓✓	✓✓	✓✓	✓✓
34	Merseyside			✓	
35	Gloucestershire	✓	✓		
36	Yorkshire			✓✓✓	
37	Merseyside		✓		
38	Lancashire	✓✓✓	✓✓✓	✓✓✓	✓✓✓
39	Staffordshire			✓	
40	West Sussex			✓✓	
41	Lancashire	✓✓✓	✓✓✓	✓✓✓	
42	Cheshire			✓	
43	Leicestershire			✓✓	

Company	County	LDPE	HDPE	PP	EPS/ PS
44	Northamptonshire				✓
45	Kent, East Yorkshire				✓
46	Hertfordshire		✓	✓	
47	Somerset			✓✓	
48	Greater Manchester	✓	✓	✓	

Telephone conversations with these recyclers gave some insight into the criteria required for waste plastic. Many recyclers are only interested in clean plastics. Most recyclers request that plastics be baled, although a few prefer non-baled plastic. Some recyclers also require a threshold tonnage of plastics from their suppliers. These criteria are important and must be taken into account by a collection scheme.

5.3 Analysis of different polymers used in the agricultural industry

Very few recyclers will accept mixed waste due to increased fears of contamination. The preference is for dealing with specific single polymers. Furthermore, several recyclers will accept only one waste stream. Below, each plastic polymer is considered in turn to determine its attractiveness to recyclers and to identify problems associated with recycling.

5.3.1 High Density Polyethylene (HDPE)

HDPE is an important polymer in the agricultural industry. It is mainly found in the form of plastic containers. These are used to store pesticides, disinfectants and other cleaning chemicals. These plastics are usually unattractive to the recycling industry as they are seen to contain hazardous waste. It is true that such plastics are contaminated by materials that in themselves would be hazardous waste. However, the level of contamination on a triple-rinsed container is unlikely to render the plastic hazardous in most situations. Although the Environment Agency considers that containers are only considered as hazardous wastes if they contain more than 0.1% of their original contents, recyclers are still reticent about dealing with these waste streams. It seems there is a perception among recyclers that, if they were to handle large numbers of containers, the hazard would increase significantly.

Two recyclers were identified that would deal with HDPE bottles. Delleve (previously known as Reprise) will buy baled containers, although these must be below 2.5 litres. They are set up to separate HDPE from PET and PVC bottle waste. However, when asked, they would not accept plastic with a potential to be contaminated with a hazardous substance. The wash water that they use is analysed twice a day to detect contamination.

Gower Chemicals Ltd. (South Wales) would welcome agricultural containers, because the company is set up to take plastic containers which have been used to hold chemicals. However they would charge up to £4.00 per container.

5.3.2 Low Density Polyethylene (LDPE) and Linear Low Density Polyethylene (LLDPE)

LDPE is used as packaging for the inner liners of fertiliser bags and feed bags. Horticultural mulch is also made of LDPE, as is silage clamp plastic. LLDPE is used for silage bale wrap and packaging shrink-wrap.

LDPE feed bags are of interest, but silage plastics (both LDPE and LLDPE) are associated with high contamination. Very few companies will take it. Those who can pre-treat this plastic waste stream charge a substantial gate fee to compensate for the cost of washing and shredding equipment. The inner liners (LDPE) of fertiliser bags often still have fertiliser residues and are thus not attractive to recyclers.

Low Density Polyethylene (LDPE) and Linear Low Density Polyethylene (LLDPE) can be processed at low temperatures and do not readily degrade – hence it is favoured as a polymer used to make low-grade components or be mixed with High Density Polyethylene (HDPE) and wood flour to make wood-substitute products.

When processing HDPE or PP, the re-processor could also incorporate a small percentage of LDPE as a filler, as LDPE is molten at lower temperatures.

In the construction industry there is demand for LDPE as damp-proof barriers. This creates a potential opening in the market for this waste.

5.3.3 Polypropylene (PP)

PP is used to make the outer load-bearing cover of IBC fertiliser bags and seed bags, string and net wrap, horticultural pots and horticultural trays. However, the grades of PP used for these waste streams are quite different in terms of process settings. PP string and netting (a higher grade), and horticultural plastic would need to be carefully segregated from PP bulk bags. Polypropylene fertiliser bags are difficult to handle and process, so will interest fewer companies. To prevent contamination of the plastic, the inner liner must be removed before processing this material. However, some recyclers, for example Bulk Lift Europe in Yorkshire, currently take these bags for recycling, and market the compounded PP pellets that are recovered.

Many companies will be interested in clean Polypropylene (PP) pots and trays, because they have a ready market and are easily processed (see Section 5.4.3).

5.3.4 Expanded Polystyrene (EPS)

EPS is mainly used on nurseries, as potting containers for bedding plants. EPS has a low bulk density and transport costs are often prohibitive. There are several methods used to size-reduce EPS – for example using applied heat reduces the volume by 80% or more. Some EPS recyclers prefer compacted waste; others require it un-compacted.

Currently the main source of EPS for plastic recyclers is electrical products packaging, a very clean source of waste. Existing recyclers may not be willing to accept any contamination as they do not have the machinery to deal with it.

EPS waste is also used as a soil/growing medium additive, for which there is a market. Thus recyclers may be interested in recycling agricultural EPS into this end product.

5.4 Information gathered during visits to recyclers

Companies that showed a particular interest in agricultural plastics were visited in order to gain a greater understanding of the plastic recycling industry and their specific requirements. The companies visited were Synbra Polymers, Reflex Recycling, Econoplas, Vannplastic, Swintex, Addcolour and Roydon Industries.

Some recyclers visited had previously carried out trials on agricultural plastic waste. These trials were unsuccessful, mainly due to contamination. All the recyclers visited (as well as those who were contacted by telephone) would require a representative sample of the plastic waste streams to be recycled before they would accept any plastic waste. The material would be tested against an in-house specification. Recently, a Publicly Available Specification (PAS) No 103 *Collected waste plastics packaging* has been written. It is currently under consideration by the UK plastic recycling industry. This PAS is described in more detail in Appendix 5.

5.4.1 PP recyclers

Synbra Polymers in Cheshire specialise in PP recycling. Synbra supply manufacturers who mould plant pots and trays. They are therefore interested in net / twine and string, as well as pots. This company has however ceased its UK recycling operation during the timeframe of this report and has opened a plant in Holland.

Reflex Recycling in Yorkshire currently take agricultural PP bulk bags and process them into pellets (some PE is recycled). The company requires that all fertiliser be removed as well as the LDPE inner liner. This company is very interested in expanding its agricultural plastic waste recycling operation. However, currently this would be difficult without external funding due to the substantial investment required.

Addcolour, based in Lancashire, expressed interest in taking some plastic waste, but contamination would have to be minimal.

5.4.2 PE recyclers

Vannplastic, based in North Wales, currently recycles post-industrial plastic waste including LDPE and HDPE. The plant compounds the plastic with wood flour to make wood-substitute products. The visit to this plant revealed that this company would be interested in taking partly processed agricultural plastic waste. However the capacity of this plant (even with anticipated expansion) is small. It will therefore not be able to deal with a significant quantity of plastics in the short term.

Swintex is based in Lancashire. It processes large quantities of LDPE and HDPE plastic waste. The company requires that the level of contamination is low and that the waste is already size reduced, washed and shredded. This company would be able to recycle significant quantities of agricultural wastes.

5.4.3 Mixed polymer recyclers

Roydon Industries, based in Lancashire, will take agricultural plastic waste in bulk (in loads of 10 or 20 tonnes). This company usually exports the plastic waste to China or India. Roydon also processes plastic wastes in the UK.

Econoplas on Teeside currently accepts plastic wastes from local farmers, and uses it to produce a drainage medium. The product is sold to golf courses and farmers, as well as other markets. This company is looking to expand its operations to process local agricultural plastic to other locations in England.

6. COLLECTION, SEGREGATION AND PRE-TREATMENT OF PLASTIC WASTE STREAMS

6.1 Introduction

This section reviews the collection, segregation and pre-treatment of plastic waste. These are issues that will impact on a proposed national collection scheme and must therefore be given consideration.

6.2 Collection of agricultural waste plastics from farms

The method of collection used to transfer the waste plastic from its source to the recycler impacts on the overall scheme in terms of efficiency and cost. It is therefore essential that collection issues be thoroughly investigated prior to any scheme becoming established.

6.2.1 Farm type

The type of the farm and its associated location impact on the collection methodology used. For example, upland beef and sheep farms tend to be scattered in remote areas, are served by poorer road networks and may be more difficult to access for larger collection vehicles. It would therefore be inefficient and costly to use a refuse collection vehicle to travel from farm to farm. It would be more appropriate to encourage farmers to take their plastic to a local hub point.

For farm types where low volumes of waste plastic would be generated it would be less efficient to use a farm-to-farm collection method – costs would be prohibitive.

6.2.2 Suitability of collection schemes

Table 6.1 below suggests the suitability of three different collection methodologies for each farm type. This table is based on existing collection schemes (see Section 8). The assessment is based on generalised farm location and remoteness (by type) and therefore looks at the applicability of collection methodology in terms of logistics, in addition to anticipated volumes of plastic produced. It can be seen that all farm types can make use of the hub centres, indicating that this type of collection scheme would work in terms of efficiency and cost at a national level.

Table 6.1: The applicability of three different collection methods for each farm type.

	Collection methodology		
Farm type	**Hub/ centre**	**Farm to farm – adapted loader**	**Farm to farm – refuse collection vehicle**
Arable	***	**	*
Dairy	**	**	**
Vegetable	**	***	**
Upland beef & sheep	***	**	*
Lowland beef & sheep	***	**	**
Pigs	***	**	*
Protected cropping	**	***	***

* Not suitable – Volumes of plastic produced and/or farm type not suited to the collection methodology
** Suitable – Volumes of plastic produced *or* farm type most suited to the collection methodology
*** Preferred– Volumes of plastic produced *and* farm type most suited to the collection methodology

6.2.3 Plastic preparation

In order to maximise the load that can be carried by a collection vehicle, it may be necessary to prepare the plastic first. This can be in the form of ensuring cleanliness, baling, compacting and using liners.

On average, baling plastic costs £5.60 per tonne. However, the costs of baling and compacting may be offset by the advantages of having material that is easier to handle and can be compacted onto the collection vehicle, reducing volume and maximising weight. Most plastic recyclers would be happy to take baled plastic (some stipulate this as a requirement) – see Section 5.

The use of liners has proved to be successful for a number of current recycling schemes (see Appendix 6). Liners help to keep the plastic clean and dry and are easy for the collector to handle.

6.3 Segregation of different plastic polymers

The majority of recyclers will only accept segregated polymers. Others will separate different types of plastic in-house. There are several reasons why plastic polymers need to be segregated. Polymers have different physical properties. For example, different plastics can be processed at different temperatures. LDPE melts at a lower temperature than PP.

Different polymers also have various chemical properties. Some plastic products may be made from a blend of LDPE and HDPE, possibly with PP. Recyclers must have control of the ratio of polymers. Many prefer, therefore, to mix polymers in-house.

Polymers also have different financial values. One recent estimate for PP value in 2003 ranged from £50 to £200 per tonne, whereas HDPE value was estimated to range from £30 to £150 per tonne[38].

6.4 Pre-treatment of plastic polymers

There are many pre-treatment methods for plastics. One technique is washing followed by shredding to size-reduce. Another method, known as plast-compaction, requires a combination of heat and abrasion to form granules of consistent size and shape. The most advanced pre-treatment process produces industry standard compounded pellets similar to virgin polymer.

Generally plastic recyclers do not wish to pre-treat polymers as pre-treatment costs are high. However, the use of variable grades of feedstock generally produces low value, low margin products. A few recyclers have washing and shredding facilities in the UK. In order to be commercially viable, such recyclers will attempt to ensure a local catchment area for their products. Few plants use more advanced pre-treatment techniques.

The higher the level or pre-treatment, the higher the output at the recycling plant and the greater the value of the recycled material. As a minimum, therefore, recyclers baled material. Plastic waste streams can also be processed into a flake to size-reduce it further. This is achieved by using a shredder. Finally, waste can be converted into compacted pellets, preferably as the standard 3 mm diameter by 3 mm length pellets. The last option has the highest value, but is also the most cost-prohibitive.

[38] AMA Research (2003) *Plastics Recycling Market - UK 2003*. Cheltenham.

7. OTHER MARKET ISSUES

7.1 Introduction

There are several factors that will affect both the supply and demand of recycled plastics. These will be described in this chapter. Potential problems have been identified and analysed, and suggestions made on overcoming these market barriers, where appropriate.

7.2 Prohibitive cost of recycling plastics

7.2.1 The high cost of recycling plastics compared to other materials

Whilst the recycling costs/tonne for glass, steel and paper have been estimated at about £25 per tonne, the equivalent figure for plastic is £95 per tonne.[39] Furthermore, the recycling of glass and metal is very well established and is usually done on a large scale taking advantage of economies of scale. By contrast, the majority of plastics recyclers are small, labour-intensive enterprises. (There are a few notable exceptions.) Many recyclers therefore choose to recycle cheaper materials – to gain a competitive advantage and reduce the risk of market failure.

7.2.2 The price of recycled plastics versus virgin polymers

The costs associated with recycling plastics are high. The price of recycled plastics is often linked to the price of virgin polymer. Low virgin prices reduce the economic incentive to recycle plastics, and have a destabilising effect. However, an important factor affecting the price of virgin plastic is the increasing price of crude oil: with a few exceptions, polymers are usually derived from crude oil. This may lead to a rise in the price of virgin plastic and have a positive effect on the recycled plastics market. Furthermore, there are economies of scale as the volume of plastics being recycled increases.[40]

7.2.3 Low value of recycled products

Recycled plastic waste is mainly used to produce relatively low specification products. Relevant examples include: crates, refuse sacks, traffic control products and recycling containers. Some is also used in construction products such as drainage pipes, damp proof membranes, wood / plastic composites. Even segregated waste plastic may often only produce low value products due to the possibility of contaminants. Recycled plastic is not as attractive as virgin polymer for many applications, for example crop cover, as there is a negative perception that recycled plastic is not strong or durable.

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[39] AMA Research (2003) *Plastics Recycling Market - UK 2003*. Cheltenham.
[40] AMA Research (2003) *Plastics Recycling Market - UK 2003*. Cheltenham.

7.3 Other disposal options for plastic

Both costs and ease of disposal will influence farmers when they consider the disposal options for different plastic waste streams. Alternative routes to recycling have been listed below, with information on their advantages and disadvantages.

7.3.1 Landfill

This is the simplest option currently offered to farmers, as there is no need to segregate the different plastic wastes and contamination is not an issue (unless contamination is from hazardous wastes such as pesticides residues). However, the cost of landfilling is increasing by £3 per tonne per year due to the landfill tax. The cost of landfilling loose plastic waste varies throughout the UK but typically in the North West it was £35 per tonne in July 2004 (if waste is delivered by the waste producer to the landfill site). This charge is set to rise by £3 per tonne per year in line with increases in landfill tax. The steady increase in landfill costs is designed to dissuade waste producers from choosing this disposal option. Furthermore, some types of plastic waste streams are hazardous and are forbidden from all but a few landfill sites. It is possible that the option of landfilling any plastic polymer will be prohibited in the future.

7.3.2 Energy from waste (EfW)

Incinerating mixed plastic waste in order to generate energy (in the form of heat and power) is a disposal route employed in some EU countries. Plastic waste from agriculture and horticulture could be used as feedstock in EfW plants through incorporation with other industrial and municipal feedstocks. The absence of PVC or PU plastic would be an advantage. The calorific value of plastic is equivalent to coal, producing a significant amount of energy per tonne. However, most EfW facilities are built to accept waste within a specific limited band of calorific values (CV) usually based on the local municipal wastes. Waste with a higher CV can cause operating difficulties, and plastic wastes from agriculture would need to be mixed with other feedstocks to avoid these problems.

This option would offer several benefits to farmers: the waste would not require segregation, and the EfW plant could tolerate significant contamination. There would be a gate fee, and although this would be lower than the landfilling costs, it would still be significant. However, this disposal route is not popular in the UK and only a few EfW sites are currently approved to take plastic waste. These plants are expensive to set up, not least because of the expensive measures needed to control exhaust gas emissions. Planning permission is difficult to obtain. It is therefore unlikely that this option would provide a recycling market in the short term.

The harnessed energy could also be used in cement production. Again, there is a gate fee, but this could be less than the landfill equivalent. However, this approach has the same disadvantages as EfW.

7.3.3 Pyrolysis

Pyrolysis is a process whereby shredded plastic waste is heated in the absence of oxygen. This breaks it down into shorter carbon chains. With the correct conditions, a yield of one litre of low sulphur diesel can be derived from 1 kg of agricultural plastic. The main advantage of this process is that there is no requirement to segregate the polymer types, and it can tolerate relatively high contamination levels. The capital cost of the plant is significant and, to date, there are no facilities in the UK to carry out this process on a large scale. One quotation for a pyrolysis facility capable of treating at least 4,000 tonnes per year has been given as £2 million.[41] Converting waste plastic to diesel could open up the prospect of using it directly as a fuel for vehicles or electricity generation. It also allows the possibility of use as a raw material for producing more farm plastic. In the very long term, this may be the most sustainable option.

7.4 Re-usable plastic

Several plastics serving the agricultural industry are now re-usable. This reduces the supply of plastics to the recycling industry. There have been several recent studies looking at take-back schemes.[42] One such study addressed the potential of re-using HDPE agrochemical containers. The study revealed that the most economic option is to return these containers to suppliers. Most studies concentrate on plastic containers, as these are the easiest plastic waste stream to deal with in such a scheme. It must be noted that currently few recyclers accept these chemical containers, as they often contain hazardous materials. This option for dealing with plastic waste will therefore not have a significant effect on recycling market issues.

7.5 Seasonal variations

Seasonal variations in the production of plastic waste can have an effect on the waste load received by the recycling companies. It must be taken into account when recycling schemes are being planned in order to satisfy any demands for a constant supply throughout the year. The times of year at which different types of plastic become available are listed below:

- Silage film, silage sheet, baler bags, baler twine and net become waste after the winter housing period.
- Horticultural film is removed from crops in early June.

[41] Figure taken from Ozmotech processing plant website, www.ozmotech.com
[42] Ross Dyer study – personal communication.

- Packaging waste from agrochemical containers is produced in spring and autumn. The containers are often stockpiled until field operations are completed before being disposed of.
- Fertiliser and seed bags become waste in spring and autumn during and after drilling and fertiliser top-dressing operations.
- Animal health and miscellaneous packaging are disposed of in small quantities all year round.
- Feed bags are produced as waste all year round but production peaks during the winter livestock-housing period[43].

Recyclers may thus prefer a more constant supply of plastics from another industry sector. Farmers would need to provide a high tonnage of waste to ensure commercial viability for the recycler, as the latter will not be prepared to store waste plastics on their site. Plastics will therefore need to be stored at some point in the supply chain.

Some farmers may wish to store plastic on farms until an annual collection service picks up their plastics. In this case, seasonal variations would not be an important factor. Some recyclers may however insist on a constant rate of materials, for example silage plastic.

7.6 Export

The majority of the plastic waste collected in the UK is currently exported, usually to China or India. These countries have low labour costs, less stringent environmental regulations and low transport costs (due to back-loading of ships bringing in imports). There are several large plastic recycling companies, such as Roydon Industries, which annually export large quantities of plastic waste.

However, although China is currently the biggest importer of plastic waste in the world, its Government is starting to regulate the industry. From September 2004, there will be a requirement to register with a Chinese agency prior to export. This agency will have the power to set up controls to restrict imports of plastic waste (including agricultural plastic). It is therefore expected that this option will no longer be available in the long term. The issue of exporting contaminants, together with the risk of spreading disease, is likely to restrict further the export of unwashed material.

7.7 Capacity

At present, there is limited recycling capacity in the UK to deal with plastics. It has been estimated that an increase of 135% in recycling capacity is required to deal with plastic

[43] Biffaward (2003) *Agricultural Waste Mass Balance: Opportunities for recycling and producing energy from waste technologies.*

waste produced. [44] Therefore it is likely, in the short term, that there will be an excess of plastic waste supply in the UK.

However, impending waste legislation will force the industry to find new disposal routes for wastes which will be diverted from landfills. The Government favours recycling over other disposal routes.

7.8 Legislation

The introduction of the End of Life Vehicle Directive (ELV) and the Waste Electrical and Electronic Equipment Directive (WEEE) will increase the supply of waste plastics for recycling, thereby reducing the demand for the recycled plastic products. The significant increase in the collection of plastic waste is not being matched by a corresponding increase in processing capability. Recyclers may prefer to recycle ELV and WEEE plastics as they are less contaminated. However, ELV and WEEE plastics require more pre-treatment, increasing the cost of recycling compared to agricultural plastics. This is because WEEE and ELV materials consist of a wide range of polymers, such as polypropylene (PP), polyethylene (PE), expanded polystyrene (EPS), polyvinyl chloride (PVC), polyurethane (PU), polyamide (PA), polycarbonate (PC), acrylonitrile butadiene styrene (ABS) and high impact polystyrene (HIPS) – see Appendix 2. A high investment in separation equipment is required to segregate ELV and WEEE plastics.

Some plastic waste streams will be considered hazardous waste once the new Agricultural Waste Regulations come into force. These plastics will subsequently be covered by the Hazardous Waste Regulations 2005. Disposal routes under these Regulations are limited. For example, some agricultural waste plastic waste streams will need to be treated before being landfilled (although they do not need to be treated before recovery)

There are however several waste disposal regulations which have the potential to increase the attractiveness of recycling to farmers. Increasing landfill costs, coupled with the impending agricultural waste regulations, both discourage landfill disposal. The Producer Responsibility Obligations promote recycling as this is a better environmental option than landfilling. Furthermore, there are stringent requirements for incineration plants, following the recent introduction of the Waste Incineration Directive. These requirements (and the need for planning permission) act as a barrier for the opening of new incineration plants. There are few incineration plants in the UK at present, so they do not create much competition with recycling. However, the PPC Regulations cover all large waste treatment plants, including recyclers. For example, they apply to plants recovering hazardous waste with a capacity of more than ten tonnes per day using specified techniques. Unless grants are provided, the cost implications of these regulations (for

[44] As reported by Mr Mark Burstall (Chairman of the Bristish Plastics Federation Recycling Council) at the Plastics Conference 2004.

example applying for and maintaining a permit) may discourage the operation of existing and new recycling plants.

It can therefore be seen that legislation will impact on the feasibility of recycling. Financial mechanisms must be implemented to promote recycling and secure recycled agricultural plastic markets.

7.9 Contamination

Waste agricultural and horticultural plastics pick up significant quantities of contamination during their use. For example, more than 60% of the weight of waste silage wraps (LLDPE) can be attributed to contamination. Contamination comes in various forms: water and inorganic matter are found in the highest proportions. These have no value to the recycler and add to the cost of recycling in terms of the weight of plastic to be transported and for certain pre-treatments.

The demand for agricultural and horticultural waste plastics as a feedstock to a recycling process is influenced by contamination. A significant number of recyclers are wary of taking this material simply because of the contamination levels and the knock-on effect this has on the cost of recycling (see Section 5).

Those recyclers who do take agricultural waste plastics as a feedstock are often only able to make a lower grade product (for example wood substitutes). This is because contaminants affect the properties of the finished product.

However, it is possible to influence the levels of contamination on waste plastics by raising the awareness of farmers and growers. Most contamination of the waste plastic is picked up during storage. A previous study has shown that when farmers follow a protocol setting out how the waste plastic should be stored, contamination levels are significantly reduced.[45]

If recyclers were to set their own criteria for waste plastic and provide guidance to suppliers, contamination levels might be controlled to an acceptable level. If recyclers could be confident that contamination levels can be kept within acceptable limits, discussions with recyclers indicated that the demand for waste agricultural plastics could increase.

[45] ADAS (2002) Research into sustainable options for the recycling of agricultural plastics, WA0809.

8. WASTE PLASTIC COLLECTION SCHEMES

8.1 Previous collection schemes in the UK

The potential to recycle farm film in the UK was first discussed in the late 1980s. However, at that time, the costs associated with collection and transport to the recycling plant were prohibitive. British Polythene Industries (BPI), a manufacturer of plastic film in Dumfries, recognised the marketing benefits of offering a plastics recovery scheme and invested in a recycling plant in Scotland. The scheme collapsed in 1992 due to a slump in the plastics market. The plant is still open however and, to remain economic, the plant receives agricultural film from other European countries as well as from the UK.

The Farm Film Producers Group established the first national collection and recycling scheme for waste silage plastics in 1994. Local agents were paid £80 per tonne to collect plastics from farms and transport them to the BPI plant. This scheme collapsed in 1997 because a levy could not be enforced due to the import of plastic materials and the prominence of free riders. There has been no nationally co-ordinated scheme since.

There are a few agricultural waste plastic schemes currently operating in England and Wales (discussed in Section 8.2). A scheme in Scotland collects film from approximately 2,500 farms in Dumfries and Galway. The scheme is sponsored by the landfill tax credit scheme and the waste plastic is recycled at the BPI plant.

8.2 Existing collection schemes in England and Wales

Five current agricultural plastics collection and recycling schemes have been identified, namely: Cumbria Farm Plastic Recycling Scheme, Second Life Plastics Wales, Gloucestershire FWAG Scheme, a Lancashire scheme and a scheme based near Scarborough. A pilot scheme has also been carried out in Somerset. The people responsible for the schemes were contacted to obtain information on the economics of these schemes. Most of these rely or have relied on external funding to supplement running costs. These collection/recycling schemes are described below.

8.2.1 Cumbria Farm Plastics Recycling Scheme

This scheme collects silage, bale wrap and bags (excluding outer fertiliser bags), but does not deal with plastic string. Farmers are encouraged to keep their plastic waste as clean as possible. Collections take place three times a year at up to twenty collection sites throughout the region. Half of the agricultural waste plastic goes to Solway and the rest is transported to the BPI site in Dumfries, Scotland.

This scheme runs at a cost of approximately £100 per tonne, which also covers the £40 per tonne gate fee. A single contractor collects all the waste plastic and charges £24 per tonne (excluding haulage costs).

About 80% of funding (or £30,000) originates from landfill tax grants. Another source of money is the rural enterprise scheme sponsored by DEFRA, but this funding stopped in June 2004. Other support comes from Cumbria Waste Management, Environment Trust, Fells & Dales Leader II Programme, Lake District National Park Authority (LDNPA), Farm and Wildlife Advisory Group (FWAG), South Lakeland District Council, Environment Agency, Carlisle City Council, The National Trust, Eden District Council, The NFU Cumbria Farm Link, and Bampton Recycling Scheme. Financial assistance received in 2003 included Cumbria Waste Management Environment Trust (£25,000), Environment Agency (£2,000), Lake District National Park Authority (£3,000) and Cumbria County Council (£4,513).[46]

Farmers pay on average £18 per tonne of plastic collected, although this contribution depends on the amount of plastic produced. In spring 2003, 204 farmers took part in collections from 15 sites. Their contributions totalled £4,918 (approximately £17.44 per tonne for the 282 tonnes collected).

8.2.2 Second Life Plastic Wales

This scheme collects silage sheet and wrap, feed bags and half-tonne fertiliser bags liners. The waste is baled in Llandeilo and transported to the BPI plant in Dumfries. The scheme has not received any funding since June 2002, although initially it was funded as a three-year project under EU Objective 5B. There is no gate fee for the agricultural waste plastic at BPI and the total cost of operating the scheme is about £114 per tonne[47]. The scheme has collected 9,000 tonnes of plastic from 18,000 farms in Wales in 2.5 years.

Farmers pay approximately £85 plus VAT per tonne for the collection of their waste plastic – the minimum collection is half a tonne. The less contaminated the plastic, the lower the cost to farmers. This encourages farmers to keep their plastics clean. The cost to farmers is also dependent on the distance travelled to the farm.

8.2.3 The Gloucestershire FWAG Recycling Scheme

A new scheme has been developed by the Farm and Wildlife Advisory Group (FWAG) in Gloucestershire to collect black plastic stretch wrap and clamp silage plastic cover sheets from farms. The plastic is collected from farms using a refuse collection vehicle and then taken to Plasmega's recycling plant (located at Sharpness Docks, also in Gloucestershire).

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[46] Cumbria FWAG newsletter.
[47] Taken from ADAS's report on pre-feasibility contract with NWDA, recycling of waste plastic from rural industries in the North West, December 2003.

The scheme receives funding from the Environment Agency and the Gloucester Waste Action Trust (GWAT). The GWAT funding relies on landfill tax money. A special arrangement has been set up with Plasmega so that there is no gate fee for this agricultural waste plastic. There is a cost of £260 plus VAT to a Service Team who collect plastic waste from farms. There is also a large in-kind contribution from FWAG.

Farmers pay £10 plus VAT to participate in the project and there is a minimum collection amount of one tonne. The cost to farmers is thus heavily subsidised.

8.2.4 Lancashire Farm Plastics Recycling Scheme

This recycling scheme relies on one farmer collecting plastic from other farms twice a year. The collected plastic is then sent to Solway Recycling in Scotland.

The cost of this scheme includes the purchase of bins and liners, gate fees, salaries, transportation costs, licences for transporting waste materials and certification costs. The cost of the gate fee is £60 per tonne. The scheme was subsidised by the Lancashire Environmental Fund, although this source of funding stopped after September 2004.

Farmers pay on average £45 per tonne for their waste plastic. There is also a £10 annual membership fee, which includes certification to the scheme. Farmers pay £2 for a plastic liner in order to store their plastic waste and may opt to buy a recycling bin for £180. The costs of the liners and the recycling bin are both subsidised.

8.2.5. The Scarborough Collection Scheme

Two separate collection schemes are being developed by different local NFU groups. These will both send the collected waste plastic to Econoplas in Scarborough. Econoplas is a recycler that accepts all types of plastic polymers used on farms (PE, PP and EPS). Silage wraps and both inner and outer liners of fertiliser bags are welcomed, but chemical and pesticide containers are not. All plastic types must be dry. Econoplas will not charge a gate fee for these NFU collection schemes, although the company may impose a charge in the future.

Econoplas has received funding from various sources in the past. Most funding has come from several private corporations.

The first collection scheme to provide agricultural waste plastic to Econoplas is being set up by the Northallerton and Teeside NFU. The second collection scheme will be managed by the Whitby and Castleton NFU.

The Northallerton and Teeside scheme is planned for launch in August 2004. Four different types of plastics will be collected: silage wrap, big fertiliser bags, net wrap and shavings bags. Disinfectant containers may also be collected in the future. The scheme will cover a 50-mile radius, although farms further afield may participate in the scheme at an additional cost to cover mileage. No funding has yet been secured but the NFU is still waiting to hear about a Defra grant which would cover 50% of the start-up fee.

Farmers will pay a minimum of £75 per collection. This price will cover the future introduction of a gate fee. Disinfectant containers may be collected at an extra cost of £10. However, the cost of collection will primarily be based on the number of each type of plastic being collected. It is anticipated that farmers will pay twenty-five pence per silage wrap, fifty pence per fertiliser bags, ten pence per shaving bag and five pence per net wrap. Farmers will be asked to fill in a questionnaire detailing the type and quantity of each type of plastic produced. They will also receive a certificate as evidence that they participate in this scheme and therefore comply with relevant environmental issues.

The Whitby and Northallerton NFU are still in the planning stages of a collection/recycling scheme and no grants have yet been finalised. The NFU is hoping that farmers will pay a contribution of £10 per tonne for the collection of waste plastic. It is uncertain when this collection scheme will be up and running.

8.2.6 Somerset Pilot Black Plastic Recycling Scheme

This pilot study was managed by Emma Dyer at Somerset Council. It looked at the feasibility of two different types of collection scheme in the Somerset region.[48] The first scheme consisted of collection at all farms and the second was based around collection points. Both schemes only collected silage sheets and bags, although it is hoped that fertiliser and seed bags will be collected in the future. Farmers were asked to separate all string and netting from the silage plastic. Both schemes sent the plastic waste to Plasmega in Gloucestershire. The study revealed that the second scheme was much more successful. It is anticipated that a collection scheme based around collection points will start in winter 2004.

The study revealed that the cost of collections from every farm was approximately £160 per tonne. The scheme with centralised collection points cost around £110 per tonne. The pilot study was externally funded by the Wybern Environmental Trust but they will not provide any future funding. The County Council is now looking for new localised funding options in order to begin a formal collection scheme.

Other costs included hiring dust carts (local firms charged between £48-£53 per hour) for the first scheme and hiring loaders and labour for the second scheme (approximately £12 per hour). Plasmega charged a gate fee of £30 per tonne. The council also made a substantial in-kind contribution to the project, particularly for the farm to farm collections. Farmers were charged £10 per farm (first scheme) or £10 per load (second scheme) but did not pay any membership fees.

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[48] Report by FWAG, Somerset.

8.3 Recycling schemes in Europe

National schemes have been successful in Ireland, Austria, Denmark, Germany, France and the Netherlands. These included pesticide packaging recycling. All the schemes are based on strong shareholder partnership between Government, manufacturers, distributors and farmers. They also seek to improve farmer awareness. In the pesticide packaging recovery schemes in Belgium and the Netherlands, farmers are charged for non-rinsed packaging.

Several countries have introduced national legislation requiring the manufacturers and importers of agricultural films to collect plastic wastes. In the **Netherlands,** Folined was founded in 1993 as a result of the Dutch Covenant on agricultural films.[49] Three sectors collaborate with this not-for-profit organisation: the producers' association, the recyclers' association and the agricultural board. In 1998, 8,000 tonnes of agricultural and horticultural plastic were collected by Folined. This represented 30% of the quantity generated.

There is also a covenant system in **Norway**. In 1999, Plastetur collected 4,500 tonnes of film waste (70% of the total arisings). Plastetur pays the plastic collectors 175 euros per tonne delivered to the recycler – this is about £100 per tonne. Between 80% and 90% of these collected films are silage films.

In **Italy**, there is national legislation requiring producers and converters of polyethylene products to form a consortium for waste collection and recycling. Under this legislation, farmers are obliged to transfer their waste films to the consortium.

In **Ireland**, participation in the film recovery scheme is a requirement of one of the agri-environment schemes.

In **Denmark**, collection is arranged by the companies from which the suppliers of film and packaged products were originally brought. About 2,000 tonnes of LDPE film are collected, from the consumed amount of about 6,600 tonnes. Packaging waste from the agricultural sector is recovered via municipal waste collection sites.

In **Austria**, two collection schemes have been developed. These deal with agricultural packaging waste. One recovers a certain amount of agricultural packaging via municipal sites; the other uses collection centres operated by private waste companies.

Small-scale, localised schemes for the recovery of silage and/or horticultural films also exist in several EU Member States, including Austria, Belgium, Germany, Portugal, Spain and Sweden. These are generally operated by film manufacturers. In **Andalusia, Spain,** there are at least five plants for recycling horticultural films and a high level of recovery due to substantial quantities of film being used in the area. In **Sweden**, an

[49] A covenant is a self-regulatory agreement between the manufacturing industry and the government. It is based on shared responsibilities for dealing with waste.

agricultural co-operative supplying silage plastics has developed arrangements to recover packaging and plastic films in some regions, both collecting from farms and using collection points on the co-operative's premises.

8.4 Non-European schemes

There are recycling programmes and initiatives underway in the **United States** and **Canada** for handling most types of plastic used in agriculture. There is a nationwide industry-sponsored network for collecting HDPE pesticide containers. An industry-sponsored programme based in Ontario collects, pays for and re-processes polystyrene-protected cropping flats and trays. There is also an LDPE greenhouse and protected cropping film collection programme in **New Jersey.** An initiative in Connecticut is to develop an industry co-operative for the collection of LDPE greenhouse films under the auspices of the Connecticut Agricultural and Business Cluster. A plastic wood recycling technology based in **Prince Edward Island, Canada** can handle "dirty" LDPE plastics used in dairying.

In **Victoria, Australia,** the Silage and Mulch Film Task Force was formed in 1997 to explore recycling options for post-consumer agricultural films. Two successful collection trials for silage film have been conducted to collect and transport film for recycling into a useful product.

9. DISTRIBUTION OF PLASTIC WASTE ARISINGS, EXISTING AND POTENTIAL RECYCLERS

9.1 Methodology

The weights of plastics, by type, were defined in Section 4.4 in terms of kilograms per animal or kilograms per hectare. Appendix 3 sets out the methodology used to estimate the plastic arisings by animal / per hectare. Several sources of published information were used and have been listed in this Appendix. Using the holding level agricultural census data for England (2000) and the ADAS 1 km^2 agricultural census for Wales (2000), these weights were applied to the relevant agricultural census categories, as shown in Table 9.1 below.

Table 9.1: Plastic products identified and the agricultural census categories used.

Plastic product	Agricultural census category
Fertiliser bags (kg/ha)	
For grass on dairy farms	G1 G2 Dairy farms
For grass on other farms	G1 G2 Other farms
For rough grass	G5
For tillage area	A1 to A27 & A31
For field horticulture area	B99
String / net wrap for straw/hay (kg/animal)	
Upland cattle	K98 upland farms
Lowland cattle	K98 lowland farms
Silage plastic (kg/animal)	
Dairy cows & cattle over 2 years	K1 K2 K4 K7 K9 K11 K13 15
Cattle 1-2 years	K3 K8 K10 K12 K14 K16
Cattle under 1 year	K17-19
Sheep over 1 year (upland)	M1 M4 M7 M9
Sheep over 1 year (lowland)	M1 M4 M7 M9
Silage net wrap / string (kg/animal)	
Dairy cows and cattle over 2 years	K1 K2 K4 K7 K9 K11 K13 K15
Cattle 1-2 years	K3 K8 K10 K12 K14 K16
Cattle over 1 year	K17-19
Sheep over 1 year (upland)	M1 M4 M7 M9
Sheep over 1 year (lowland)	M1 M4 M7 M9
Feed bags (kg/animal)	
Sheep over 1 year – all areas	M1 M4 M7 M9

Plastic product	Agricultural census category
Mulch for field vegetables (kg/ha)	
Early potatoes	A10
Other field vegetables	B99

Mulch, film for soft fruit (kg/ha)	
Strawberries, raspberries, blackcurrants	C5 C6 C7

Upland and lowland areas had to be defined to separate the upland and lowland animals. This was done using the holding level data for England. This allowed the use of main farm types to distinguish between upland and lowland areas. For Wales, individual 1 km^2 main farm types were not available so the area was defined using the moorland line and the total area farmed by each farm type in Wales as a proportion of the total farmed area.

Using the main farm types and the estimates of kg of plastic per hectare per animal, the plastic arisings for England and Wales could be estimated through a series of Microsoft Access queries. This was done by multiplying the area or number of animals represented by each of the categories in Table 9.1 by the estimates of plastic arisings per hectare per animal in Table 4.4 (see Section 4.4). This provided estimates of total plastic arisings per holding in England and per 1 km^2 in Wales. This could then be summarised by relevant spatial units, in this case by county.

Data from Section 5 was used to map existing plastics recyclers by polymer type.

Once the plastic arisings had been estimated, the current collection schemes were overlaid and new collection schemes were identified in areas not already covered. These were weighted towards the higher density plastics regions. Once all the collection schemes were in place, a series of hubs were identified to collect plastics and transfer them to the main collection points.

The total amount of plastic being collected directly by each collection point was then calculated, along with the plastic being collected by each hub (using the assumption that they would collect plastics from the nearest holdings). It was assumed that all hubs would take all their plastic to the nearest collection point, allowing the total amount of plastic going to each collection point to be calculated.

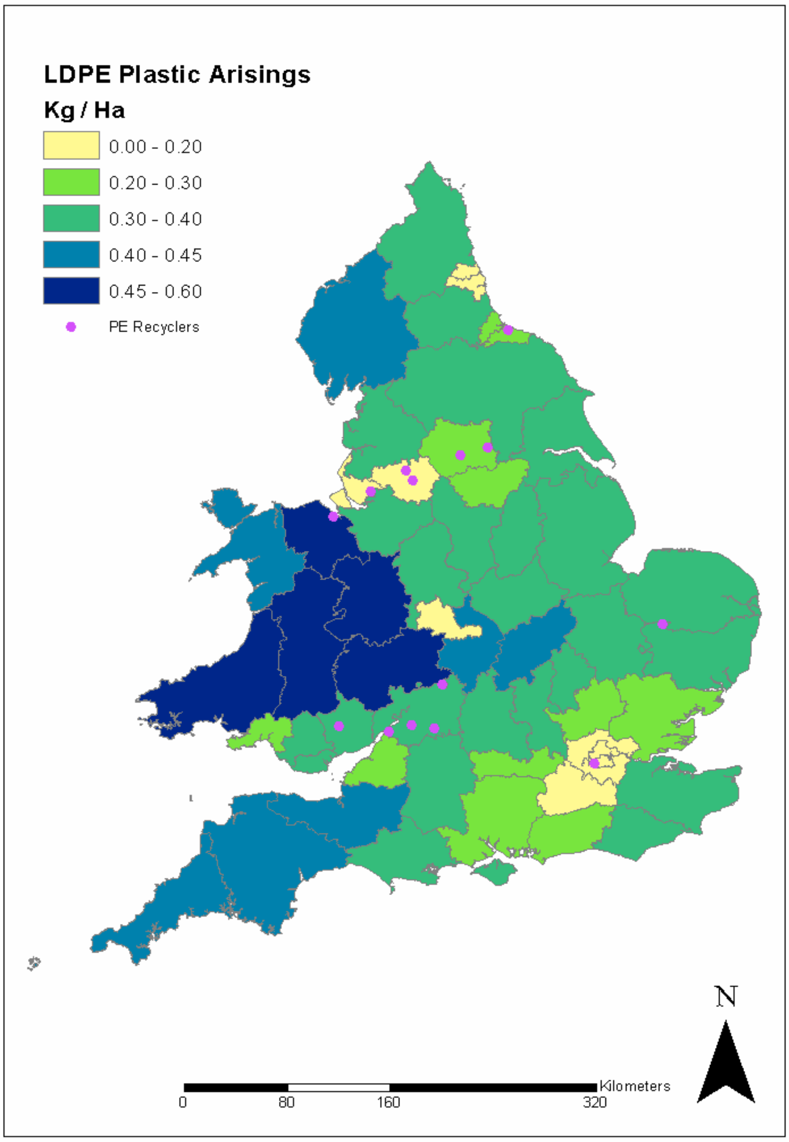
Distances from the collection points to their nearest **three** PE and PP recyclers were then calculated. This allowed an estimate to be made of the average distance travelled from each collection point to the recyclers.

9.2 County waste arisings

County waste plastic arisings were extracted by type. The weight of plastic per hectare of the county was calculated by dividing the total amount of each plastic type by the area of the county. Using kilograms per hectare of plastic provides a density which is a better illustration of arisings than simply presenting totals. This is because larger counties will naturally have greater arisings.

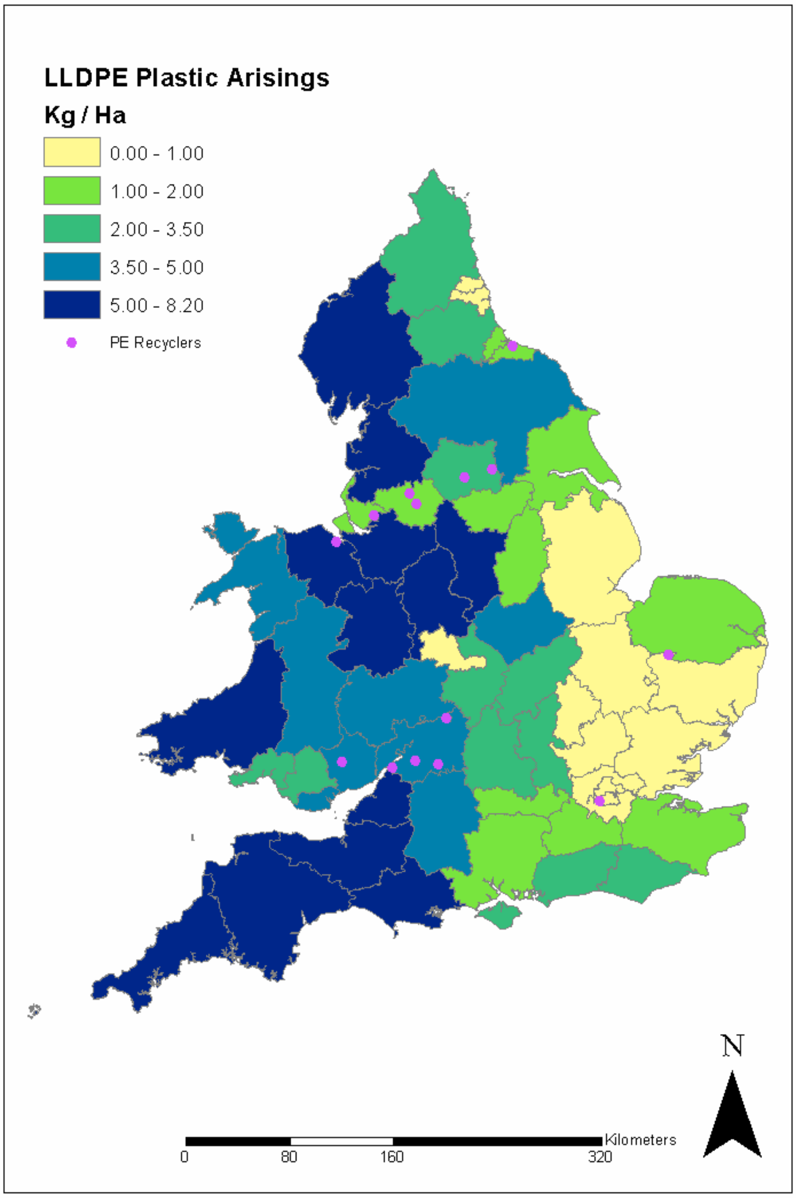
Figures 9.1, 9.2, 9.3 and 9.4 show range of the density of LDPE, LLDPE, HDPE and PP respectively by county. The overall density of all agricultural plastics is presented in Figure 9.5. Tables 9.2 and 9.3 show the total arisings of each plastic type in kilograms by county.

Figure 9.1: LDPE plastic density (kg/ha) by county, including recycler locations.



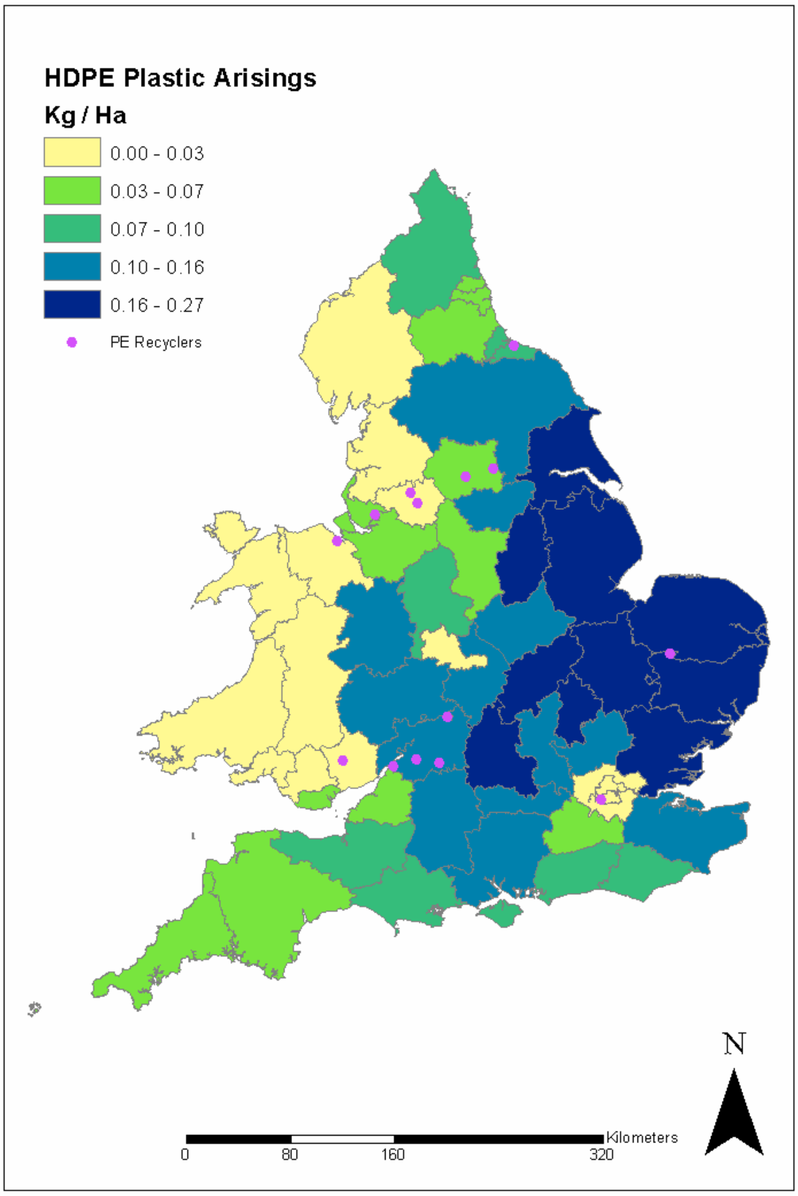
Note: LDPE (low density polyethylene) is normally used as sheeting for silage clamp and horticultural crop covers and polytunnels, small sacks, and the inner lining of bulk fertiliser bags.

Figure 9.2: LLDPE plastic density (kg/ha) by county, including recycler locations.



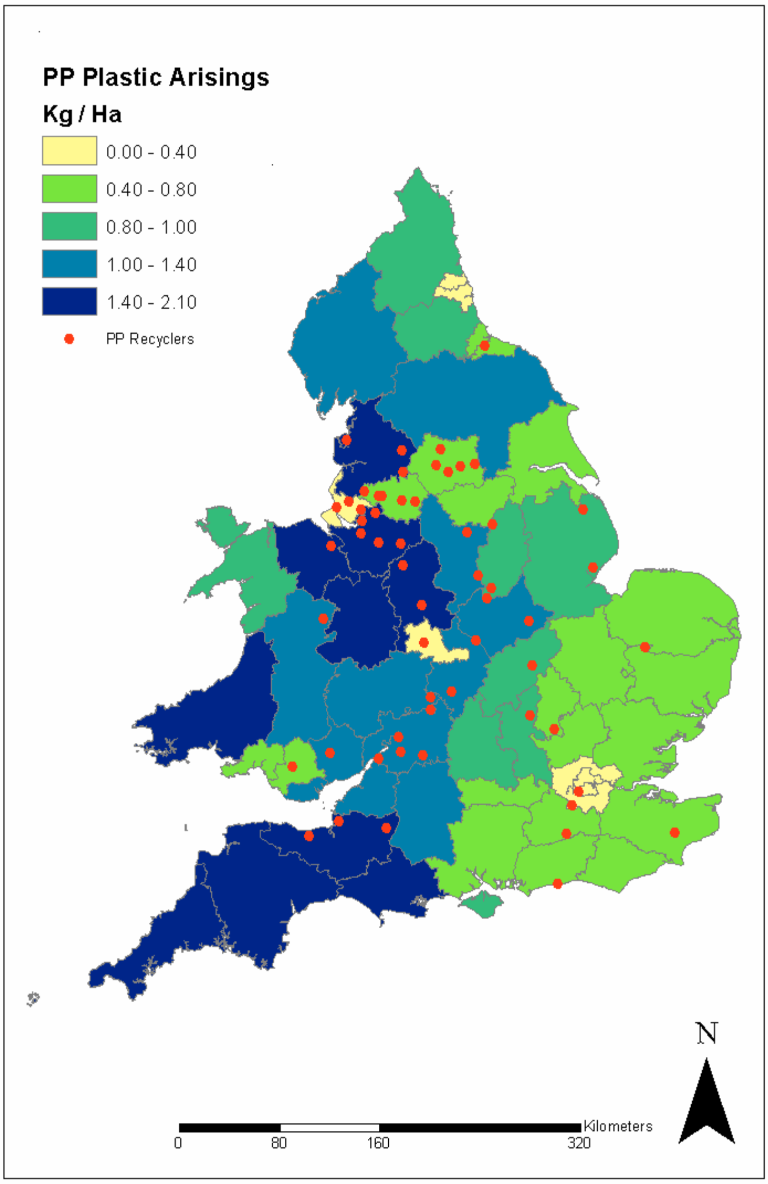
Note: LLDPE (linear low density polyethylene) is mainly used as stretch film for wrapping silage bales and for securing loads on pallets.

Figure 9.3: HDPE plastic density (kg/ha) by county, including recycler locations.



Note: HDPE (high-density polyethylene) is used as containers for liquid materials such as disinfectant, pesticides, etc.

Figure 9.4: PP plastic density (kg/ha) by county, including recycler locations.



Note: PP (polypropylene) is used in the woven outer covers of bulk seed and fertiliser bags, string and netting.

Figure 9.5: Total plastic density (kg/ha) by county, including recycler locations.

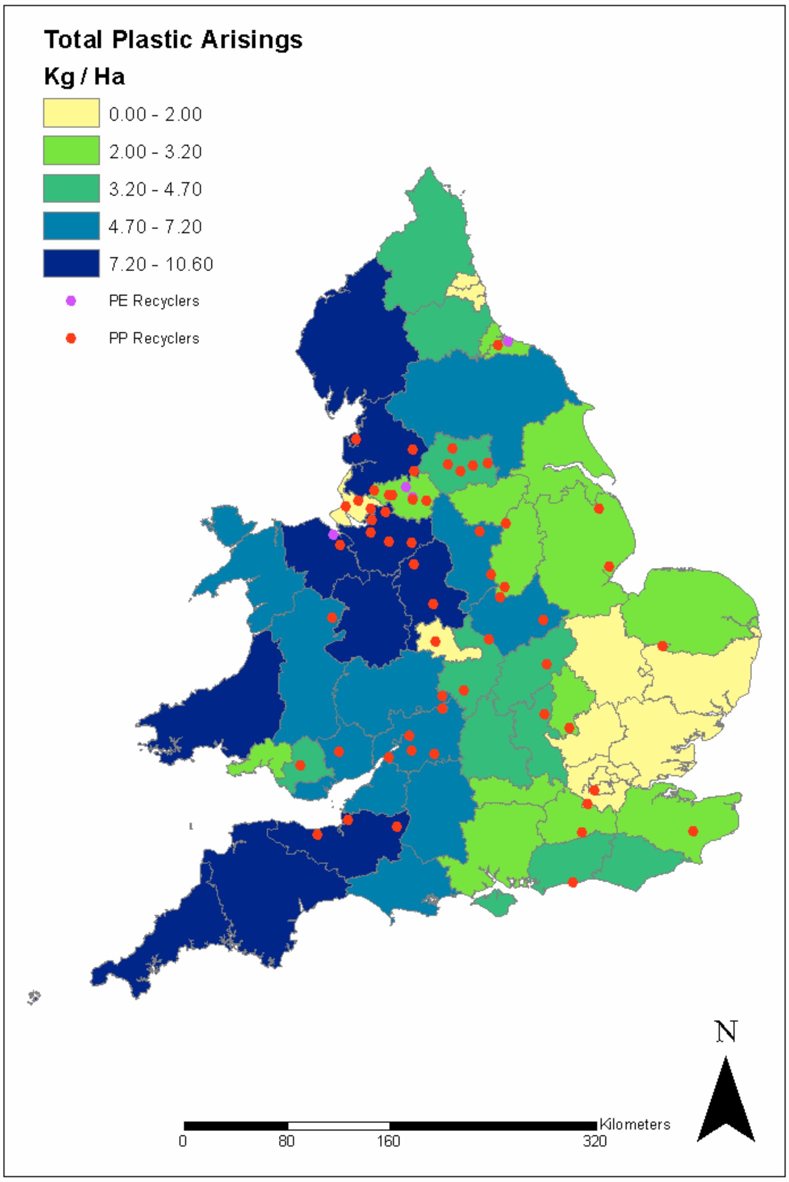


Table 9.2: Plastic arisings (tonnes) by polymer by region in England and Wales.

Government Office Region	PP (t)	LDPE (t)	HDPE (t)	LLDPE (t)	TOTAL (t)
East Midlands	1,561	5,752	295	3,857	11,465
Eastern	1,273	7,145	416	1,503	10,337
London	15	92	2	37	145
North East	685	503	61	2,278	3,527
North West	1,977	1,486	42	8,072	11,577
South East	1,381	4,253	212	3,698	9,543
South West	3,663	2,456	194	13,495	19,808
Wales	2,481	968	26	11,012	14,488
West Midlands	1,744	3,148	144	6,064	11,100
Yorkshire and Humber	1,483	3,289	206	4,401	9,379
TOTALS	**16,262**	**29,092**	**1,599**	**54,416**	**101,369**

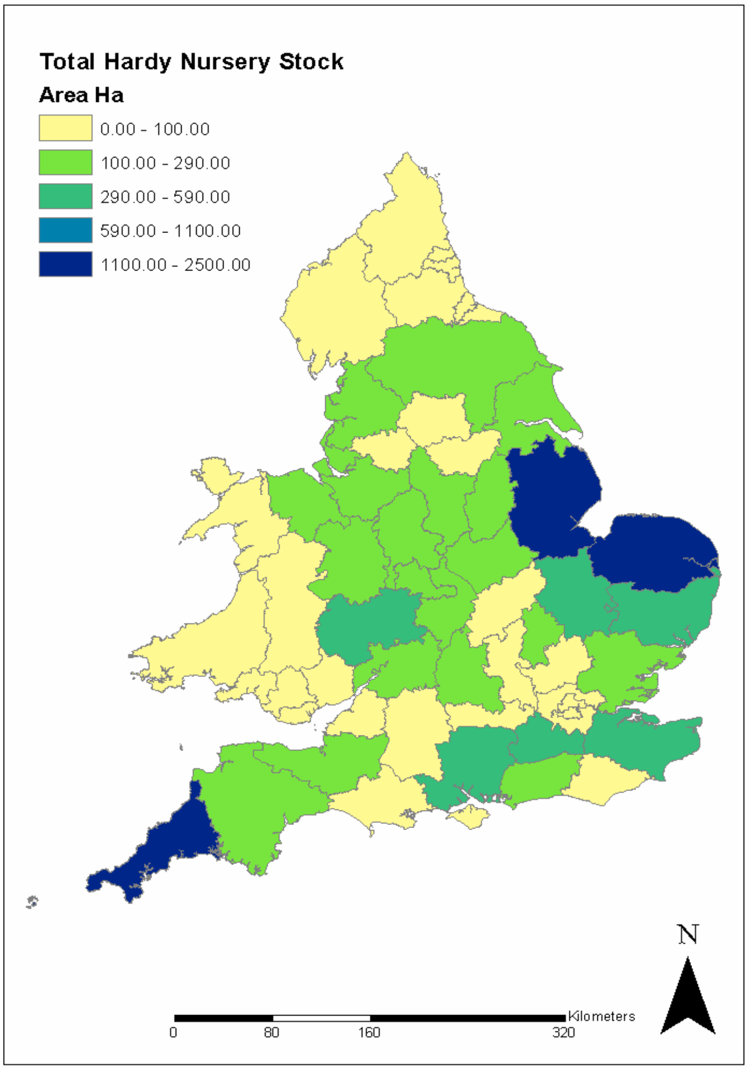
	PP (t)	LDPE (t)	HDPE (t)	LLDPE (t)	TOTAL (t)
England	13,781	28,124	1,572	43,404	86,881
Wales	2,481	968	26	11,012	14,488
TOTALS	**16,262**	**29,092**	**1,599**	**54,416**	**101,369**

The above table is based on county data, calculated to provide information to construct the maps above, which has been aggregated up to regional level. It should be noted that the apparent accuracy of the data may be misleading owing to the small number of farms on which the base data is calculated. However, the authors are confident that the above table provides a good indication of the relative volumes of each of the main polymer arisings produced in the regions.

Horticulture

As discussed in Section 4, large amounts of plastic waste can be generated from mixed protected cropping/horticultural units. However, it has not been possible within the scope of this report to make sensible assessments of the amounts of each type produced. In order to highlight the potential areas where this may be important to plastics arisings, the area of hardy nursery stock throughout the country is shown in Figure 9.6. 'Hardy nursery stock' has been identified because it is the enterprise in the census data that is most closely related to these mixed protected cropping/horticultural units. In the census, it refers to the total area of Christmas trees, perennial herbaceous plants (not cut for flowers), other hardy nursery stock/ mixed areas, and bulbs and flowers grown in the open.

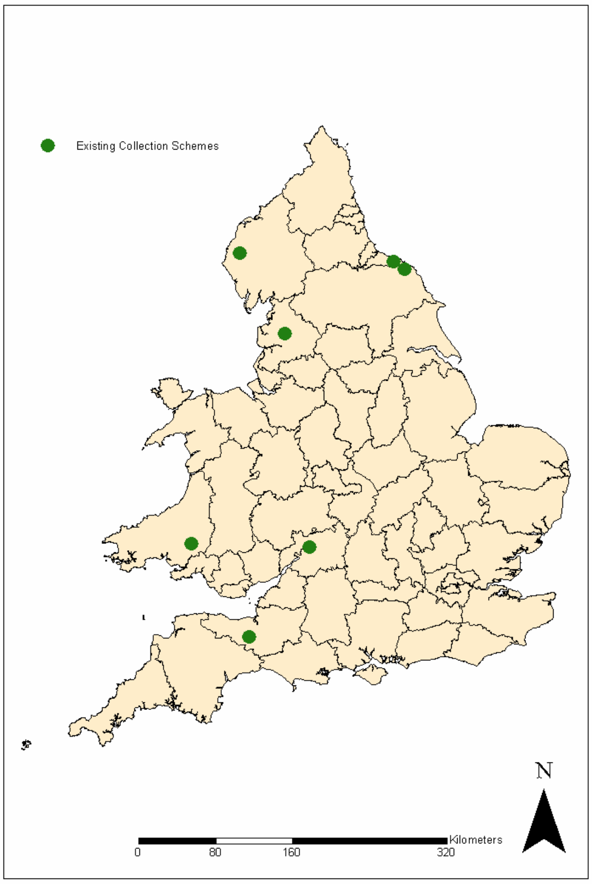
Figure 9.6: Total hardy nursery stock in England and Wales by county.



9.3 Potential collection centres and hubs

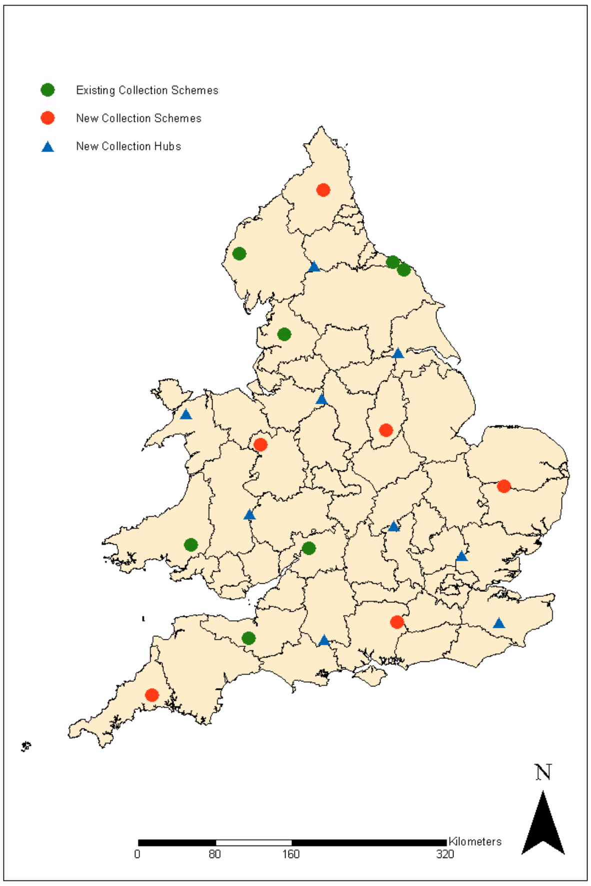
Existing and planned agricultural plastic collection centres operating in the England and Wales were identified and mapped in Figure 9.7 below.

Figure 9.7: Existing agricultural plastics collection schemes.



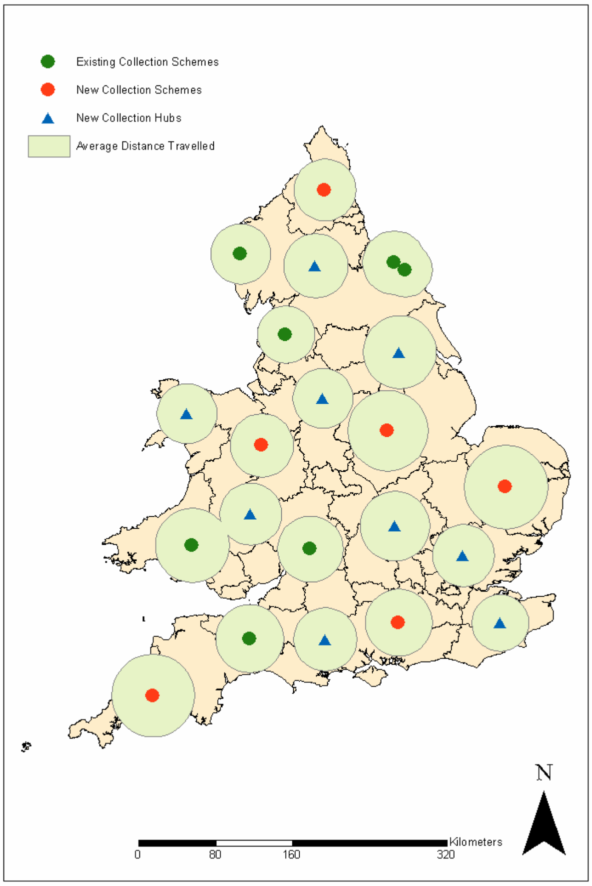
These existing collection centres are clearly not sufficient to collect all agricultural plastic waste. For the purposes of developing a model, further centres have been identified and defined. In areas not sufficiently covered by the distribution of existing and proposed collection centres, a number of collection hubs were identified to supplement the collection schemes. The density of waste plastic generated was also taken into account. Figure 9.8 shows the new collection centres and hubs that were identified, along with existing collection centres.

Figure 9.8: New collection centres and hubs identified, along with existing collection centres.



The final step in determining the location of these collection centres and hubs was to calculate the average distance between each hub, or collection point, in order to collect the waste plastic described by the model. Figure 9.9 illustrates the results of these calculations. These results were then used to assess recycling costs (see Section 10).

Figure 9.9: Average distance travelled from each collection point (or hub) to collect plastics.



10. ECONOMICS OF A NATIONAL COLLECTION SCHEME

10.1 Introduction

The section below proposes a model for a collection network for waste plastics from farms in England and Wales. This model takes into account the three different components of a collection scheme:

- farm to hub or to collection centre (whichever is closer);
- hub to collection centre;
- collection centre to recyclers.

It is just one of a number of possible models for an agricultural waste plastic collection scheme. Further models have been suggested in Section 11.

It should be noted that the costs of the various elements of the collection system have been calculated on the basis of a limited sample of base farm data. While the authors are confident that this is the best estimate with the data available, confidence levels would be strengthened by a larger sample using additional data from other sources.

In total, the model is based on **six main collection centres**, **seven existing collection centres** and a further **nine collection hubs**. Figure 10.1 is a schematic diagram describing a typical collection scheme. Figure 10.2 shows the distribution of proposed collection centres and collection hubs. Hubs have been located in areas not covered by the distribution of existing and proposed collection centres. The sites have been selected according to the density of plastics produced across England and Wales. Hubs and collection centres could be operated either by farmers who have identified an opportunity to diversify or by waste companies looking to set up the service to secure the supply of material. However, the model assumes that all collections will be carried out by a pre-organised scheme and thus will not involve farmers taking their plastics to these hubs or collection points.

Figure 10.1: Schematic diagram of a typical collection scheme.

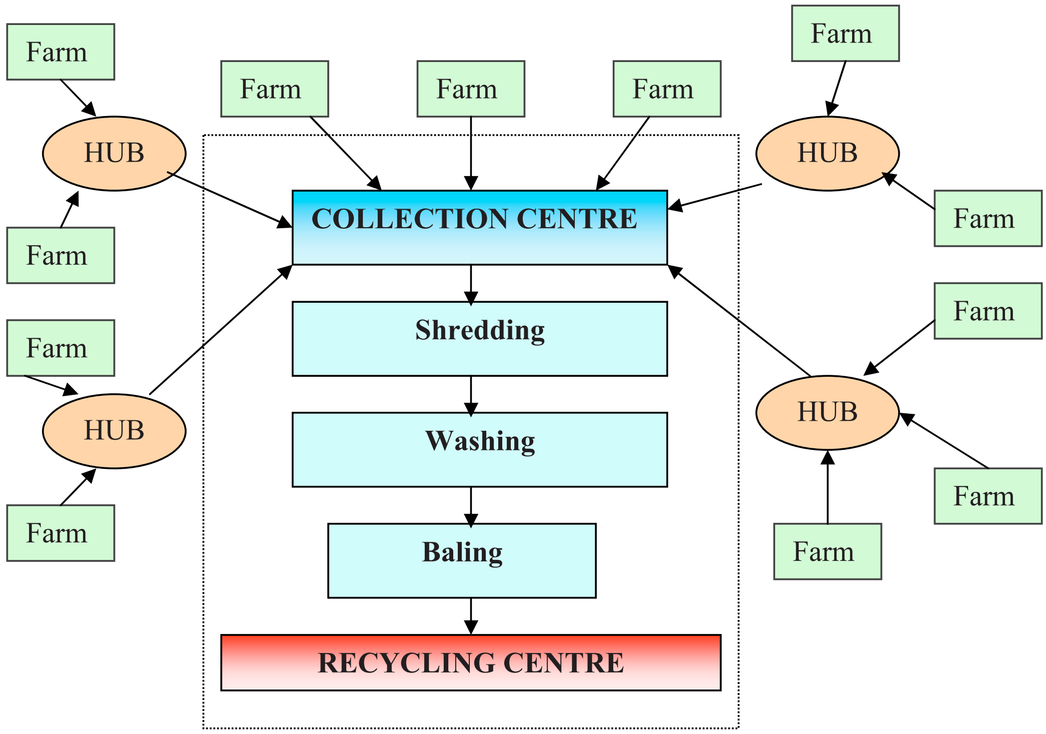
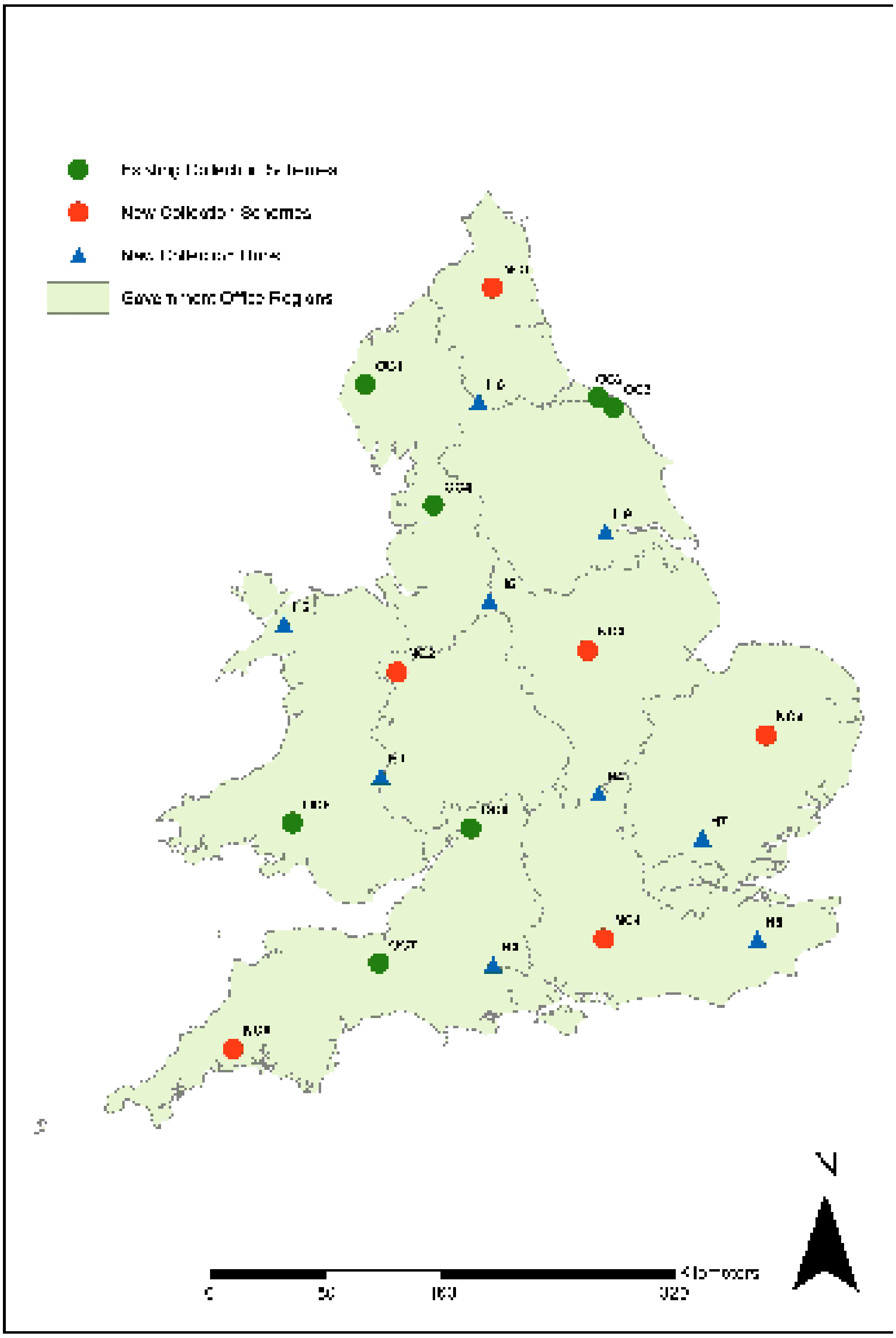


Figure 10.2: Proposed location of collection centres and hubs used in this model.



10.2 Calculations made in the model

The following assumptions were made to derive the economic model for a national network of collection schemes (the assumptions related to the collection of contaminated material from farms):

• Percentage of waste arising to be collected [see note (a)]	80%
• Maximum weight of plastic carried on a trailer pulled by a truck [(b)]	2,000 kg
• Maximum weight of plastic carried on a lorry [(b)]	5,000 kg
• Annual cut-off volume, below which it is not worth running a lorry [(c)]	1,000 tonnes
• Split of total tonnage transported by trailer to a collection centre [(c)]	10%
• Split of total tonnage transported by lorry to a collection centre [(c)]	90%
• Average distance between pick-ups, after arriving at the first farm from the collection centre	5 km
• Pick-ups from each farm per year [(d)]	1

Explanatory notes on the above assumptions:

(a) *In a commercial operation, not all waste can be collected economically. Given the structure of farms in England & Wales, 80% is thought to be a reasonable figure. Also, some of the more remote farms will be inaccessible.*
(b) *It is anticipated that the lorry or trailer will pick up from farms until they are full and then return to base. This may lead to a part load, say 85-90% of capacity. No allowance has been made for this in the calculations.*
(c) *Given the above it is assumed that in the majority of cases (90%) a small lorry will be used for collection. However, for more remote areas or where the pick-ups are small, a trailer pulled by a four-wheel drive vehicle may be used.*
(d) *Pick-ups will be made on a "milk-round" basis. It is assumed that on-farm storage will overcome the need to provide storage capacity at base caused by seasonal variations.*

This particular model assumed that no shredding or washing of plastic is to be undertaken by the collection scheme. The costs of this operation are difficult to assess and are dependent on local conditions, including the availability of water and the treatment and disposal cost of both waste and effluent. A comparison of the value added by sorting, shredding and washing is provided in Figure 10.5 later in this section.

10.3 Estimated costs of a collection service

The estimated costs according to this model are illustrated in Table 10.1 below. This table shows the total cost of the entire process in transporting plastic waste from farms to the recycling centres. It includes the costs of collection, baling, handling and road transport. An allowance has also been calculated for the cost of business overheads.

The cost per tonne varies principally due to the density of plastic in the catchment area and the distance to the recycling centres. The cost of a storage building at the collection centre has been included, but no additional costs have been allocated for on-farm storage prior to the pick-up.

Table 10.1: Total estimated costs of collection, baling, handling and transport.

Hub/Centre	£/tonne
H1*	41
H2	42
H3	42
H4	47
H5	42
H6	42
H7	70
H8	58
H9	52
NC1**	44
NC2	34
NC3	55

Hub/Centre	£/tonne
NC4	62
NC5	47
NC6	58
OC1***	41
OC2	53
OC3	65
OC4	37
OC5	42
OC6	36
OC7	37
Average	**48**

* H = hub, ** NC = new collection centre, *** OC = old collection centre.

The average cost of collection across the proposed collection sites is £48 per tonne (£45 per tonne if weighted by volume). These are **costs**: they do **not include** an anticipated **profit.**

The weighted figures obtained take account of the fact that a greater weight or volume of plastic will be processed via the hubs and centres with lower processing costs. For example, if 1,000 tonnes are transferred via OC3 and 2,000 tonnes come from OC6, the weighted average is calculated as (1,000 * 65) + (2,000 * 36) = £137,000. The weighted cost per tonne when 3,000 tonnes of material are collected and transported is 137,000/3,000 = £45.67. However, the average cost per tonne for the two sites is (65+36)/2 = £50.50.

The range in costs reflects the different efficiency achieved at the different sites. Efficiency is a measure of the volume of plastics processed through each site and the density of plastic waste from farms supplying the collection site. In order to arrive at the above total costs for each site, calculations of the costs for baling, handling and road transport have been made. These are described on the following page.

Baling and handling plastics at the hub or collection centre

The costs of baling plastic using different sizes of baler were calculated, as were the costs of handling bales at the hub or centre. It is assumed that all collection centres and hubs will have baling machinery. Table 10.2 below summarises the economics of a small and larger baler.

Table 10.2: The economics of a small and a large baler.

	Small baler	**Large baler**
Cost of purchase of baler	£3,000	£16,000
Years of life	5	5
Annual ownership costs	£750	£3,625
Processing capacity	2 tonnes/hour	5 tonnes/hour
Materials (wrap, etc) per tonne packed	£1	£1
Running costs (total)	£1,200	£5,525
Running costs per tonne packed	£2	£3.68
Labour costs per hour	£8	£8
Labour costs per tonne	£4	£1.60
Processing costs per tonne	£6.00	£5.28
	Average = £5.64	

Table 10.3 below illustrates the annual costs of using a materials' handler to feed the baler and load lorries with bales. Labour costs (the driver) will be covered in the above costs for the baler, ie the same driver will operate both machines.

Table 10.3: Annual costs of a materials handler.

	For a small baler	For a large baler
Materials handler * (annual ownership costs)	£7,540	£8,740
** Also used to load the baler. Assumes the labour costs will be included in the labour costs for baling.*		

Road haulage

Road haulage costs were also estimated. It must be noted that a proportion of the plastics will have a two-phase transport to the recycling centre. The first stage is transport to a local hub, where plastic will be sorted and packed ready for the second-stage transport to the nearest main collection centre. The road haulage calculations below refer only to the transport of high-density bales.

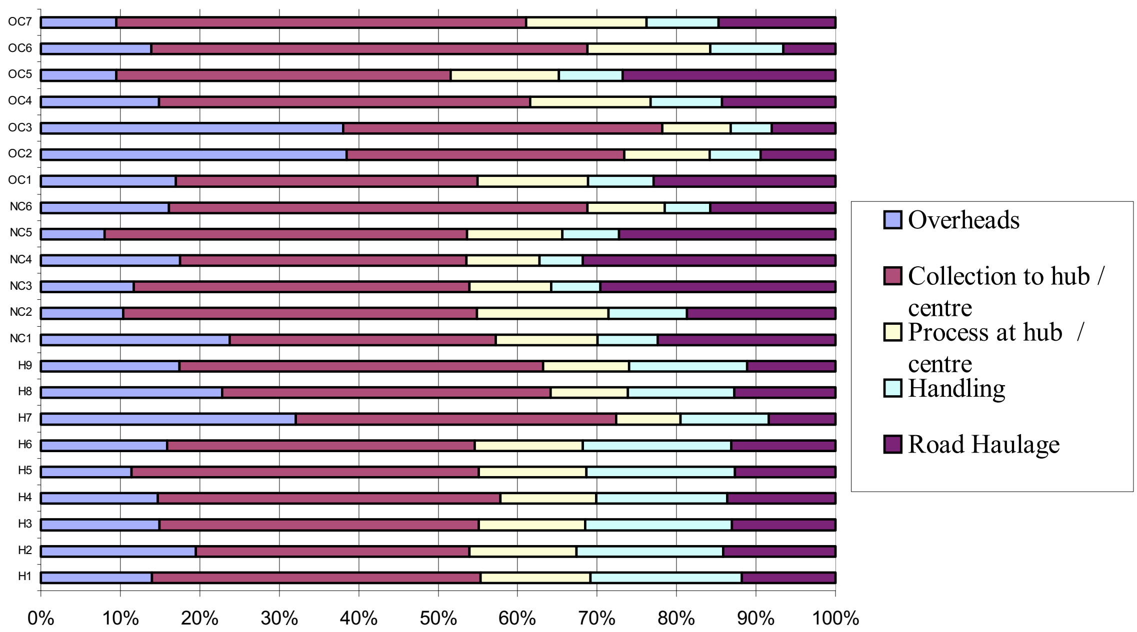
Road haulage assumptions have been based on a goods vehicle operating cost plus 25% profit (source: RHA) and an average load for an articulated lorry of 20 tonnes. These assumptions are summarised in Table 10.4 below. RHA figures assume that back loads will be available. If this is not the case, an increase in costs will result.

Table 10.4: Road haulage costs.

		Transport costs		
		£/km	£/return trip	£/tonne
Average distance from hubs to collection centres	83 km	0.70	116.35	5.82
Average distance from collection centres to PP recyclers	63 km	0.70	88.92	4.45
Average distance from collection centres to PE recyclers	95 km	0.70	133.07	6.65

In summary, Figure 10.3 illustrates the different cost components of the process for the different collection centres. Overall, those sites processing greater volumes of plastics are able to spread overhead costs and processing costs over a larger volume – so reducing the unit costs of collection and processing.

Figure 10.3: Distribution of costs for each collection site.



10.4: Regional difference in plastic collection services

The assessment of the regional costs of plastic collection is based on the location of the collection sites. This is illustrated in Figure 10.4 below. However, the reality is that the collection service and the farmers producing waste plastic have no regard to regional boundaries.

Figure 10.4: Analysis of collection costs by Government Office Region.

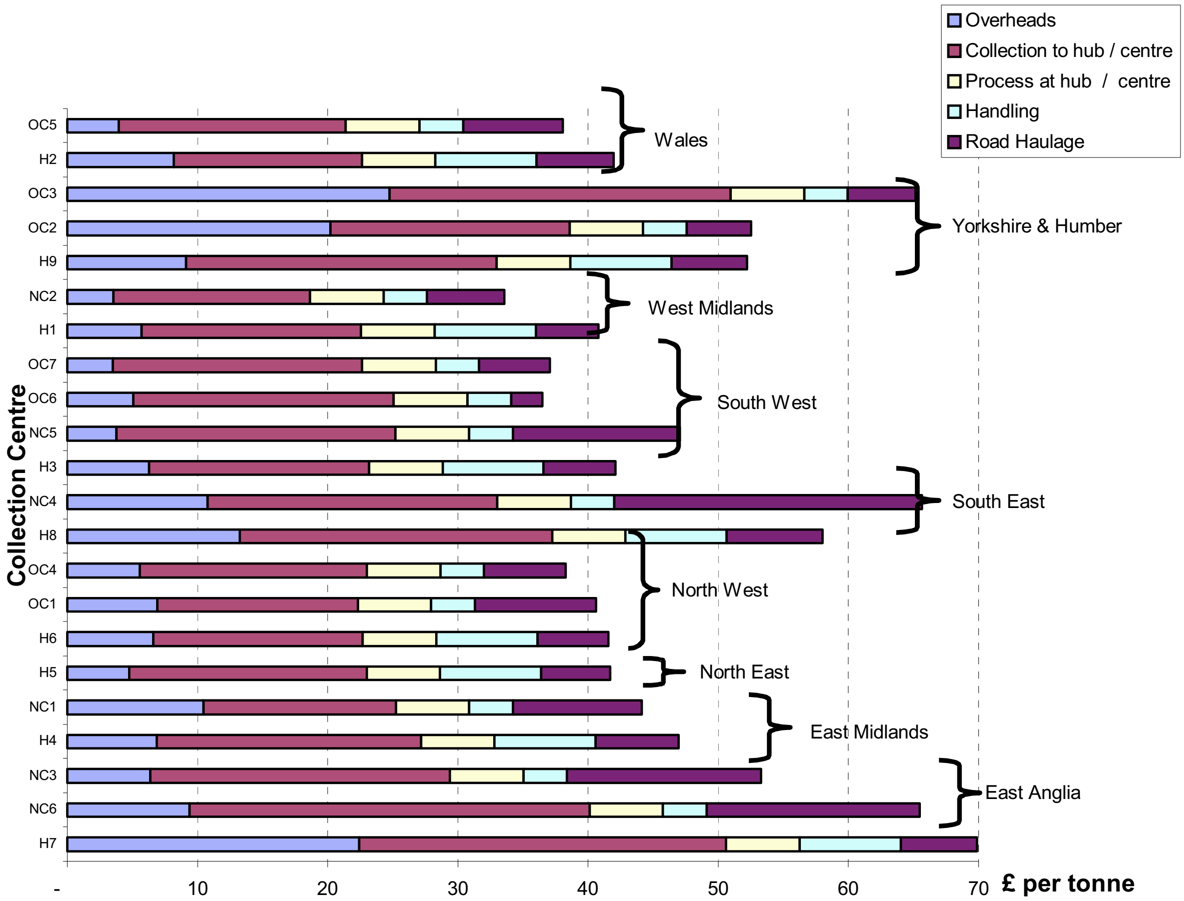


Table 10.5 below summarises the average costs for the regions of England and Wales.

Table 10.5: Average costs of a collection service for agricultural waste per Government Office Region (to the nearest £).

	Overheads (£/tonne)	Collection to hub/centre (£/tonne)	Process at hub/ centre (£/tonne)	Handling (£/tonne)	Road Haulage (£/tonne)	Total* (£/tonne)
East Anglia	13	30	6	5	13	67
East Midlands	7	22	6	5	11	51
North East	10	15	6	3	10	44
North West	6	17	6	6	6	41
South East	12	23	6	5	16	62
South West	5	20	6	4	6	42
West Midlands	4	16	6	5	6	37
Yorks & Humber	15	23	6	6	5	55
Wales	5	17	6	5	7	40
Average	9	20	6	5	9	49

*The overall collection costs are greater in the South East and East Anglia. This is due to the lower density per hectare of plastics in the regions, as compared to the livestock-dominated areas in the West and Wales.

Grant aid under the Defra Rural Enterprise Scheme (RES) could be made available to farm businesses looking to diversify from core farming activity. This would effectively reduce the set-up cost incurred by the farmer.

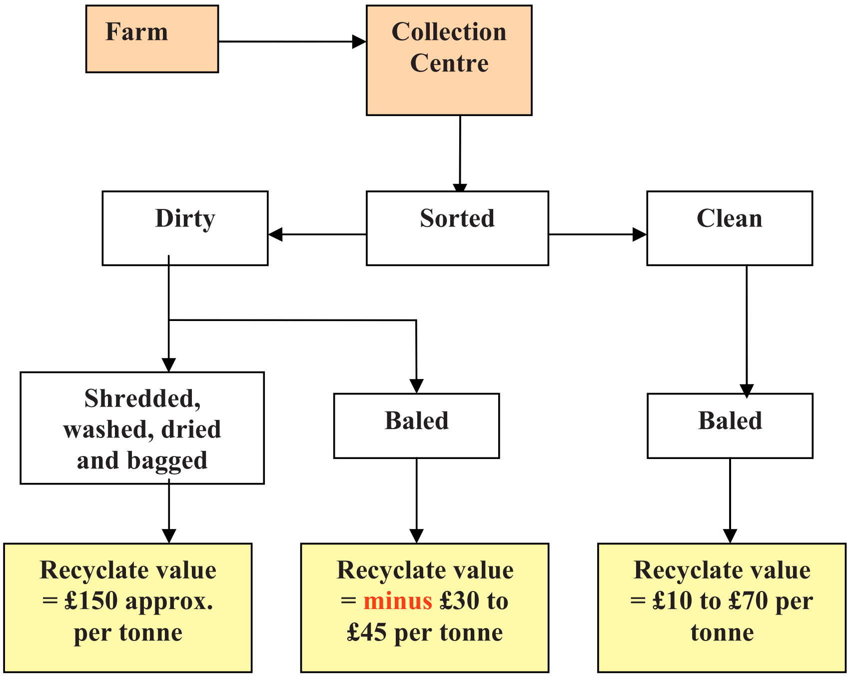
10.5 Gate fees

Gate fees have not been included in the above calculations. However all collection schemes will need to take account of any gate fee charged by their customers.

A gate fee is the fee charged, per tonne, by the recycler on receipt. In most cases the level of gate fee charged is related to the level of contamination in the waste material. The heavier the contamination, the higher the cost of the recycling process and this is passed on to the supplier. It is therefore in the interests of the supplier, or collection organisation, to present the waste material to the recycler in as clean a state as possible and in a form which is readily handled prior to the recycling process.

Gate fees vary considerably from recycler to recycler and from polymer to polymer. They have not been included in the analysis of costs above. Figure 10.5 below shows, from the authors' experience, the range of gate fees which are currently charged for polythene. In some cases, where the plastic is clean and baled or where it has been washed, shredded and bagged, the feedstock has a positive value and the recycler will purchase the material. Currently, however, most agricultural feedstock is heavily contaminated and may attract a gate fee up to £45 per tonne.

Figure 10.5: Value of recyclate at the gate of the recycler.



11. RECOMMENDATIONS FOR FURTHER WORK

- The calculations used in this report are based on a small sample of farms. Therefore, the confidence level in the data presented is low. It is strongly recommended that additional measurements be taken of waste arisings from a much larger sample of farms over a period of at least twelve months.

- Following the collection of additional data, further models may be generated to cover a range of scenarios. For example, one model should assume that there is only 40% take-up by farmers. Models should also be generated assuming that the only recyclers accepting agricultural waste plastic are those already taking such plastic.

- In the past two to three years there has been a significant increase in the use of plastic crop covers for field vegetables and fruit production. Further work should be carried out to assess the total plastic arisings from these horticultural enterprises and to identify the issues for recycling (bearing in mind the type and level of contamination).

- A comparative study on biodegradable versus non-biodegradable agricultural plastics should be undertaken to ascertain the feasibility of moving to the use of some biodegradable polymers instead. It is possible that in the future biodegradable plastics may provide a partial solution to the disposal of agricultural waste plastics.

- The set up and running costs associated with plastic washing and/or shredding facilities should be established.

- There should be an on-line database of recyclers which is specifically aimed at collection schemes for farmers and growers. The database could also include cement works and EfW plants that might take agricultural plastic wastes.

- An in-depth study of the specific requirements of all recyclers should be carried out – to obtain a better understanding of the criteria set by recyclers for agricultural waste plastics.

- There should be an updated list of products which are or could be made from plastic wastes. This could be used by farmers and growers who wish to buy such products. It could also provide ideas for those wishing to manufacture products made locally.

12. CONCLUSIONS

Table 13.1 summarises some of the information gathered for this project. It shows the principle wastes arising by farm type and gives each a recycling rank. It can be seen that the waste plastic with the highest rank is PP, from straw/hay string and netting. Among the lowest ranking polymers are LDPE and LLDPE*. However LLDPE and LDPE are the most significant wastes in terms of tonnages produced and are thus of greatest concern to farmers and growers.

Table 12.1: Summary of information gathered for plastic arisings on farms, and their interest to recyclers.

Farm type	Waste product	Polymer type	Recycling rank	Pre-treatment option[2]	Best collection option[3]	No. of recyclers interested in polymer[4]
Dairy	Fertiliser outer	PP	medium	A, B	3	19
	Fertiliser inner	LDPE	low	A, B	3	9
	Silage cover	LDPE	low	A, B	3	9
	Silage net/string	PP	high	A, B	3	19
Arable	Fertiliser outer	PP	medium	A, B	1	19
	Fertiliser inner	LDPE	low	A, B	1	9
	Seed bags	PP	medium	A, B	1	19
	Agrochemicals	HDPE	low	A, B, C	3	1
Cattle	Fertiliser outer	PP	medium	A, B	1	19
	Fertiliser inner	LDPE	low	A, B	1	9
	Silage cover	LLDPE	low	A, B	1	9
	Silage net/string	PP	medium	A, B	1	19
	Straw net/string	PP	high	A, B	1	19
Sheep (Upland)	Feed bags	LDPE	medium	A, B	1	9
	Silage cover	LDPE	low	A, B	1	9
	Silage net/string	PP	medium	A, B	1	19
Sheep (Lowland)	Feed bags	LDPE	medium	A, B	1	9
	Silage cover	LDPE	low	A, B	1	9
	Silage net/string	PP	medium	A, B	1	19
Horticulture	Mulch	LDPE	low	A, B	2	9
	Fertiliser outer	PP	medium	A, B	2	19
	Fertiliser inner	LDPE	low	A, B	2	9
	Seed bags	PP	medium	A, B	2	19
	Agrochemicals	HDPE	low	A, B, C	3	1

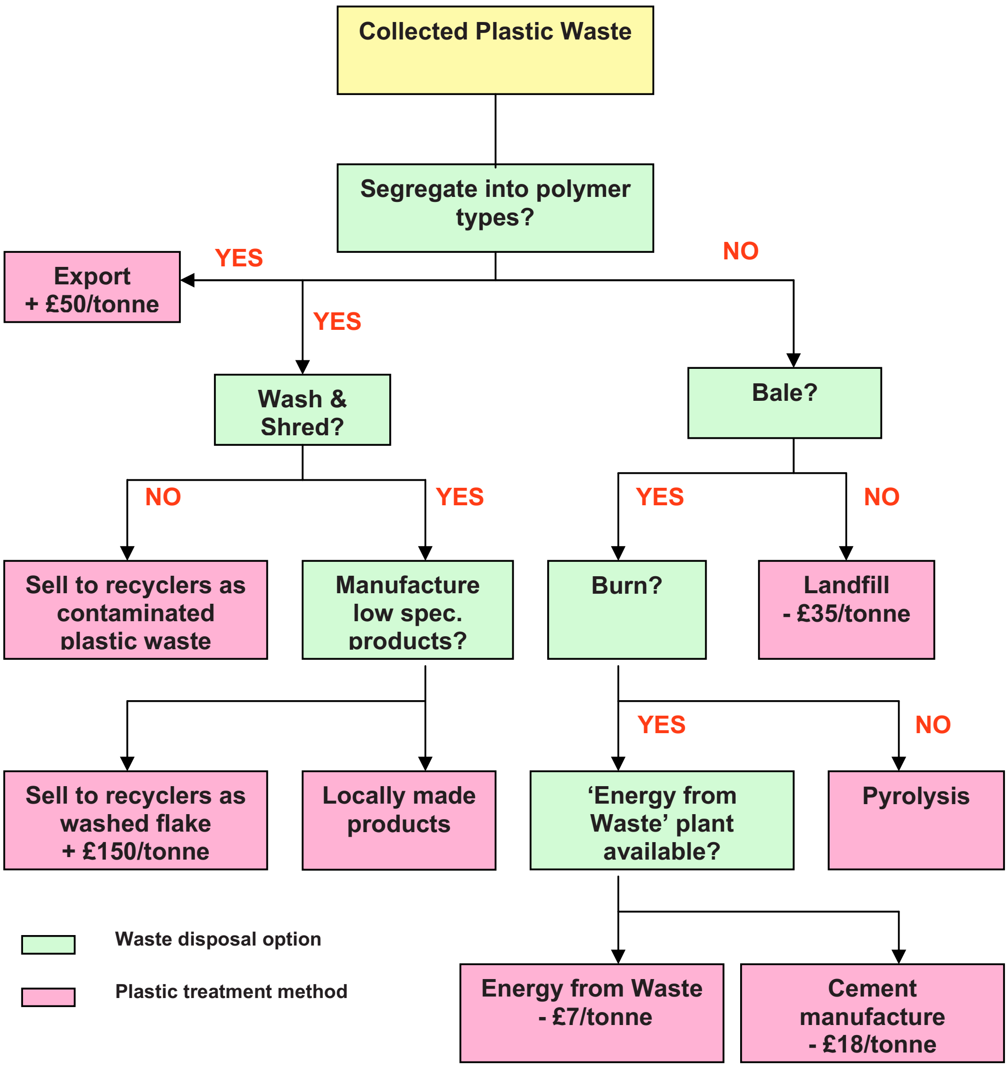
1 Adapted from data in Section 4.
2 Pre-treatment options: A = bale; B = clean; C = shred.
3 Collection options: 1 = hub; 2 = farm-to-farm, adapted loader; 3 = farm-to-farm, refuse collection vehicle.
4 Based on information given in Table 5.1 (see Section 5).

Although this report has focused on recycling agricultural plastic waste, it must be remembered that there are several different waste disposal routes available to individual farmers or growers. These have been summarised in Figure 12.1, which also indicates the cost or value of different options. It should be noted that the values used are based on June 2004 figures and are likely to change with time.

There are many factors that affect the final destination of agricultural plastic waste. For example, there are few disposal routes that can cope with contaminated plastic. Therefore farmers and growers will have few options available for these and the cost of disposal will be high. Neither are there many disposal routes that can deal with different plastic polymers that have not been segregated or with individual polymers that have not been baled. In general, issues such as current and impending legislation, location, tonnage generated and the prevailing supply and demand for the waste will play a role.

Most farmers and growers will prefer the cheapest disposal route. At present, this disposal route for agricultural plastics is export, as it has the highest return per tonne. However, the situation will change in the future as foreign governments enforce stricter regulations relating to the imports of these plastics, reducing the demand for this waste. Should the export of plastics cease both the Energy from Waste option and the cement manufacture option may be considered. The associated gate fees are relatively low, compared with landfill gate fees. The gate fee of recyclers accepting contaminated and/or mixed plastic is higher, as such recyclers will need to invest in washing and shredding facilities. Although in Figure 12.1 the value of washed plastic flake is extremely high, the investment in appropriate machinery, as well as fluctuations in the price for this flake, may not justify this extra cost. Therefore the implications for collection schemes are that they should ensure segregation of polymers and minimal contamination.

Figure 12.1: Decision tree for the disposal of agricultural plastic waste.



Where available, the approximate value (+£) or cost (- £) is shown for the various plastic disposal options.

Recycling Agricultural Waste Plastic

Appendices

List of Appendices

APPENDIX I

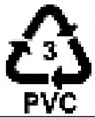
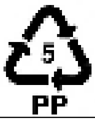
AGRICULTURAL PLASTIC WASTE STREAMS

Types of waste streams found on farms include:

- Packaging plastics:
    - agrochemical packaging, primarily plastic bottles
    - silage bags
    - animal feed bags
    - animal health packaging
    - fertiliser bags
    - oil containers
    - seed bags
    - sheep dip/drench packaging
    - shrink-wrap
- Non-packaging plastic films:
    - silage stretch films (for silage bales)
    - silage sheet films (silage clamp cover)
    - greenhouse and tunnel film
    - mulch film and crop cover
- Other non-packaging plastics:
    - bale twine and net wrap
    - bale twine and net wrap cores
    - mushroom bags
    - seed trays and pots
    - silage wrap cores
    - tree guards
    - plastic International Bulk Containers
    - hoop house covers and row covers

APPENDIX II

CODING SYSTEM DEVELOPED BY ABS TO IDENTIFY PLASTIC POLYMERS

Number	Material	SPI Acronym
	Polyethylene Terephthalate	PET, PETE
	High Density Polyethylene	HDPE
	Polyvinylchloride	V
	Low Density Polyethylene	LDPE
	Polypropylene	PP
	Polystyrene	PS
	All other resins	Others

APPENDIX III

QUESTIONNAIRE USED DURING FARM VISITS

Contact name:……………………………………………….

Name and address of farm: ………………………………..
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………

Postcode: ………………………………………………………
Tel No: ………………………………………………………

1. Size of holding (ac/ha)……………………………..

2. What crops are grown on the farm?

Crop	Area (ha or acres)	Grown under mulch/film?	Other comments

3. What livestock on farm?

Type of livestock	**No.**
Cattle	
Dairy cow	
Dairy heifer replacement	
Suckler cow	
Young cattle (1-2 years)	
Young cattle (less than 1 year)	
Sheep	
Pigs	
Breeding sows (inc piglets to 3.5 weeks)	
Maiden gilt	
Finishers	
Poultry	
Laying hens	
Broilers or broiler breeders	
Other	

4. What types of plastics used on farm?

Type	**Present (✓)**	**Amount**	**Contam. ? High/Med/Low**	**When available?**
A. Packaging plastics.				
Agrochemical packaging, primarily plastic bottles				
Silage bags				
Animal feed bags				
Animal health packaging				
Fertiliser bags				
Oil containers				
Seed bags				
Sheep/drench packs				
Disinfectant containers				
AI containers				
Others				

Type	**Present (✓)**	**Amount**	**Contam. ? H**igh/**M**ed/**L**ow	**When available?**
B. Non-packaging plastics (i) Films				
Silage stretch wrap films				
Silage clamp sheeting				
Greenhouse and tunnel film				
Mulch film and crop cover				
Shrink-wrap				
Others				

Type	**Present (✓)**	**Amount**	**Contam. ?** **H**igh/**M**ed/**L**ow	**When available?**
B. Non-packaging plastics (ii) Other than films:				
Bale twine				
Net wrap				
Net wrap cores				
Mushroom bags				
Silage wrap cores				
Seed trays & pots				
Tree guards				
Plastic IBC				
Hoop house covers & row covers				
Others				

5. **How much do you buy per year of the following? (as a double check)**

Fertiliser – in 50 kg bags	
Fertiliser – in 1 ton bags	
Fertiliser – in other bags	
Seed	
Silage wrap	
Silage clamp plastic sheet	
Net wrap	
Bailer twine	
Agrochemical containers	
Animal feed	

6. **How do you currently dispose of your plastic wastes?**

7. **How much do these plastic waste disposal methods cost?**

8. Would you pay towards a disposal/recycling scheme?

9. Are there any procedures in place on your farm to reduce the quantities of contaminants attached to the plastic waste?

10. Have you ever participated in a waste plastic collection/recycling scheme? If yes, was this scheme successful? If not, why not?

APPENDIX IV

ASSUMPTIONS USED TO CALCULATE UNIT WEIGHTS OF DIFFERENT AGRICULTURAL WASTE PLASTICS

1. Fertiliser Bags

The Survey of Fertiliser Practice (SFP) 2002 gives various statistics on fertiliser use from autumn 2001 to autumn 2002. These statistics provided information on the total tonnage of fertilisers bought by all farms and horticultural enterprises in England and Wales during that period. The total tonnage of fertiliser use was 3,721,000 tonnes.

Tillage crops (all crops except grass, forestry, glasshouse crops and set-aside) account for 64.1% of these 3,721,000 tonnes, or 2,385,161 tonnes. As the total tillage area is 4,552,000 ha, then 1 ha of tillage land uses 2,385,161 / 4,552,000 = 0.52 tonnes of fertiliser. Although it is clear that different crops receive different amounts of fertiliser, it is not feasible to deduce the quantities of fertiliser applied to the different crops. Thus it is assumed that all tillage crops will receive the same amount of fertiliser.

Grass crops (all grass except rough grazing) accounts for 35.9% of total fertiliser usage (3,721,000 tonnes), or 1,335,830 tonnes. As the total grass area is 5,808,000 ha, 1 ha of grass uses 1,335,830 / 5,808,000 = 0.23 tonnes fertiliser. However different farm types apply different amounts of fertiliser annually on their grass crops, as is illustrated in Table 1 below:

Table 1: Estimated amounts of different fertilisers used on different farms.

Type of holding	Amount and types of fertiliser used
Dairy	140 N; 22 P_2O_5; 37 K_2O
Beef/sheep	52 N; 16 P_2O_5; 17 K_2O
Other farms	80-90 N; 16 P_2O_5; 22 K_2O

It can therefore be seen that less fertiliser is used on beef/sheep farms and general mixed farms than on dairy farms. Furthermore, the SFP data does not show the tonnages used for grass on different farm types. An assumption was therefore made for these tonnages: 0.40 tonnes/ha on dairy farms; 0.15 tonnes/ha on beef/sheep farms and mixed livestock/cropping farms; and no fertiliser on rough grass.

A further assumption is that all fertiliser is supplied as 500 kg bags. The weights of the outer bag and inner bag are 0.62 kg and 0.45 kg respectively. Table 2 summarises the assumed weights of annual fertiliser bag arisings.

Table 2: Weights of fertiliser bags required by different crops.

	Outer bag (PP)	Inner liner (LDPE)
Tillage (arable & outdoor vegetables/salad)	645 g/ha	468 g/ha
Dairy grass	500 g/ha	360 g/ha
Other grass (except rough grass)	186 g/ha	135 g/ha
Rough grass	Nil	Nil

2. Seed bags

Much seed is stored in paper bags (for instance all maize seed). Grass seed is also mainly supplied in paper bags, although a small amount is supplied in plastic bags. However, an increasing amount of combinable crops seed (such as cereals and rape) is supplied in 0.5 tonne polypropylene bags. Using weighed samples from the farms, the average weight of such bags is 0.2 kg/ha. It is assumed that this figure is constant for all tillage crops.

3. Silage plastic, net wrap and string – cattle

Silage plastic, net wrap and twine weights were calculated using livestock numbers. Table 3 illustrates the amount of silage eaten by one animal over a 6-month housing period.

Table 3: Amount of silage eaten by one animal over a 6-month housing period.

Dairy cows & cattle over 2 years:	1.25 t per month x 6 = 7.5 tonnes
Cattle 1-2 years:	1.0 t per month x 6 = 6.0 tonnes
Cattle under 1 year:	0.5 t per month x 6 = 3.0 tonnes

Other assumptions were also made for silage plastic, net wrap and twine:

- One silage bale contains 400 kg silage.
- 33% of silage is wrapped, with the rest being placed in clamp.
- The wrap around one silage bale will weigh 1.5 kg.
- The amount of plastic clamp cover is 60 g/tonne (estimated from two farms visited during the project) and clamp plastic will weigh 100 g/m^2.
- The bale will have a covering either of string or net wrap (both made from PP), with an average weight of 0.2 kg.

On this basis, the following weights of silage plastic and net wrap/string are assumed in Table 4:

Table 4: Unit weights of silage plastic, net wrap and string for cattle.

	Per animal over a 6-month housing period				
	No. of silage bales	Silage bale wrap	Silage clamp cover	Total (wrap & clamp cover)	Net wrap or string
Dairy cows & cattle over 2 years	6.25	9.40 kg	0.30 kg	9.70 kg	1.25 kg
Cattle 1-2 years	5	7.50 kg	0.20 kg	7.70 kg	1.0 kg
Cattle under 1 year	2.5	3.75 kg	0.10 kg	3.90 kg	0.5 kg

Some cattle feed is supplied in 25 kg LDPE bags (usually to young stock/ calves) but the amounts are considered to be insignificant.

4. Plastic arising from sheep production

It has been assumed that:

- Only sheep over one year of age will receive animal feed. On average, sheep will eat 250 kg silage over a typical four-month winter feeding period.
- Sheep in the uplands will eat less silage than in the lowlands (200 kg/ha and 300 kg/ha respectively).
- 30% of silage eaten is from clamps; 70% is from wrapped bales.
- Silage wrap for a 400 kg silage bale weighs 1.5 kg and silage clamp cover use is 60 g per tonne of clamp silage.
- The sheep will receive concentrates – assumed to be 20 kg in the four-month period. All concentrates come in 25 kg LDPE bags, weighing 150 g per bag. This equates to 120 g/sheep.

This information is summarised in Table 5 below.

Table 5: Plastic arisings for sheep production.

	Per animal per winter period (4 months)						
For 1 sheep	Bag silage eaten	Silage bales used	Silage wrap used	Clamp silage used	Clamp plastic used	Total silage plastic used	Total (for silage & concentrate)
Lowland	210 kg	0.52	790 g	90 kg	5.4 g	795 g	915 g
Upland	140 kg	0.35	530 g	60 kg	3.6 g	534 g	653 g

Using the calculations as for cattle, silage net wrap/string for sheep can therefore be estimated as:

Lowland sheep over one year of age: 0.16 kg/ sheep
Upland sheep over one year of age: 0.100 kg/sheep

5. String and wrap for straw and hay

String and net wrap for straw and hay originate from either cereal straw from arable farms or hay made on both arable and grassland farms. Most straw and hay are used on livestock farms, although insignificant amounts are used for horticulture, for example for covering carrots in the winter. It has therefore been assumed in this study that all hay and straw are only used on livestock farms.

Quantities of string and net wrap varied on farms visited. Farms located at a considerable distance from large arable centres generally used less straw due to the high costs of transporting it from an arable area. Therefore less waste string and wrap were produced. The type of animal housing (whether on a slurry-based or straw system) and the length of housing during the year were both factors affecting plastic string and net wrap production. On farms visited during this study, total annual arisings ranged between 12 kg and 740 kg per year, with an average value of 230 kg. It can be seen that the quantities of net wrap and string produced on farms are highly variable. However, significant quantities of this waste stream can be found on some farms.

Several assumptions were made to obtain values of string and net wrap produced on different holdings. It was first assumed that straw usage for sheep is negligible. Using data from cattle farms visited, it was found that the weight of string/net wrap per animal ranged widely, from 0.19 to 15.3 kg/animal. The modal value however was 1 kg/animal. A further assumption was that upland farms use less straw than lowland farms. Thus for lowland cattle, it was assumed that net wrap and string weighed 1 kg/animal, whereas for upland cattle, net wrap and string were assumed to weigh 0.5 kg/animal.

6. Agrochemical (pesticide) containers

Agrochemical containers are made from HDPE. The containers usually range in size from 1 litre to 25 litres. It was assumed that the average container size was 5 litres and weighed 275 g**.** (see Table 6).

Agrochemicals are generally applied to arable land, with only an insignificant amount used on grassland. It was therefore assumed for the purposes of this study that no pesticides were sprayed on grassland. Four arable farms were visited during this study. Data for agrochemical containers was used to calculate the weight of pesticide containers found on farms each year and required per hectare of arable land. This information is summarised in Table 6.

Table 6: Weights of pesticide containers produced on farms annually per unit area of arable land.

Farm	Cropping area (ha)	Pesticide container weight – tonnes/year	HDPE weight – kg per ha
1	154	0.097	0.62
2	1,355	0.635	0.46
3	187	0.152	0.81
4	400	0.138	0.35
Average	**524**	**0.256**	**0.56**

The farms that were visited only grew arable crops with an insignificant area of set-aside. The average amount of HDPE container plastic arising per year from arable land is 0.56 kg/ha. However, some farms are organic, some farms will endeavour to use less pesticides and crops need different quantities of pesticides to thrive. It was therefore assumed that the average use of pesticides on farms across England and Wales was 0.4 kg/ha. It was further assumed that similar amounts would be applied to field-grown horticultural crops.

The above assumptions for agrochemical container plastic arisings are based on very limited information. A source of information that could provide a more accurate estimate is the Pesticide Usage Survey, carried out by Central Science Laboratories. This survey is bi-annual and considers information on all pesticides used on all agricultural and horticultural holdings. Although the published reports quote the pesticide applications as amounts of *active ingredients* applied, the information collected relates to the amounts of *product* applied. Thus information for weights and volumes of different products for all crops is provided. On the other hand, the survey does not take into account that some products may be sold in different sizes of containers. Conversations with Dr Miles Thomas revealed that it would be possible to estimate an average container size in these situations and that good quality, relevant information could thus be compiled.

7. Other plastic containers

There are a wide range of non-agrochemical containers used on farms, such as mineral feeds tubs and oil drums. However the amounts used are highly variable. Some are returned to suppliers (typically large oil drums); many are re-used on the farm as containers; others are given away or disposed of with the household refuse. The farm visits illustrated that the actual arising of these containers is quite small and can therefore be considered negligible for the purposes of this report.

8. Horticultural mulch for field vegetables and soft fruit

ADAS Horticulture has recently carried out a survey on horticultural plastic waste arisings for Defra. This survey includes total values for horticultural plastic for England

and Wales. The information is not broken down by county or region. Table 7 summarises the information obtained from this study.

Table 7: Horticultural plastic waste from previous ADAS study.

Crop	Area of covered crops (ha)	Weight of dirty' plastic (t)	Plastic on crop area basis kg/ha
Early potatoes	550	559	1,010
Field vegetables	13,613	13,951	1,020
Soft fruit	4,533	8,787	1,940

Plastic was spread pro-rata over all the areas of those crops. For instance, for early potatoes the total amount of early potatoes (as given in the census) was divided by 550 ha – this gave the percentage of the national early potato crop that was grown under cover. This was then multiplied by 1,010 kg/ha to give an average plastic arising from the entire early potato crop. This clearly introduces an error as it gives the impression that horticultural plastic is evenly spread out across the country instead of occurring in hot spots, as is the real situation.

9. Fruit

Fruit production comprises top fruit (such as apples and pears) and soft fruit (such as strawberries, raspberries, grapes). An estimate was made for plastic used for crop cover and weed suppressant for the main soft fruit crops. It was not feasible however to assess the plastic arisings for other inputs to soft fruit growing or top fruit (for instance fertiliser or pesticides). Fruit production has therefore not been considered further in this report. Further detailed work could evaluate the amounts of different types of plastics arising from fruit production.

10. Protected crops and nurseries

Values for fertiliser and pesticide use, as well for plastic mulch, have been estimated. However horticultural production covers a very wide range of cropping situations, including salad crops grown in glasshouses and polytunnels, mushroom growing, flowers, bulbs, trees and pot plants. Cropping methods are even more diverse for mixed nurseries. This leads to differing amounts being produced from individual holdings, even when the same crops are grown.

It is recognised that substantial amounts of different plastics could be produced by horticultural units. For instance, one protected cropping visited during this study produced 70 tonnes per year of EPS trays. However it was not possible, within the time-frame for this report, to carry out a comprehensive evaluation of all plastics produced in horticulture. Future detailed work is therefore required.

11. Poultry

As most feed is bought in bulk, there is little plastic arising from feed bags. Some veterinary medicines are used, but these represent insignificant amounts. Wood shavings are required for broiler and egg layer bedding, both for deep-litter and free-range systems. Wood shavings are either supplied in 25 kg bales or, increasingly, in 250 kg bales. These bales are wrapped in plastic. However, most wood shavings are supplied in bulk. For this report, it was therefore assumed that all wood shavings are provided in bulk and that the total plastic arising from poultry processes is therefore insignificant.

12. Pigs

The main source of plastic waste is feed. Finishing pigs (bacon) will mostly receive bulk feed. However some piglets in a breeding herd will receive ‘creep feed’ from one week pre-weaning to two weeks post-weaning. As it was not possible to assess the likely amount of plastic waste generated, it was assumed that this was not significant. Some units receive waste food products in plastic bags which then must be disposed of. One pig farm visited during this study used waste crisps delivered in one-tonne polypropylene bags. This represented 165 tonnes of plastic waste from this source per year. This figure cannot however be extrapolated to provide a national value, as this was the only example of feed being provided in this manner. It is assumed that even though there may be ‘hot spots’ of plastic waste from some pig farms, the overall contribution of pig enterprises to national agricultural plastic waste arisings is negligible.

Other plastic arisings from pig production include veterinary medicine containers, semen containers and disinfectant containers. However this is likely to constitute only small volumes which are assumed to be insignificant.

13. Other plastic wastes

Both the farm visits and previous studies illustrated the vast diversity of plastic waste streams that arise on farms. These include veterinary medicine containers, sheep drench packs, shrink-wrap and even such items as plastic grease cartridges. Most waste streams are negligible however. As the objective of this study is to give a national overview of plastics arisings, only waste streams that were significant were considered in subsequent sections.

APPENDIX V

PAS 103 STANDARD FOR WASTE PLASTIC PACKAGING

This document, written by a team of experts, attempts to rationalise the whole subject of plastic waste, in terms of how it is described. The aim is to provide standard terms of reference for everyone involved in the production, transportation and recycling of plastic wastes.

For example, a batch of material would be assessed in terms of:

- source
- weight
- form
- number of units
- type of packaging
- original form (for example film or flake)
- post or pre-consumer
- whether it is subject to producer responsibility controls.

For PAS 103, the intention is to have a table that will set out how many bales should be sampled for quality control purposes. For example:

- 2-8 bales will require 2 bales to be sampled;
- 20-23 bales will require 5 bales to be sampled;
- 91-150 bales will require 20 bales to be sampled.

APPENDIX VI

Glossary of terms and acronyms used in this report

ABS	Acrylonitrile Butadiene Styrene
ASPI	American Society of Plastics Industry
BPF	British Plastics Federation
BPI	British Polythene Industries
COMAH	Control of Major Accident Hazards Regulations
EfW	Energy from Waste
ELV	End of Life Vehicles Directive
EPS	expanded polystyrene
ERDP	England Rural Development Programme
FWAG	Farming and Wildlife Advisory Group
H	hub
ha	hectares
HDPE	high density polyethylene
HIPS	high impact polystyrene
kg	kilograms
km	kilometres
km^2	square kilometre
l	litre
LDPE	low density polyethylene
low	lowlands
LLDPE	linear low density polyethylene
m^2	metre squared
NC	new collection centre
NFU	National Farmers' Union
No.	number
OC	old collection centre
PA	polyamide
PAS	publicly available specification
PC	polycarbonate
PP	polypropylene
PPC	Pollution Prevention and Control Regulations
PRN	Packaging Recovery Note
PU	polyurethane
PVC	polyvinyl chloride
R&D	research and development
RES	Rural Enterprise Scheme
SI	Statutory Instrument
t	tonne
UK	United Kingdom
up	uplands
veg	vegetables
WEEE	Waste Electrical and Electronic Equipment Directive
yr	year

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