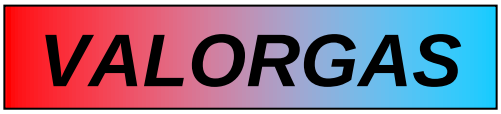
SEVENTH FRAMEWORK PROGRAMME
THEME ENERGY.2009.3.2.2
Biowaste as feedstock for 2nd generation



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D2.3: A case study for collection schemes serving the South Shropshire Biowaste Digester, Ludlow, UK

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Greenfinch Ltd, Shropshire, UK (Greenfinch)

Main contributors: Dr Rebecca Arnold and the staff of Greenfinch Ltd

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D2.3 A case study for collection schemes serving the South Shropshire Biowaste Digester, Ludlow, UK

1 Introduction

The South Shropshire Biowaste Digester located in Ludlow, Shropshire, UK was one of the projects set up under the UK Government's Defra New Technologies Demonstrator Programme (Defra, 2012). It was the first AD plant in the UK to accept source segregated municipal waste in the UK and as a consequence, encountered a variety of challenges (Chesshire, 2006; Arnold et al., 2010). The plant currently processes in excess of 4,500 tonnes of source segregated food waste, mainly derived from Local Authority collection schemes, with small contributions from localised commercial sources.

This report brings together the results from a number of studies of food waste collection schemes that supplied the digester during a 3-year reporting period (2007 – 2010), including work carried out for the FP7 VALORGAS project. Three weekly source segregated municipal collection schemes (all based in Shropshire) are considered in detail, examining the effect of scheme maturity on participation rate and public attitudes to the scheme. Compositional waste analysis was undertaken on waste streams from seven Local Authorities to determine the nature and properties of source segregated biowaste as a substrate for anaerobic digestion (AD).

2 Aims and objectives

The specific aims and objectives of this study are:

1. To compare and contrast the characteristics of the source segregated food waste collection schemes serving the South Shropshire AD plant during a 3-year reporting period (2007 – 2010).
2. To determine the set out and participation rates of food waste collections schemes operating in 3 market towns in South Shropshire, and to compare these with collection schemes within other Local Authority areas.
3. To determine the effect of scheme maturity on public participation rate.
4. To determine the average food waste yield generated by domestic premises in Ludlow and to compare with yields generated within other Local Authority areas.
5. To undertake compositional analysis on waste generated by a variety of collection schemes in order to determine the nature and properties of domestic food waste as a substrate for anaerobic digestion and to quantify contamination rates.
6. To determine the effect of seasonality on the physio-chemical composition of domestic food waste.

3 UK waste collection strategies

In setting its policies, the UK Government is required to ensure that these will fulfil requirements of the EU Waste Framework Directive (2008/98/EC**)** and the Landfill Directive (99/31/EC). These Directives require member states to bring into force laws, regulations and administrative powers to comply with the legislation.

Following referendums in Scotland, Wales and Ireland (1997 and 1998), the UK Parliament transferred a range of powers (including waste strategy) to National Parliaments. Therefore

England, Wales, Scotland and Ireland have developed individual waste strategy documents all with a slightly different focus.

The UK Government has promoted AD as its preferred technology treatment strategy for food waste. It has indicated that food waste should not be sent to landfill and that source segregated food waste collections would be an ideal mechanism to achieve this. However, the Government has permitted individual Local Authorities to commission their own individual waste collection systems (providing they meet the over-reaching aims of the UK strategy). Therefore, unlike the situation in some EU member states, there is considerable variation within the waste collection strategies within the UK.

Waste collection in the South Shropshire area was the responsibility of South Shropshire District Council, now part of Shropshire Council. This was a very forward-thinking local authority, as demonstrated by its involvement in the South Shropshire Biowaste Digester project at a time when most Local Authorities still included food waste in their residual waste collection schemes. Together with Greenfinch Ltd South Shropshire DC formed Biocycle south Shropshire Ltd, a not-for-dividend company to oversee the operation of the digester.

4 The South Shropshire Biowaste Digester

4.1 Background

As noted above, the South Shropshire Anaerobic Digestion (SSAD) plant (Figure 4.1.1) was set up under the Defra New Technologies Demonstrator Programme. Before construction could to commence the digester had to obtain planning consent from Shropshire County Council. This was achieved after an extensive programme of public consultation, as a result of which it took only 11 weeks from the submission of the application to its approval. Construction started on site in June 2005 and work was completed 8 months later in February 2006.

Figure 4.1.1 The South Shropshire Biowaste Digester (Biocycle)

As the plant was first digester in the UK to accept source segregated municipal waste, it was expected that there would be some difficulties to overcome. This was the main purpose of the Demonstrator Programme, and the project created valuable knowledge and experience which has since been disseminated to Local Authorities, industrial partners and the general public

resulting in increased participation and development countrywide. A key outcome has been identifying and operating a collection system that made this approach technically and economically feasible for all Local Authorities.

4.2 Overview of the Plant and Process

The core of the process plant is anaerobic digestion, a natural biological process which stabilises organic waste in the absence of air. The by-products are biogas and biofertiliser. The biogas is used to fuel a combined heat and power unit (CHP) to produce electricity and heat, some of which is used for the process itself. The digestate is pasteurised in a batch reactor prior to storage and ultimately land spreading for beneficial fertilizer use.

The South Shropshire AD plant is currently processing in excess of 4,500 tonnes per year of source segregated food waste derived from Local Authorities. Typically, the food waste consists of 27% dry matter (DM or total solids, TS), of which 90% is organic dry matter (ODM or volatile solids, VS). The food waste is collected in biodegradable bags totalling approximately 2 – 4.5% (by wet weight) of the weight collected.

The typical biological methane potential (BMP) of the food waste is 420m^3 CH_4 per tonne ODM.

The process flow and mass balance of the digester is illustrated in Figure 4.2.1. The individual process stages are as follows:

4.2.1 Reception Hall

- Food waste is delivered into the reception hall via a roller shutter door by road vehicle and discharged into the tipping area. The reception area is designed to accommodate refuse collection vehicles and hook loader skip vehicles.
- Vehicles are cleaned with a high pressure washer before leaving the building which ensures contaminated material is not deposited outside.
- The roller shutter door is permitted to be open only when vehicles are either entering or leaving the reception hall; when the vehicle is inside the building discharge of waste is permitted only when the door is closed.
- The food waste is transferred from the reception tipping area using a wheeled bucket loader (Bobcat or similar) and loaded into the feed hopper which is located above the primary shredder.
- The food waste is shredded onto a 2-stage belt conveyor which allows the manual removal of contaminants such as bags, fabric material or plastic (Figure 4.2.2).
- The second belt conveyor feeds the shredded foodwaste into a second hopper above an auger feeder which mixes the waste with re-circulated digestate and process liquids.
- The conditioned food waste is passed through a ‘knockout pot’ to allow any heavy objects (utensils and coins) to fall out of the waste stream prior to being macerated. These rejects are disposed of via reception hall skip.
- The macerator further reduces the particle size to produce homogenous slurry which is pumped into the raw waste buffer tank.
- All food waste is normally cleared from the reception hall by the end of each working day.

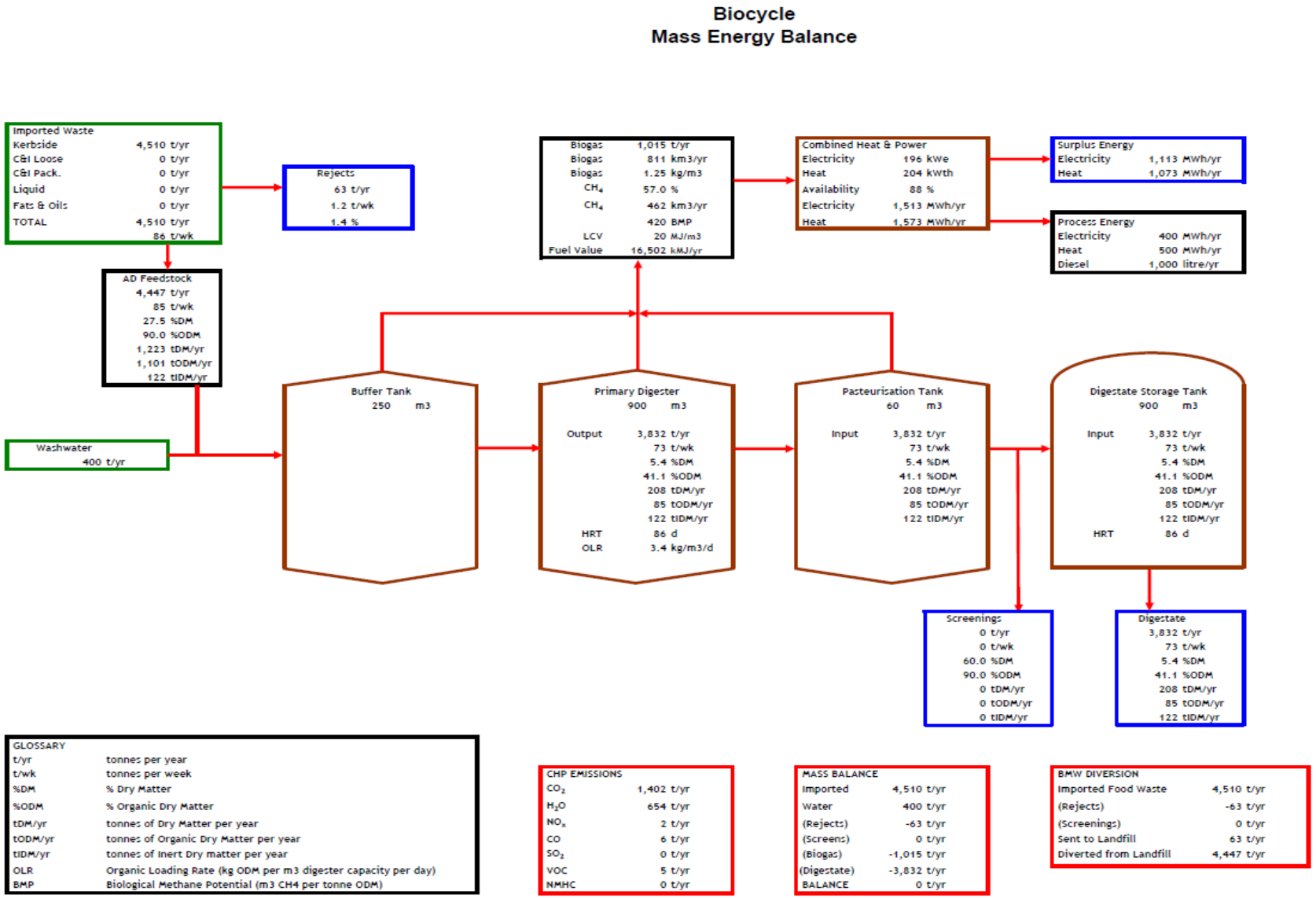


Figure 4.2.1. Process flow and mass balance of the digester

Figure 4.2.2 Reception hall conveyors

4.2.2 Plant Room

Pumps, heat exchangers and control the panel are located in a plant room (Figure 4.2.3) which also houses the CHP and standby boiler.

Figure 4.2.3 Plant Room

4.2.3 Raw Waste Buffer Tank

- Conditioned food waste and reception hall wastewater are pumped into the sealed raw waste buffer tank (capacity 249 m^3), which is located outside the reception building and inside the process bund area (Figure 4.2.4).
- The buffer tank is designed to hold 4 days of digester feed which enables the anaerobic digestion process to operate seven days a week whilst the reception hall operates for only five days a week.
- The buffer tank is mixed using the Greenfinch proprietary gas mixing system.

4.2.4 Anaerobic Digester

- Conditioned food waste is pumped semi-continuously (every hour) from the buffer tank into the digester tank (total capacity 900 m^3).
- The temperatures of the digesters are maintained at 40 ^oC by re-circulating its contents through Greenfinch proprietary external heat exchangers.
- The digesters are mixed using the Greenfinch proprietary gas mixing systems.

Figure 4.2.4 The Tank Compound

4.2.5 Pasteurisation

- Digestate is pumped from the digester to the sealed pasteurisation tank (capacity 57 m^3) where it is batch pasteurised at a minimum temperature of 70^oC for of minimum of one hour to guarantee the eradication of pathogens.
- The pasteurisation tank is heated by re-circulating its contents through a proprietary Greenfinch external heat exchanger.
- The pasteurisation tank is mixed using the Greenfinch proprietary gas mixing system.

4.2.6 Digestate Storage

- Pasteurised digestate is pumped to a sealed digestate storage tank (capacity 900 m^3).
- The onsite digestate storage capacity provided will cater for the storage requirements of the facility for a duration of 86 days.
- The onsite digestate storage tank is mixed and aerated using the Greenfinch proprietary gas mixing system.
- Digestate is exported from site for land application under the control of a contract haulier using road tankers.
- Digestate is pumped from the digestate storage tank to the road tanker by a high-rate pump which is located in the digestate hall.

4.2.7 Biogas Collection

- Biogas is collected from the roof of each sealed tank: raw waste buffer tank, anaerobic digesters and pasteurisation tank; this maximises capture of biogas and minimises odour emissions.
- The biogas is piped to a double membrane gas holder (capacity 150 m^3) which maintains the biogas at a constant pressure (20 mbar) and acts as a buffer between supply and demand.

4.2.8 Combined Heat and Power (CHP)

- The biogas is piped into the plant room where it is used as the fuel for a combined heat and power (CHP) unit (Figure 4.2.5).
- The engine consumes about 100m^3/hour of biogas (equivalent to 597 kW) to produce 207 kW of shaft power which in turn produces 197 kW of electricity continuously. The engine brake efficiency is therefore 34.8%, the generator efficiency 95%, and the overall electrical efficiency 33.0%. The CHP unit has a second purpose which is to produce heat.
- Some of the electricity produced by the CHP unit is used to power the shredders, pumps and mixers for the digester and the surplus is exported to the National Grid. The

electricity qualifies as renewable and therefore attracts renewable obligation certificates (ROCs) which are traded on the electricity market.

- Some of the heat produced by the CHP unit is used to provide heat for the digester and for the pasteurisation unit, as well as heating the building itself in the winter. It is planned that in the future a district heating system will enable heat to be exported to the adjacent industrial units.

Figure 4.2.5 CHP and Standby Boilers

4.2.9 Surplus biogas burner and standby boilers

Surplus biogas, produced when the CHP unit is down for maintenance, is burned in the standby boilers (which will also provide process heat) and surplus gas burner which will operate only intermittently.

4.2.10 Visitor centre

The visitor centre has received more than 4,500 visitors since opening in 2006, including the general public, academic institutions, government departments and overseas visitors (Figure 4.2.6).

Figure 4.2.6 Visitor Centre

4.3 Digester initial digester performance (2006-2007)

The vision for the project was to provide a local, sustainable, solution for the diversification of all the biodegradable municipal waste arising within the 23,000 domestic premises within the South Shropshire District Council controlled areas. The design throughput of the digester was therefore 5,000 tonnes per year of co-collected biodegradable municipal waste comprising green garden waste, food waste and cardboard. On the basis of data collected

during previous research within the South Shropshire area (Chesshire, 2006) it was assumed that food waste would comprise 55% of the total tonnage, with the remaining 45% being garden waste and cardboard (with an expected bias towards an increased tonnage of green waste during the spring and summer months).

At the commencement of the project, South Shropshire District Council operated a collection scheme comprising a fortnightly collection of dry recyclables (paper, glass and cans) collected in green boxes and an alternate weekly collection of co-mingled cardboard, food waste and green garden waste (240-litre wheeled bins) with residual waste also being collected in 240-litre wheeled bins. A total of 10% of households were unsuitable for wheeled bins and so were provided with compostable sacks (green waste), a 25-litre bin (food waste) and black sacks (residual waste). At the insistence of Greenfinch, the Council was very specific that the green waste should comprise 'grass clippings and soft pruning's < 2 mm in diameter'. Soil, stones, branches and woody material should be collected with the residual waste.

The plant was commissioned between March and May 2006. During the first year of operation the digester accepted approximately 50% of its design throughput, and the operational experience was dominated by the nature of the biowaste (Figure 4.3.1) which was significantly different to the design throughput. In order to quantify these differences compositional analysis was undertaken during June and November 2006. On each occasion a two tonne sample of biowaste was hand sorted into separate fractions. An average of 71% of the waste was garden material (much of which was woody), 17% was paper and cardboard, 6% food waste, 4% soil and stones and 2% was contamination in the form of textiles and plastics (Figure 4.3.2; Arnold et al., 2010). There was no significant difference between the composition of the waste between June and November (Table 4.3.1; Arnold et al., 2010), contradicting the belief that the winter collection would be dominated by food waste.

Figure 4.3.1 Nature of the Delivered Biowaste.

Table 4.3.1 Composition of the source separated biodegradable municipal waste (source: Arnold et al., 2010)

Waste type	July 2006	November 2006
Cardboard and paper	16.0%	19.0%
Contamination	2.0%	1.6%
Food waste	6.0%	5.1%
Green waste	70.0%	73.3%
Soil and stones	6.0%	1.0%

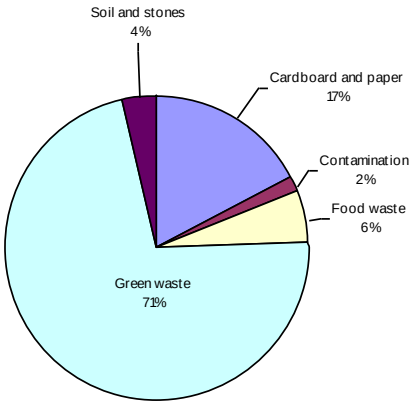


Figure 4.3.2 Average compositional analysis of the delivered biowaste (Source, Arnold et al., 2010)

The average dry matter and organic dry matter values for the feedstock were 45 % and 78% respectively, compared to the expected values of 27% and 87%. The combination of the dominance of green waste comprising an excessively high proportion of woody material, high volume of plastic, soil and stones and low tonnages of food waste meant that this feedstock was not ideal for the AD process. As a consequence, the plant experienced higher operating costs (including damage to machinery and the accumulation of grit and sediment in tanks and pipes) and a lower biogas yield than predicted resulting in marginal economics.

Feedback gathered at open days, events, presentations and displays indicated that whilst supporting the principles of the anaerobic digester scheme, residents had concerns regarding the alternate weekly nature of the collection scheme and this was directly contributing towards the lower than anticipated food waste yields. These concerns were particularly with regards to difficulties experienced in cleaning the large (240-litre) wheel bins (particularly the biodegradables bin), and the generation of odours and flies. Residents were requested to wrap their food waste in newspaper and this was perceived to be not hygienic, problematic, and leading to odour and flies. These problems were exacerbated by the nature of the alternate week collection (particularly during the summer months). As a consequence, many residents admitted to disposing of their food waste in which ever bin was being collected on that particular week.

At the end of 2006 the project partners agreed to stop accepting co-mingled waste and to amend the feedstock to source separated food waste only. This was enabled by the inclusion of South Shropshire in a WRAP-funded source segregated weekly food waste collection trial (WRAP, 2009). Additional food waste was sourced from other Local Authority areas who had either introduced collections prior to securing their treatment technology, or where the collected tonnages exceeded the treatment capacity. It was also agreed that the plant would continue to accept a small amount of uncontaminated green waste (in the form of grass cuttings from the South Shropshire Housing Association). Financial constraints meant that the separate food waste collection scheme was only introduced to 3 market towns within the South Shropshire region (using a phased approach over a 12 month period). The remaining households continued to use the co-mingled collection scheme, the products of which were transported out of County to a composting site.

The experience of the first year's operation of the South Shropshire Biowaste Digester clearly indicates the importance of the collection scheme for the success of an anaerobic digestion

plant. Alternate weekly collections of co-mingled cardboard, kitchen and garden waste generate a low food waste capture rate and do not produce a suitable feedstock for successful anaerobic digestion without considerable front end sorting facilities (including the ability to remove plastic contamination). The remainder of the report considers the operation of the plant between June 2007 – December 2010, during which time it operated on 99.3% source segregated food waste.

5 Summary of waste origins received during the reporting period

5.1 Sources and quantity of biowaste received

The total tonnage of biowaste accepted at the plant during the study period (June 2007 – December 2010) was 11,363.1 tonnes, with an annual tonnage between 2000 and 4000 tonnes (Figure 5.1.1). The waste was derived from 15 sources (Table 5.1.1; Figure 5.1.2), with food waste comprising 99.3% of the total tonnage on a wet weight basis, and grass clippings and glycerol (a by-product of the biodiesel production) comprising 0.6% and 0.1% respectively.

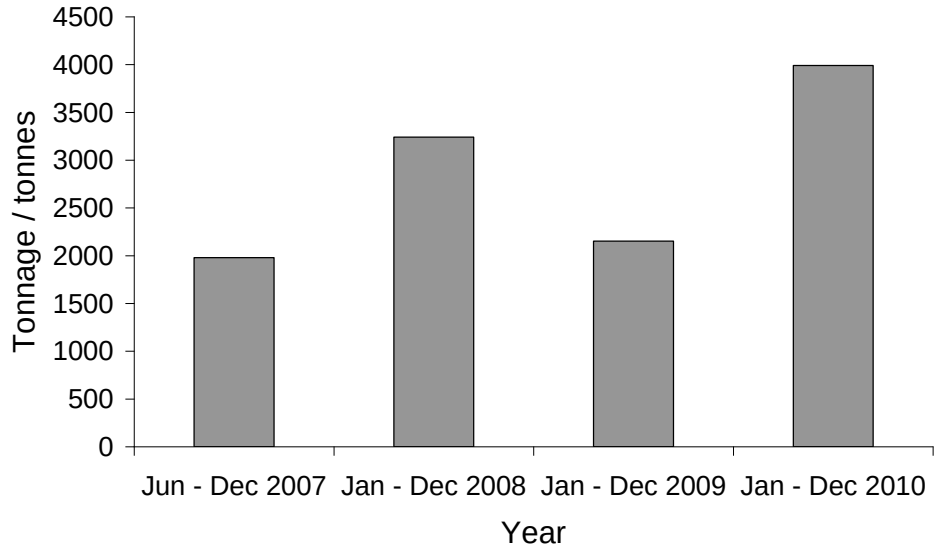


Figure 5.1.1 Annual tonnage of biowaste input during the study period

During the first 6 months of operation, waste was accepted from 6 individual sources, with 67% (on a wet weight basis) of the sourced material derived from Somerset, 17% from Ludlow (domestic rounds), 12% from Newtown, 1.74 % grass clippings and minor contributions from whey (0.2%) and Ludlow commercial food waste (0.1%). There was a 64% increase in the tonnage of waste accepted during 2008, with increased tonnages being accepted from all sources (except grass clippings), the introduction of collection schemes in Church Stretton and Craven Arms (Section 8), and the extension of the commercial collection scheme in Ludlow (Section 11). Food waste derived from Somerset constituted 54% of the total waste accepted during 2008, and therefore, despite relatively consistent (or increased tonnages) from existing sources, and the addition of 2 new contracts (Ceredigion and Cadburys) the tonnage was significantly affected when the Somerset contract ceased in early 2009. The Ludlow, Church Stretton and Craven Arms collection schemes ceased in 2010; however additional tonnage from Presteigne, Flintshire, wash down water and glycerol increased the throughput to 4000 tonnes.

Table 5.1.1 Annual Biowaste input during the study period by source

Source	Accepted input / tonnes June-Dec 2006	Jan - Dec 2008	Jan - Dec 2009	Jan - Dec 2010	Total
Ludlow Domestic	335.3	541.7	555.4	389.2	1821.6
Ludlow Commercial	2.5	198.2	234.8	196.5	632.0
Craven Arms		44.3	105.2	70.3	219.7
Church Stretton		90.6	222.7	149.9	463.3
Presteigne	0.0	0.0	0.0	91.9	91.9
Newtown	245.4	546.6	473.2	327.1	1592.3
Somerset	1358.5	1755.9	314.2	236.5	3665.1
Monkland Dairies	4.4	28.2	36.0	52.8	121.3
Ceredigion			168.9	232.4	401.3
Flintshire	0.0	0.0	0.0	1130.4	1130.4
SSHA (grass clippings)	33.4	35.7	0.0	0.0	69.2
Cadburys	0.0	0.0	41.3	0.0	41.3
Wash down water	0.0	0.0	0.0	25.2	25.2
St Ivel	0.0	0.0	0.0	1076.5	1076.5
Glycerol	0.0	0.0	0.0	12.1	12.1
Total tonnage	1979.4	3241.2	2151.7	3990.8	11363.1

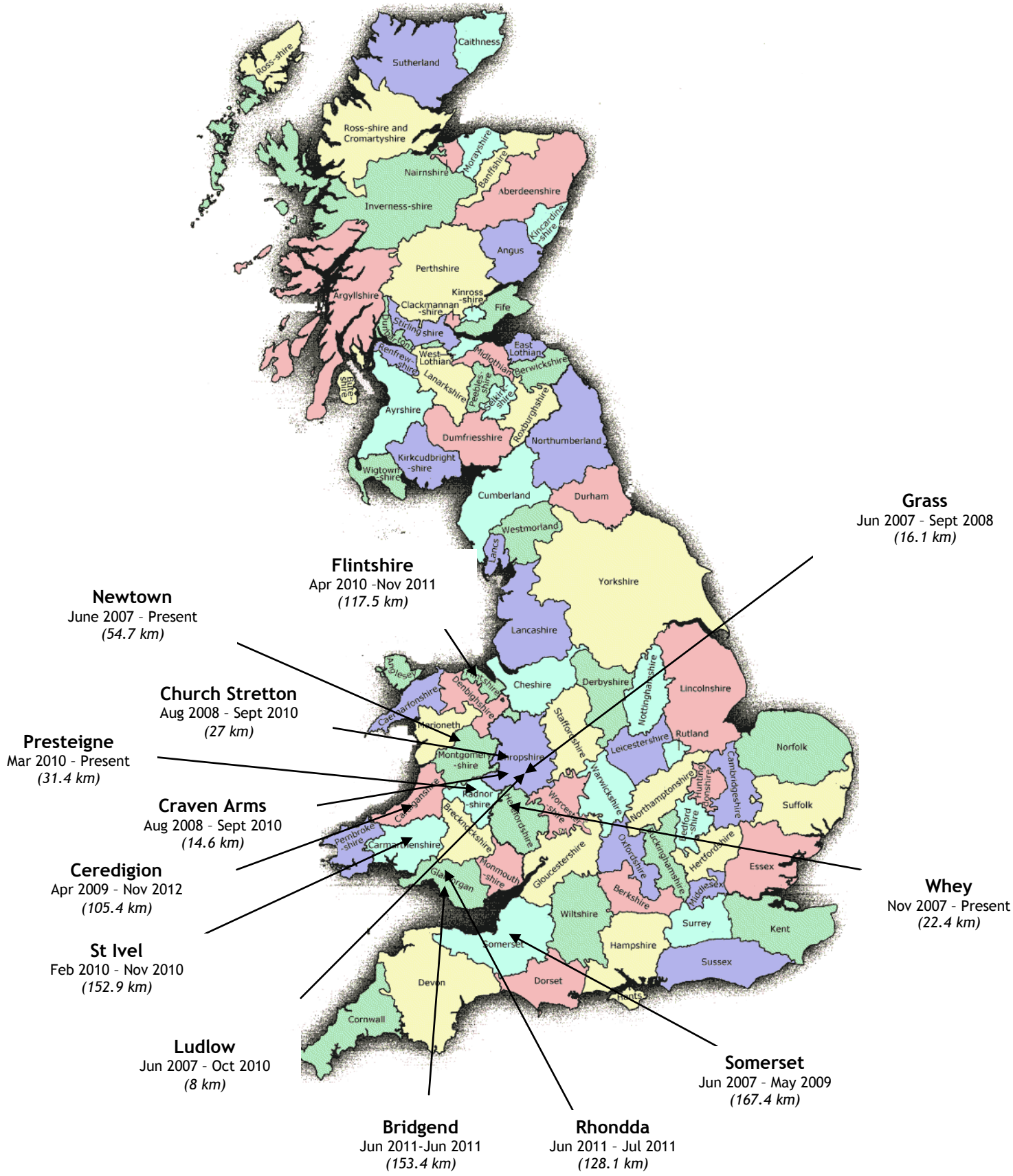


Figure 5.1.2. Locations of sources of feedstock material during the reporting period *(numbers in italics indicate distance from digester)*

5.2 Seasonal variability

The seasonal variation in the tonnage of food waste delivered from domestic sources was analysed for waste streams for which digester was the sole processor and for which more than 1 year's data was available (Figure 5.2.1). Domestic food waste from Somerset and Newtown was primarily processed by alternative technologies, with waste being accepted at South Shropshire digester only when the supply exceeded the existing processing technology; therefore, the true effect of seasonality on food waste generation cannot be determined.

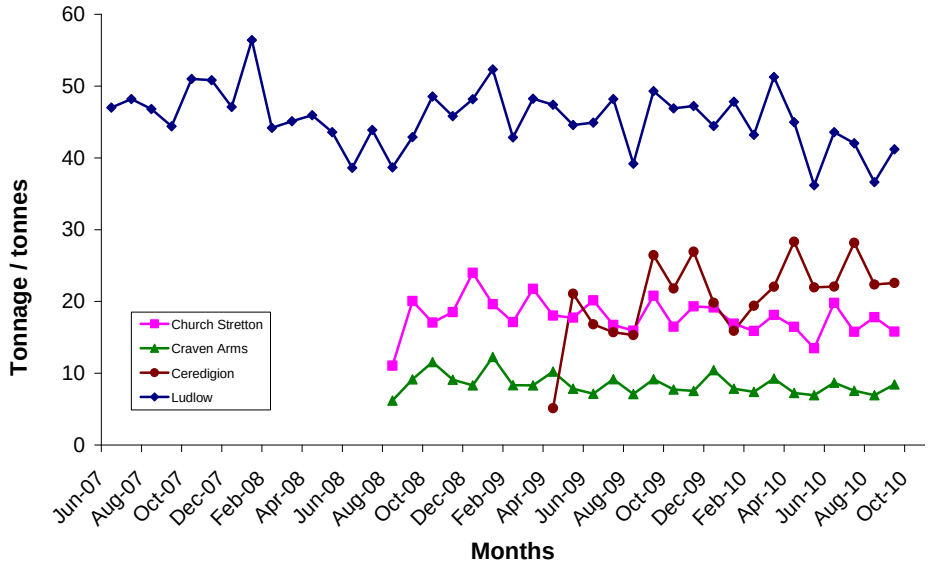


Figure 5.2.1 Seasonal variation in food waste derived from South Shropshire and Ceredigion

Ludlow – The average weekly tonnage from the Ludlow collection round was 45 tonnes, with a maximum and minimum weekly tonnage of 56 and 36 tonnes respectively. Peak deliveries occurred during January 2008 (56.4 tonnes) and January 2009 (52.3 tonnes) which reflects the effects of the Christmas period. The smallest deliveries were consistently recorded during August (which coincides with the major UK holiday period); however there was also a significant decrease in May 2010 which cannot be explained.

Church Stretton – The average weekly tonnage derived from the Church Stretton collection round was 17.8 tonnes. The maximum tonnage (23.8 tonnes) was generated in December 2008, with the minimum (11.04 tonnes) in August 2008 (the first collection). Similarly to Ludlow, there was a significant decrease in the tonnage of waste collected in May 2010.

Craven Arms – The collection round in Craven Arms generated the smallest tonnages of waste, with average weekly tonnages totally 8.4 tonnes (minimum and maximum tonnages were 12 and 6.18 tonnes respectively). There was very little seasonal variation in the weight of food waste collected from Craven Arms.

Ceredigion – There was a wide variation in the tonnage of food waste collected from the Ceredigion region. Excluding the first month of the collection scheme (which only generated 5 tonnes; although this is to be expected), the minimum masses (15 tonnes) were recorded in July and August 2009 (explained by the UK holiday season) and January 2010. The decreased weight in January is unusual and contradicts the dominate trend seen in most collection schemes which record an increase in food waste generated over the Christmas period.

5.3 Rejected feedstock

The presence of contamination in feedstock can cause severe operational, financial and environmental issues, and therefore the operators are required to follow very strict input acceptance criteria procedures to ensure that contamination is kept to a minimum. Greenfinch works closely with Local Authorities, waste collection contractors and other suppliers to ensure that they all are fully aware of the implications of contamination for the operation of the digester and the application of digestate to agricultural land. The input supply agreements in place between Greenfinch and the waste suppliers permit Greenfinch to reject loads which are highly contaminated (at the suppliers cost); however, due to the generally high quality of the waste streams, rejection is rare. Determination of contamination is achieved through visual inspection. Food waste collected in biodegradable cornstarch bags comprises >95% of the tonnage of material accepted at the digester, and the colour and translucency of the bags can determine the ease with which contamination can be identified (Figures 5.3.1 and 5.3.2).

Figure 5.3.1 Deliveries in cornstarch bags in which the presence (or absence) of contamination was very obvious to determine by visual determination

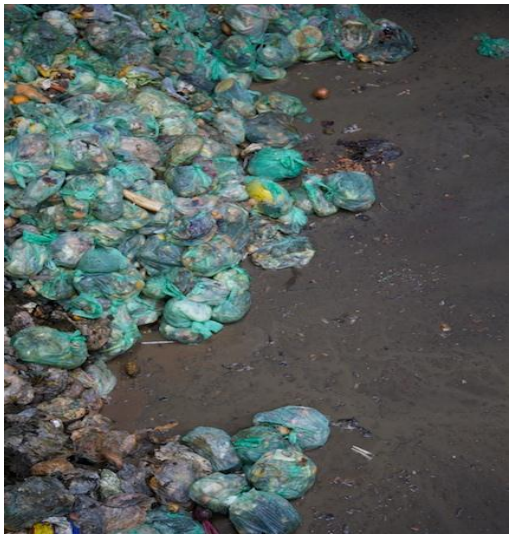


Figure 5.3.2 Deliveries in cornstarch bags in which the presence (or absence) of contamination was hard to determine by visual interpretation

In excess of 95% of the rejected material arises within the reception hall. All rejected material is collected and stored in a 4 tonne skip prior to removal from site (Figure 5.3.3).

Figure 5.3.3 The rejects skip located in the reception hall

The tonnage of material rejected throughout the reporting period, and the weight of rejects as a percentage of the total feedstock inputs are shown in Figures 5.3.4 and 5.3.5 respectively. A total of 86.5 tonnes of material was removed from site during the whole reporting period (June 2007 – December 2010), which equates to an average monthly tonnage of 2.62 tonnes.

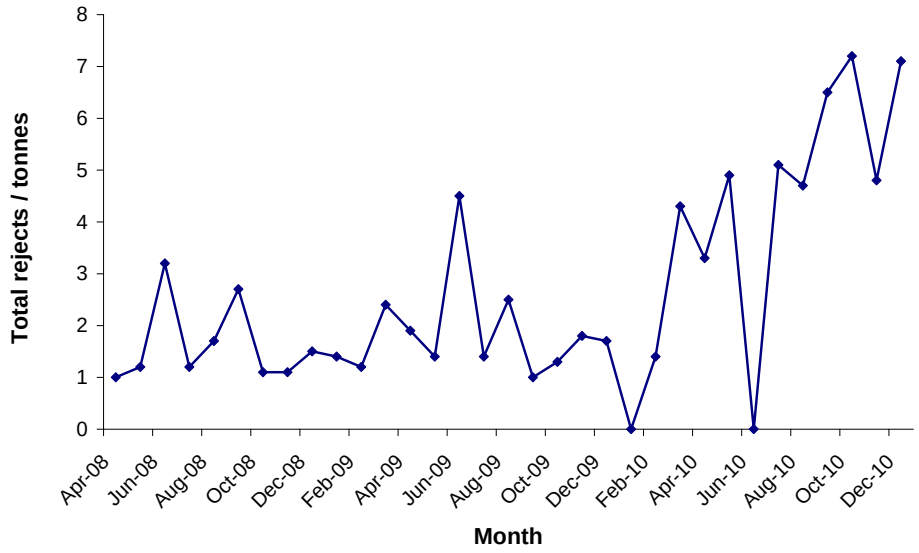


Figure 5.3.4 Monthly tonnage of rejected material removed from site

Figure 5.3.4 indicates that no rejected material left site in February and June 2010. This is very unusual and it possible that weighbridge data may be missing, or that waste was carried over to the following month.

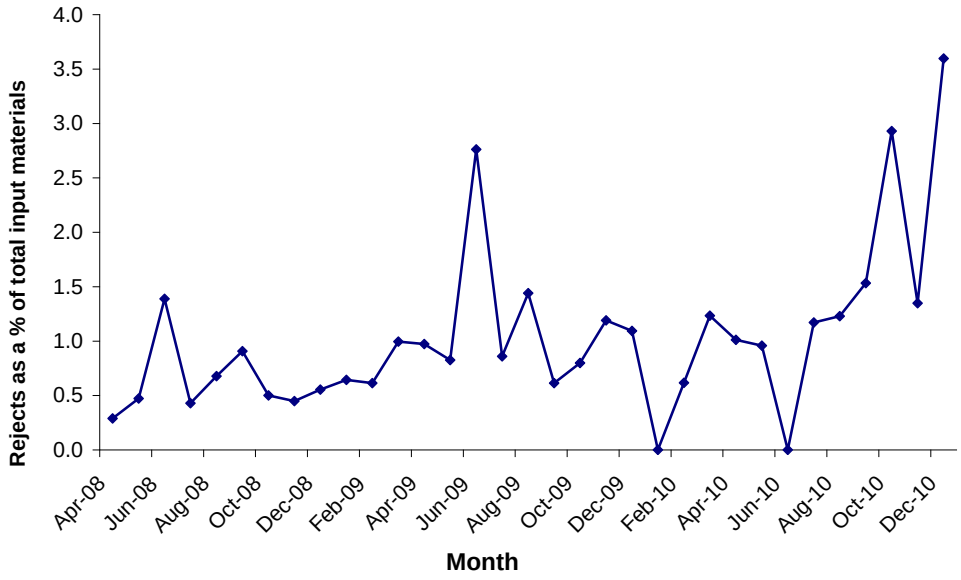


Figure 5.3.5 Rejected material expressed as a percentage of the total input material

During 2008 – 2009 the average tonnage of material rejected from the plant was <2 tonnes / month during 2008 – 2009 (<1% of the total input material); however a sharp increase was recorded during 2010 (Table 5.3.1). The absolute figures are partially a reflection of the increased tonnage of input material, however, the rejected material expressed as a percentage of the total input material indicates a steady increase over time with the 2010 reject quantity figure (1.3%) being twice that of the 2008/2009 figure (0.6%) (Table 5.3.1).

Table 5.3.1 Materials rejected from site

Reporting period	No of months in reporting period	Total input/ tonnes	Total rejects / tonnes	Monthly rejects / tonnes	Rejects as % of input / %
April 08 - March 09	12	3049.3	19.7	1.6	0.6
April 09 - March 10	12	2229.3	23.2	1.9	1.0
April 10 - Dec 10	9	3259.2	43.6	4.8	1.3

The majority of the weight of the rejected material comprised shredded cornstarch bag, however incorrect feedstock (mainly plastics and packaged waste which could not be easily de-packaged on site) and the contents of the 'knock out pot' for heavies were also included. Cornstarch bags are considered to be a major asset in encouraging householders to segregate and collect their food waste, (the 2007 attitudinal study in Ludlow concluded that 96% of householders found them useful (WRAP, 2008a)). However, they become twisted around the teeth of the primary shredders and macerators, and due to their physical and chemical properties do not fully degrade in the anaerobic digestion process. Whilst in some plants, these bags would pass through the front end and would need to be screened out prior to the application of digestate to land; the design of the South Shropshire plant facilitates the removal of contamination at shredding stage and there is no facility for digestate screening. During food waste processing, the operators regularly remove shredded material from the conveyor belt and also remove large volumes of shredded bag from within the teeth of the shredders (Figure 5.2.6). Prior to May 2010, the front end handling of the waste was frequently undertaken by Agency or temporary workers. However, a new, permanent (very

diligent) operator was employed in May 2010. It is thought that the increase in rejects evident during 2010 is mainly due to the diligence of this employee consistently removing biodegradable bag rather than a significant increase in the contamination of the feedstock.

a) removal of biodegradable bag (by hand) from the shredded food waste on the belt

b) shredded material removed from the teeth of the shredder

Figure 5.2.6. Front end handling of food waste

6 Comparison of collection schemes

During the reporting period (May 2007 – December 2010), the South Shropshire AD plant received waste from 15 sources (Table 5.1.1), of which 9 were Local Authority collection schemes. WRAP has published comprehensive guidance for the introduction and operation of weekly source segregated food waste collection schemes (WRAP, 2010), which has been adopted by many Local Authorities within the UK; therefore, many schemes operate in a similar manner.

The characteristics of 6 weekly food waste collection schemes serving the plant were examined (Table 6.1). The South Shropshire schemes (Ludlow, Church Stretton and Craven Arms) are discussed in detail in Section 7, but are included in Table 6.1 for comparative purposes.

6.1 Aberystwyth (Ceredigion)

Aberystwyth is a historic market town, administrative centre and holiday resort in Ceredigion on the west coast of Wales (Figure 5.1.2). The population is 15,935 (2001 census), with an additional 10,000 students attending the University during term time. Aberystwyth is an isolated town, with the nearest substantial conurbations (Swansea, Shrewsbury and Wrexham) being in excess of an hour's drive away.

In its Waste Strategy, the Welsh Assembly Government (WAG, which has devolved powers from the UK's Government) stated that all households would be served by a weekly source segregated food waste collection scheme by March 2015. The food waste collection scheme in Aberystwyth was introduced in May 2009 as part of a trial funded by the Welsh Assembly to demonstrate the principles to other Councils in Wales. The scheme was extended to all properties within the Ceredigion region from November 2010.

Households were provided with 7-litre kitchen caddies and 23-litre kerbside collection bins. The provision of biodegradable caddy liners to all households in the Ceredigion region was beyond the financial capability of the Council and therefore these were not provided to households in the Aberystwyth trial. Instead, householders were requested to wrap their food waste in newspaper or tissue paper, or they could purchase cornstarch bags from the Council for a small fee.

The collection scheme covered 1000 households over a 5-day period (serving approximately 200 households per day). Only households in the town centre itself and three adjoining districts (Waunfawr, Penparcau and Llanbadarn) were included in the scheme which covered approximately 4.8 km^2.

Waste was collected in a 12-tonne refuse collection vehicle (RCV), which was operated by 1 driver and 1 crew member. A slave bin was used for properties on streets which were not accessible by the RCV. The collection vehicle deposited its load daily at the County Council's waste depot (also in Aberystwyth; approximately 3.2 km from the town centre) where it was bulked in a 5 tonne sealed skip and transported to South Shropshire (105.9 km single journey) once per week. The total daily mileage of the collection rounds was very small (<19 km, including the return journey to the Council depot).

6.2 Presteigne

Presteigne is a small town in Powys on the border of England and Wales (Figure 5.1.2). It has a population of 2,463 (2001 census) and has a small manufacturing base, but is becoming increasingly known as a tourist location.

The local Councillors and inhabitants of the town unanimously voted to develop Presteigne into a Zero Waste Town whereby all its waste is seen as a resource for others and is reused, with no material going for landfill or for incineration. These principles have been widely adopted by the residents who are very proud of the town's green credentials. Cwm Harry Land Trust (CHLT) commissioned and operates the entire waste collection system for the town (food waste, recycling and residual waste) under a contract initially funded by WAG. The collection scheme employees are local residents and are specifically trained to identify and reject waste containing contamination.

The collection serves 1,200 households over 5 days (approximately 250 households per day) and an important part of the collectors' job is to talk to, and educate the public on contamination. An electric powered converted milk float is used to collect food waste and all the recycling materials (paper, cardboard, glass, plastic, tetra pak and tins) on one vehicle (Figure 6.2.1).

Figure 6.2.1 Collection vehicle used in the Presteigne. Food waste and dry recyclables are collected on the same vehicle. The food waste pod is the stillage closest to the drivers cab (Photo courtesy of Cwm Harry Land Trust)

The material is returned to the waste collection depot on the edge of the town. The site does not have the appropriate Environment Agency permit to store the waste and therefore it is transported daily to South Shropshire (31.4 km single journey) (Figure 6.2.2). The fuel consumption of this vehicle is 11.4 litres/100km (40 litres/gallon).

Figure 6.2.2 Vehicle used by Cwm Harry Land Trust to transport food waste from Presteigne to Ludlow (Photograph courtesy of Cwm Harry Land Trust)

The participation rate in this scheme is 93% with a 75% capture rate (David Clarke, CHLT, *personal communication*). Of the food waste which is retained within the residual waste stream, the majority is packaged waste which (without removing the packaging) would have been rejected from the collection scheme.

6.3 Montgomeryshire

Cwm Harry Land Trust operate the weekly source segregated collection scheme in Montgomeryshire (Figure 5.1.2), the northern principle area of Powys, Wales, and contains the principle conurbations of Machynlleth, Llandidloes, Montgomery, Newtown and Welshpool. The food waste collection scheme serves 13,000 households within these 5 towns, and covers 48 km from end to end (as the crow flies). Householders are provided with

7-litre kitchen caddies, 23-litre kerbside bins and cornstarch caddy liners are available free of charge and on request.

Two vehicles are used on the collection rounds:

1. A 7.5 tonne purpose built vehicle with a collection pod and bin lift. This is operated by 1 driver and 2 crew members and also has a slave bin for streets which do not have access suitable for the vehicle (Figure 6.3.1). The fuel consumption is 18.9 litres/100km (24 km per gallon).
2. A smaller vehicle (Figure 6.2.2) is used in certain parts of the towns where there are large numbers of narrower streets which are not accessible by the 7.5 tonne vehicle. The fuel usage of this vehicle is approximately 11.4 litres/100km (25 miles per gallon).

Figure 6.3.1 The 7.5 tonne purpose build 'pod and bin lift' vehicle operated by Cwm Harry Land Trust (Photographs courtesy of Cwm Harry Land Trust)

All waste is taken to CHLT's depot and composting in vessel unit (IVC) in Newtown. South Shropshire only receives waste which exceeds the capacity of the IVC unit, and therefore it is bulked at the Newtown depot is transported to South Shropshire (56 km single journey) using the 7.5 tonne vehicle once or twice per week.

6.4 Flintshire

Flintshire is a county on the north eastern side of Wales, bordering Cheshire and covering 483 km^2 (Figure 5.1.2). Approximately 57% of the population live in 5 conurbations in the east and centre of the county with the remainder of properties being very rural.

The food waste collection scheme, operated by Flintshire County Council was initiated during 2010, and during the reporting period served 24,148 households (although this was subsequently extended to approximately 55,000 households). Similarly to the other schemes already described, householders were provided with a 7-litre kitchen caddy, a 23-litre kerbside bin and cornstarch bags free of charge on request.

Waste was collected using a fleet of 4 Isuzu Fargo Micro L vehicles with a payload of 3500 kg; a capacity of 5m^3 and a hydraulic wing for semi-compaction. Each vehicle was operated by 1 driver and 1 crew member. At the end of the round, or when the vehicle was full (which ever was soonest), the waste was transferred to a waste transfer station at Buckley, bulked in a Euro Container and transported to South Shropshire three times per week (~121 km single journey). For further information on the Flintshire collection scheme see also VALORGAS deliverable D2.7.

Table 6.1 Summary of characteristics of collection schemes serving South Shropshire

Collection Scheme	Nature of collection area	Area of round (km2)	No of Households served	Details of collection rounds	Collection vessels	Participation rate	Average weekly tonnage provided to South Shropshire	Proportion of collected waste received by South Shropshire
Ludlow, Shropshire	Small market town	8	5277	Weekly kerbside collection, 5 rounds, 2 of approximately 1000 households, 2 of 1500 households and 1 of 500	7-litre kitchen caddies, 23-litre kerbside bins, cornstarch bags provided free of charge on request	69%	9.2 tonnes	100%
Craven Arms, Shropshire	Small market town	5	1025	Weekly, kerbside collection, 1 round	7-litre kitchen caddies, 23-litre kerbside bins, cornstarch bags provided free of charge on request	75%	n/a (domestic waste co-mingled with commercial waste)	100%
Church Stretton, Shropshire	Small market town + 3 outlying villages and hamlets	16	2012	Weekly kerbside collection, 2 rounds	7-litre kitchen caddies, 23-litre kerbside bins, cornstarch bags provided free of charge on request	64%	n/a (domestic waste co-mingled with commercial waste)	100%
Aberystwyth, Ceredigion	Town of Aberystwyth + three adjoining districts; outlying villages not included	5	5,000	Weekly kerbside collection, 5 collection rounds	7-litre kitchen caddies, 23-litre kerbside bins, food waste wrapped in newspaper, tissue or householders to purchase cornstarch bags	65%	5 tonnes	100%
Flintshire, Wales	4 major conurbations + numerous rural villages and isolated hamlets	483	24,150	Weekly, kerbside collection, 5 collection rounds	7-litre kitchen caddies, 23-litre kerbside bins, cornstarch bags provided free of charge on request	60%	36.5 tonnes	100%
Presteigne, Powys, Wales	Small town	6.5	1,200	Weekly, kerbside collection, 5 collection rounds	7-litre kitchen caddies, 23-litre kerbside bins, cornstarch bags provided free of charge on request	93% (75% capture rate)	2.5 tonnes	100%
Montgomeryshire	5 medium sized towns	48	13,000	Weekly, kerbside collection, 5 collection rounds	7-litre kitchen caddies, 23-litre kerbside bins, cornstarch bags provided free of charge on request	70% in 2010, although has been as high as 80%	6.71 tonnes	n.a. plant received the surplus which could not be treated in local compost facility

7 South Shropshire source segregated collection scheme – domestic premises

7.1 Background

Between January 2007 and March 2009 WRAP provided funding and technical support to 21 Local Authorities in England and Northern Ireland to carry out trials of the collection of food waste separately to green and residual waste. Although all slightly different, the key characteristics of all the trials were similar; provision of small separate containers (with liners and kerbside bins) collected on a weekly basis using a small, dedicated vehicle. South Shropshire District Council was granted funding to purchase liners, caddies and bins, and a dedicated electric vehicle for the collections. A dedicated food waste collection officer was appointed by South Shropshire District Council whose role was to co-ordinate the scheme and liaise between the participants, the Collection Contractor (Veolia) and the South Shropshire Biowaste Digester.

The efficiency, participation and public perception of the collection scheme was closely monitored by both WRAP (WRAP, 2009; MEL 2008a; 2009b) and South Shropshire District Council. Greenfinch Ltd (the contracted operators of the digestion facility) monitored the composition of the food waste in terms of its potential for biogas production and levels of contamination. Greenfinch also conducted a comprehensive participation rate survey during May 2010 (Section 9).

The scheme was initially introduced to 5277 households in Ludlow in May 2007. The scheme was extended in 2008 to include 1025 households in Craven Arms and 2012 households in Church Stretton (two small market towns approximately 14.6 and 27.0 km from Ludlow respectively; Figure 7.1.1). A separate commercial and industrial collection scheme was introduced in all three market towns in 2008 (Section 10).

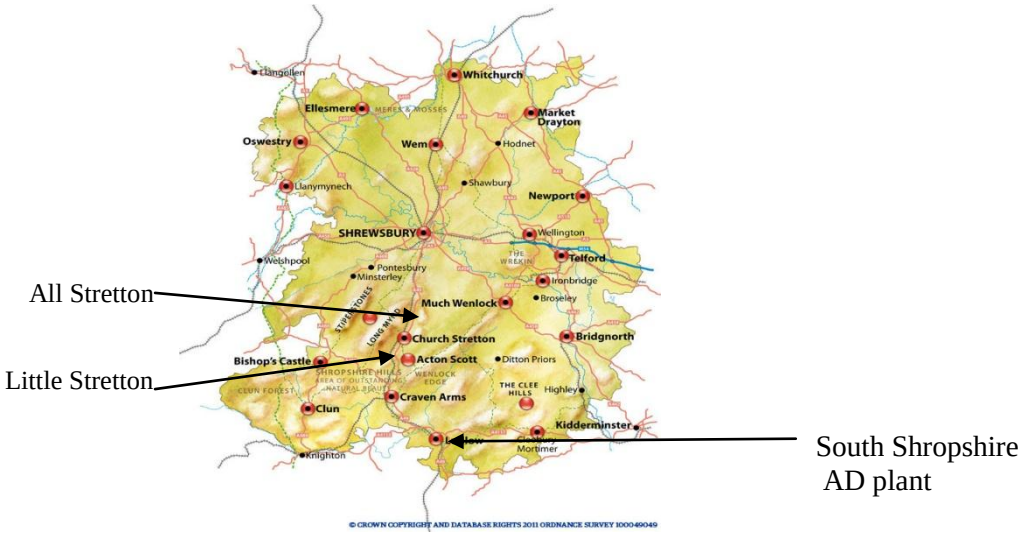


Figure 7.1.1 Location of the collection scheme areas

7.2 The South Shropshire Domestic Food Waste Collection scheme

Participation in the domestic collection scheme was on a voluntary basis. Premises were supplied with a 7-litre kitchen caddy, rolls of cornstarch biodegradable bags (which

conformed to the European Standard EN13432, and were available free of charge on request) and a 25-litre kerbside bin with a lid and a catch to restrict access by birds, animals and vermin. The cornstarch bag had handles and therefore once full the bag could be tied and deposited in the kerbside bin for collection which was on a weekly basis (Figure 7.2.1).

(a) cornstarch biodegradable bags

(b) 7-litre kitchen caddy

(c) filled bag placed in kerbside bin

(d) kerbside bin ready for collection showing clip to prevent access by vermin

Figure 7.2.1 South Shropshire domestic food waste collection scheme

Materials accepted by the collection scheme included: cooked and uncooked foods, fruit and vegetables, meat, fish, dairy (eggs and cheese), bread and bakery products, tea bags, and tea and coffee granules. Householders were asked not to include liquid materials (which had the potential to leak through the caddy liners), and were asked to remove all food waste from its original packaging.

7.3 Collection rounds

7.3.1 Ludlow

Ludlow is a small English market town in South Shropshire, close to the Welsh border (Figure 5.1.2; 7.1.1), and has a population of approximately 10,000 (2001 census). It has a reputation as being a centre of gastronomic excellence, and is beginning to develop a secondary reputation for being a 'green town' and a 'centre of environmental excellence' (including being home to 3 anaerobic digestion technology providers).

The food waste collection system was introduced to 5277 households in May 2007. The town was divided into 5 daily rounds of varying length and number of households (Table 8.3.1).

Table 7.3.1 Characteristics of the Ludlow food waste collection rounds

Round	No of households	Distance / km	Approx duration / hours	No of tips at South Shropshire AD plant
Monday (A)	1071	14.5	4	2
Tuesday (B)	1406	17.2	3.5	2
Wednesday (C)	1398	27	4	3
Thursday (D)	927	24.1	3.5	2
Friday (E)	475	12.8	3	1
Total	5277	95.7	18	

The collection scheme was operated by Veolia Environmental Services and a single-compartment dedicated electric vehicle (Figure 7.3.1) was used. The vehicle was charged overnight at the South Shropshire AD plant site and had a capacity to travel approximately 40 km when fully charged. The mileage on each round was small (<32 km; Table 7.3.1). The AD plant was adjacent to Veolia's depot and therefore the lorry tipped a number of times per round, the timing of which generally coincided with the crew's break time. The average speed of the electric vehicle was slow (<30mph) and therefore the routes avoided travelling on the A49 (the main trunk road running north – south throughout the county) and therefore the routes were not necessarily as short (or as optimal) as they might otherwise have been.

Figure 7.3.1 Electric powered vehicle used for the Ludlow collection rounds

7.3.2 Craven Arms and Church Stretton

Craven Arms is a small market town 14.5 km north of Ludlow (Figure 5.1.2), with a population of 2,289 residents (2001 census). Church Stretton is a similar sized town approximately 27 km north of Ludlow, with a population of 2,789. The latter collection round also included the adjacent settlements of Little Stretton and All Stretton with an additional population of 1397 (2001 census). The collection rounds for this region (also operated by Veolia Environmental Services) served 2012 households in Church Stretton and 1025 households in Craven Arms (Table 7.3.2).

A 7.5 tonne Isuzu single compartmented dedicated vehicle (Figure 7.3.2) with a fuel consumption of 0.22 litres per km was used for both rounds.

Table 7.3.2 Church Stretton and Craven Arms food waste collection rounds

Round	No of households	Distance / km	Approx duration / hours	No of tips at South Shropshire AD plant
Church Stretton - Monday	1099	82.5	5.5	1
Church Stretton - Tuesday	1003	68.1	6	1
Craven Arms Wednesday	1025	45.2	6.25	1
Total	3127	195.8	17.75	

7.4 Publicity and Public Awareness Campaigns

The Local Authority (supported by Greenfinch Ltd) conducted an extensive public awareness campaign both prior to the introduction and throughout the lifespan of the collection scheme in South Shropshire. The system was promoted to the householders through an introductory leaflet (Figure 7.4.1) and other publicity material in the local media (newspapers, journals, Local Authority newsletter, posters and radio adverts). A more detailed leaflet and a label for the kitchen caddy were provided to each household at the start of the scheme and a list of permitted materials was also printed on the caddy liner to act as a reminder (Figure 7.4.2).

Figure 7.4.1 Introductory leaflet provided to domestic users of the food waste collection scheme prior to its introduction

(a) (b)

Figure 7.4.2 Information provided to domestic users at the onset of the scheme. (a) detailed information leaflet; (b) reminder label on the kitchen caddy

Information regarding the tonnage of food waste processed, the electricity generated and the mass of biofertiliser created was frequently published in the Local Authority's quarterly newsletter, and most information bulletins from the Council also referred to the scheme and the digester. Press releases were also regularly made in a variety of local newspapers both highlighting the benefits of the scheme and reminding residents of any changes to the collection days. A comprehensive summary of the scheme and the permitted materials was published on South Shropshire District Council's website and a telephone hotline (a free telephone number) was also provided.

Greenfinch Ltd was also strongly participative in public engagement work, both encouraging participation in the scheme, ensuring householders were aware of which materials were permitted within the collection scheme, and also raising awareness of the technology and the facility. Greenfinch hosted numerous open days at the digester inviting local residents, community and youth groups as well as schools to see the process in action. A total of 3500 visitors were received at the site between 2006 and December 2010. Whilst time consuming for Greenfinch Research staff, the benefits of this work were twofold: Firstly, education of the public regarding anaerobic digestion and encouraging participation in the scheme (and therefore resulting in increased tonnage); and secondly, being able to show the participants of the scheme the potential problems which were caused by the presence of contamination in the feedstock. Feedback from these visits indicated that the public were very surprised by the simplistic nature of the front end handling system, and the inability to remove contaminants. From the onset of the scheme the contamination levels in the food waste were low (and certainly significantly lower than those of the co-mingled green and garden waste), however, the feedstock contamination levels were not quantitatively measured until the compositional analysis work undertaken by Greenfinch in 2010 (Section 12). Anecdotal evidence provided by the operational staff record a noticeable decrease in contamination levels following the introduction of open days and visits.

South Shropshire District Council and Greenfinch staff also regularly attended fairs, fetes, festivals and other local events (for example the Ludlow Food Festival, Ludlow Festival and the Green Fair) to promote the scheme. Stalls were frequently set up with information about the scheme and the digester and also included games, competitions, publicity material and free gifts (Figure 7.4.3). Staff also worked with the organisers in order to collect food waste from these events in a high profile manner in order to encourage future participation.

Although covering a wide area, South Shropshire is a close knit community which is very proud of its 'green credentials', and appears to be particularly proud of having the first anaerobic digester in the UK to process only source segregated food waste. Greenfinch Ltd is a well-respected, local business, with the majority of the staff living within the local community, or within 32 km of Ludlow. It is strongly believed that the combination of the interest from residents and the openness of the operators to engage with the local community significantly contributed towards the success of the scheme, and in particular, the low contamination rates.

Figure 7.4.3 South Shropshire DC and Greenfinch joint publicity stand at Ludlow Food Festival

The scheme ceased in September 2010 due to Local Authority financial constraints. The scheme was initiated by South Shropshire District Council prior to the creation of the Unitary Authority (Shropshire Council) in 2010, and therefore only covered the south of the County. Shropshire Council operated a co-mingled green and kitchen waste collection scheme and could not afford to introduce the weekly collection scheme Countywide. Politically, they could not operate two different collection schemes, and therefore, despite fierce opposition by the local inhabitants of South Shropshire, the collection scheme ceased in September 2010.

8 Comparison of participation rates in 3 South Shropshire towns

8.1 Background

Participation monitoring is a technique for monitoring the uptake of kerbside recycling schemes. It provides a count of the number of households that take part in a scheme over a pre-defined period of time (usually 3 consecutive weeks). It is a powerful tool which is useful for assessing the effectiveness of a collection scheme and identifying areas of disproportionately low participation.

8.2 Aims and objectives

The participation rate of the Ludlow collection rounds operated on Monday – Wednesday had previously been measured by (MEL 2008a; 2008b) at 4, 5 and 8 months following the introduction of the scheme. A second phase of participation monitoring was undertaken by Greenfinch Ltd in May 2010 (36 months after the start of the scheme).

The aims of the current participation monitoring survey were threefold:

- To determine the set out and participation rates of 5277, 2012 and 1025 households in the target areas of Ludlow, Church Stretton and Craven Arms respectively
- To determine the changes in participation rates with scheme maturity
- To determine the average weight of waste generated per served and participating household

8.3 Methodology

The two key performance indicators measured throughout these trials were set out rate and participation rate. Set out rate is defined as the percentage of households that put out (set out) their container out for collection in any one collection and is calculated as follows:

$$\frac{\text{Number of households presenting their bin for collection on a given day}}{\text{Number of households monitored on that day}} \times 100$$

Participation rate is defined as the percentage of households that put out their container for collection at least once in the whole monitoring period and is calculated as follows:

$$\frac{\text{Number of households recorded as setting out their bin at least once in a defined monitoring period}}{\text{Number of households monitored in that period}} \times 100$$

WRAP has published guidance on participation monitoring which is now seen as best practice this and was used throughout the trial (WRAP, 2010). The project brief was reviewed by a WRAP Monitoring Officer to ensure that it was scientifically and mathematically robust.

The WRAP guidance suggests that a minimum of 1100 monitorable households are required for each reported figure, with 1500 households being included in all surveys (to allow for some properties not being monitored or an incomplete data set). WRAP recommends that if a round consists of <2000 households then all should be surveyed, and if the round consists of >2000 households then a minimum of 1500 should be included. The survey should also incorporate a variety of socio-demographic profiles (as determined by ACORN / MOSAIC), housing types and ethnicities.

The number of households included in the food waste collection schemes within the 3 towns is given in Table 8.3.1. The number of households within the Craven Arms collection region was lower than the recommended sample size.

Table 8.3.1 Total number of households included in the South Shropshire food waste collection scheme

Sample location	**No of households**
Ludlow	5277
Church Stretton	2102
Craven Arms	1025
Total	8404

The ethnicity of South Shropshire residents is predominantly White British (98%) which is significantly higher than the average for both England (86.5%) and the West Midlands (86%). ACORN data (derived from the 2001 census) was provided by South Shropshire District Council, but could not easily be translated into the collection rounds with purchasing more data. Consequently, it was difficult to design survey rounds to include a variety of socio-demographic and ethnic profiles and therefore the decision was taken to survey all the properties within all three collection areas.

In order to ensure that the participation rate survey conducted was as accurate and statistically robust as possible the following recommendations of best practice (WRAP, 2010) were adhered too:

1. Collections were monitored for 3 consecutive collection periods spanning 3 weeks
2. The survey was undertaken following full consultation with the Local Authority, the Waste Collection Contractor (Veolia) and the Police
3. A series of meetings were held with Veolia Senior Management and Waste Collection Operatives to highlight the existence and the reasons for the trial and to ensure the full co-operation of the collection crews. This included identifying 'unofficial changes' to the collection order, location of breaks, timings of returning to base tipping loads etc.
4. The timing of the survey was chosen to avoid specific or unusual events, although unavoidably it did include a bank holiday (although not a school half term). Data from Veolia suggested that the collection system was so well established that bank holidays rarely affected participation
5. The Survey Manager and Survey Staff were all local residents with extensive local knowledge of the area. The rounds were walked by all members of the team to ensure that they were familiar with the route order and that all properties could be identified
6. In communal dwellings where it was not possible to identify which households were participating were excluded from the survey
7. A core team performed all analyses to ensure consistency
8. The survey solely measured participation – contamination or waste quantity assessments were not performed. Feedback from the collection crews suggested that very few bins (<0.05%) were ever rejected due to contamination, but agreed to record those which were rejected for the duration of the trial
9. Households which presented waste in an alternative form (i.e. a bag, kitchen caddy or box) or presented more than 1 bin on any one occasion were counted as participating, but a note was made of the mode of presentation
10. There were no assisted collections within the survey region
11. In order to capture 'late presenters' (households who put out their bin when they hear the collection vehicle) the survey staff walked just in front of the collection crews
12. Only one survey staff member was required for the majority of the rounds in Ludlow, however, two were used in roads where the collection crews separated and used slave bins. Surveys undertaken in Church Stretton and Craven Arms also required two survey monitors due to the remote location of many of the dwellings (1 driver and 1 monitor)
13. Strict quality control procedures were enforced throughout the study period:
    a. The monitor liaised with the collection staff prior to each round
    b. On completion of the survey the key researcher went through the rounds with the monitor to identify discrepancies, check monitoring records and download any observations
    c. All data was inputted into a computer database within 24 hours of collection
    d. A random 15% of entries where independently checked against the monitoring sheets for accuracy of data entry. Where errors were identified all data was checked
    e. Monitoring responses were recorded as:
        1 = set out
        2 = not set out
        E = delete (i.e. not monitored or couldn't be found). All households recorded as E were deleted from the entire survey.

The majority of dwellings in Ludlow, Church Stretton and Craven Arms were single occupancy, terraced, semi-detached or detached dwellings with drives, or with specific locations for householders to set out their bins (Figures 8.3.1 and 8.3.2). In these instances the bins could be easily attributable to individual premises. There were a small number of dwellings with shared refuse facilities (for example blocks of sheltered accommodation for the elderly) where it was not possible to determine which households were participating and therefore these were removed from the analysis (Figure 8.3.3). There were also a number of apartment blocks in the centre of town where the bins were in locked storage units (Figure 8.3.4) for security. The participation monitors were not able to work alongside the collection crews as they unlocked all the bins on every monitoring occasion, and therefore these premises were also excluded from the analysis.

Figure 8.3.1 Participation monitoring


Figure 8.3.2 Typical town centre and housing estate dwellings included in the Ludlow, Church Stretton and Craven Arms collection rounds. The origin of the waste were very obviously identifiable


Figure 8.3.3 Examples of multiple occupancy dwellings in Church Stretton and Craven Arms. The origins of the waste was unidentifiable in these situations and therefore the premises were removed from the participation survey

Figure 8.3.4 Locked refuse bin storage

8.4 Statistical analysis

All statistical analyses were undertaken using Minitab 16. The data was tested for a difference between the mean values of groups of data, classified with respect to one factor, and therefore the One-Way Analysis of Variance test (ANOVA) was used.

A One-Way ANOVA table was computed using the data being tested, which provided the residuals of the data (i.e. the deviations of the data from the mean values). These residuals were tested for normality of distribution using the Anderson-Darling test; if the P value generated ≥ 0.05 then the residuals were normally distributed, if $P<0.05$ the residuals were not normally distributed and one of the assumptions of ANOVA had been violated. The data was

also tested for Equal Variances by performing the Bartlett's test, with a P value of ≥0.05 indicating homogeneity of variances and P <0.05 indicating non homogeneity.

When the residuals were normally distributed and the variances homogeneous, the data did not require transformation. However, when either of the assumptions of ANOVA were violated the data required logarithmical transformation. If after the data was transformed the variances were homogeneous and the data was normally distributed, an ANOVA was performed using the transformed data and interpreted as normal. If after transformation the data still violated the assumptions of ANOVA, the Kruskal-Wallis test (an alternative non-parametric test) was used.

One-Way ANOVA only indicates an overall significant difference between mean values, to enable a pair-wise comparison of mean values the Tukey-Kramer *A Posteriori* test (TK-AP) was used. This test indicated if one particular mean value was significantly different from the other mean values; there was a significant difference if the Confidence Intervals both had the same sign.

The non-parametric Kruskal-Wallis (KW) test generated a P value which indicated whether there was a significant difference between mean values or not. If P>0.05 then the null hypothesis of no significant difference between medians was accepted, and if P≤0.05 the null hypothesis was rejected. For this test there was no pair-wise comparison of medians equivalent to Tukey-Kramer test, and therefore to identify significant differences between pairs of medians the One-tailed Mann-Whitney test (MW) was used. Each pair of medians was tested individually, with a P value of >0.05 indicating no significant difference between the two median values, and if P≤0.05 the null hypothesis was rejected as there was a significant difference between the 2 data sets.

8.5 Participation and set out rate in Ludlow, Craven Arms and Church Stretton

8.5.1 Background

The aims of this section of the study are given in Section 9.2. In order to determine the changes in participation rate with the maturity of the collection scheme, participation was measured 1, 5, 8 and 36 months after the scheme commenced (Table 8.5.1). Data for phases 1, 2 and 3 of the study was collected and published by MEL Research Ltd (2008a; 2008b), with phase 4 data being collected by Greenfinch Ltd.

During May 2010 (phase 4) participation rates were additionally determined for the towns of Church Stretton and Craven Arms (Table 8.5.1). The aim of this study was to determine whether there was a significant difference in the participation rates for the 3 market towns. Differences between participation rates for individual collection rounds within all 3 towns were also determined, as were the set out rates for each collection round, with comparisons being made to investigate any differences in the set out rates for the same collection rounds on different weeks.

8.5.2 Effect of scheme maturity on participation and set out rates for Ludlow

Participation rates were determined 1, 5, 8 and 36 months after the start of the collection scheme (Table 8.5.1). Data for phases 1, 2 and 3 data was collected by MEL Research Ltd (MEL 2008a; 2008b), and phase 4 data was collected by Greenfinch Ltd. The analysis

undertaken by Greenfinch Ltd analysed the whole collection scheme; however, the MEL scheme only monitored 3 collection rounds (Monday - Wednesday inclusive) and therefore comparisons for the Thursday and Friday collection rounds over the scheme duration were not possible.

Table 8.5.1 Timetable for data collection in Ludlow

PHASE 1 (1 month after start of scheme)			
Week Commencing	**25/06/2007**	**02/07/2007**	**09/07/2007**
Monday	Round A	Round A	Round A
Tuesday	Round B	Round B	Round B
Wednesday	Round C	Round C	Round C
Thursday	*		
Friday	*		

PHASE 2 (5 months after start of scheme)			
Week Commencing	**15/10/2007**	**22/10/2007**	**29/10/2007**
Monday	Round A	Round A	Round A
Tuesday	Round B	Round B	Round B
Wednesday	Round C	Round C	Round C
Thursday	*		
Friday	*		

PHASE 3 (8 months after start of scheme)			
Week Commencing	**21/01/2008**	**04/02/2008**	**11/02/2008**
Monday	Round A	Round A	Round A
Tuesday	Round B	Round B	Round B
Wednesday	Round C	Round C	Round C
Thursday	*		
Friday	*		

PHASE 4 (36 months after start of scheme)			
Week Commencing	**03/05/2010**	**10/05/2010**	**17/05/2010**
Monday	Round A	Round A	Round A
Tuesday	Round B	Round B	Round B
Wednesday	Round C	Round C	Round C
Thursday	Round D	Round D	Round D
Friday	Round E	Round E	Round E

* Data not available.

Approximately 1000 households were included in the Monday and Thursday collection rounds (Table 8.5.2). The collection rounds on Tuesday and Wednesday were approximately 1500 households each, and Friday's round was considerably smaller (500 households). A significant increase in the number of houses served by the scheme can be observed in Phase 4 compared to phases 1 - 3. This is mainly due to the additional monitoring of Thursday's and Friday's collection rounds, however, compared to Phase 3 an additional 300 houses had also been added to the Tuesday collection round, with moderate increases in the Monday and Wednesday rounds.

Table 8.5.2 Number of households monitored per collection round for each phase in Ludlow

	Sample size			
Collection round	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**
Monday (round A)	1055	1044	1030	1071
Tuesday (round B)	1091	998	1033	1406
Wednesday (round C)	1380	1312	1334	1398
Thursday (round D)	*	*	*	927
Friday (round E)	*	*	*	475
Overall	3526	3354	3397	5277

* Data not available.

The participation and set out rates (Section 9.3) were calculated for all four phases. The overall participation rates for Ludlow are given in Figure 9.5.1. There is no significant difference between rates within phases 1, 3 and 4. However, the participation rate for phase 2 is significantly higher than that for the other phases (MW, P values listed in Table 8.5.3). This is attributed to an extensive publicity campaign carried out by the Local Authority during the summer of 2007.

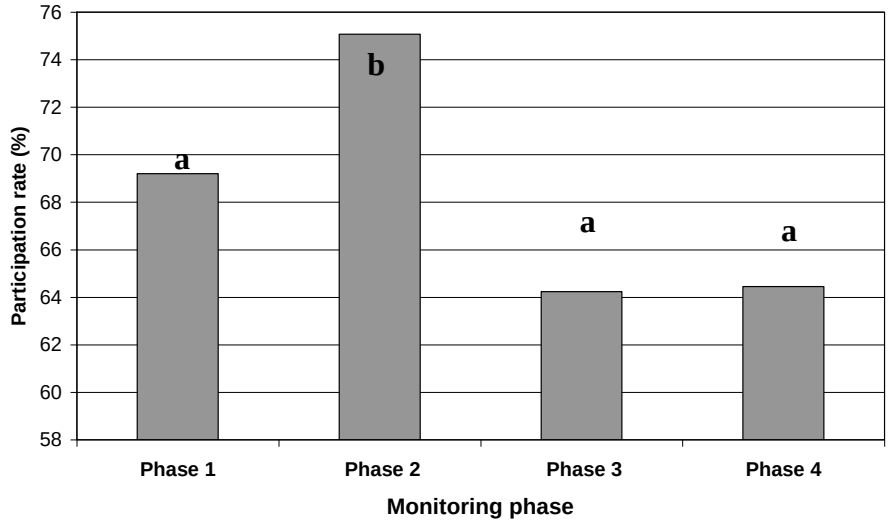


Figure 8.5.1 Overall participation rate for the four phases of the study Ludlow. (For each column labelled with the same letter there is no significant difference (P<0.05))

Table 8.5.3 P values for comparison of overall participation rate for the four phases of the study in Ludlow

	Phase 1	***Phase 2***	***Phase 3***	**Phase 4**
Phase 1	-	<0.005	>0.05	>0.3
Phase 2	-	-	<0.001	<0.005
Phase 3	-	-	-	>0.1
Phase 4	-	-	-	-

Figure 8.5.2 shows the participation rates for the Monday, Tuesday and Wednesday collection rounds over all 4 phases of the monitoring period. There was no significant variation in the number of households participating in the scheme over the scheme duration for the Tuesday (KW, P=0.420) or Wednesday (KW, P=0.052) collection rounds. There was however a significant difference between participation rates over time for the Monday

collection round (Figure 8.5.2a; Table 8.5.4), with the rate during phase 3 being significantly lower than in other phases. There was no apparent reason for this temporary decrease.

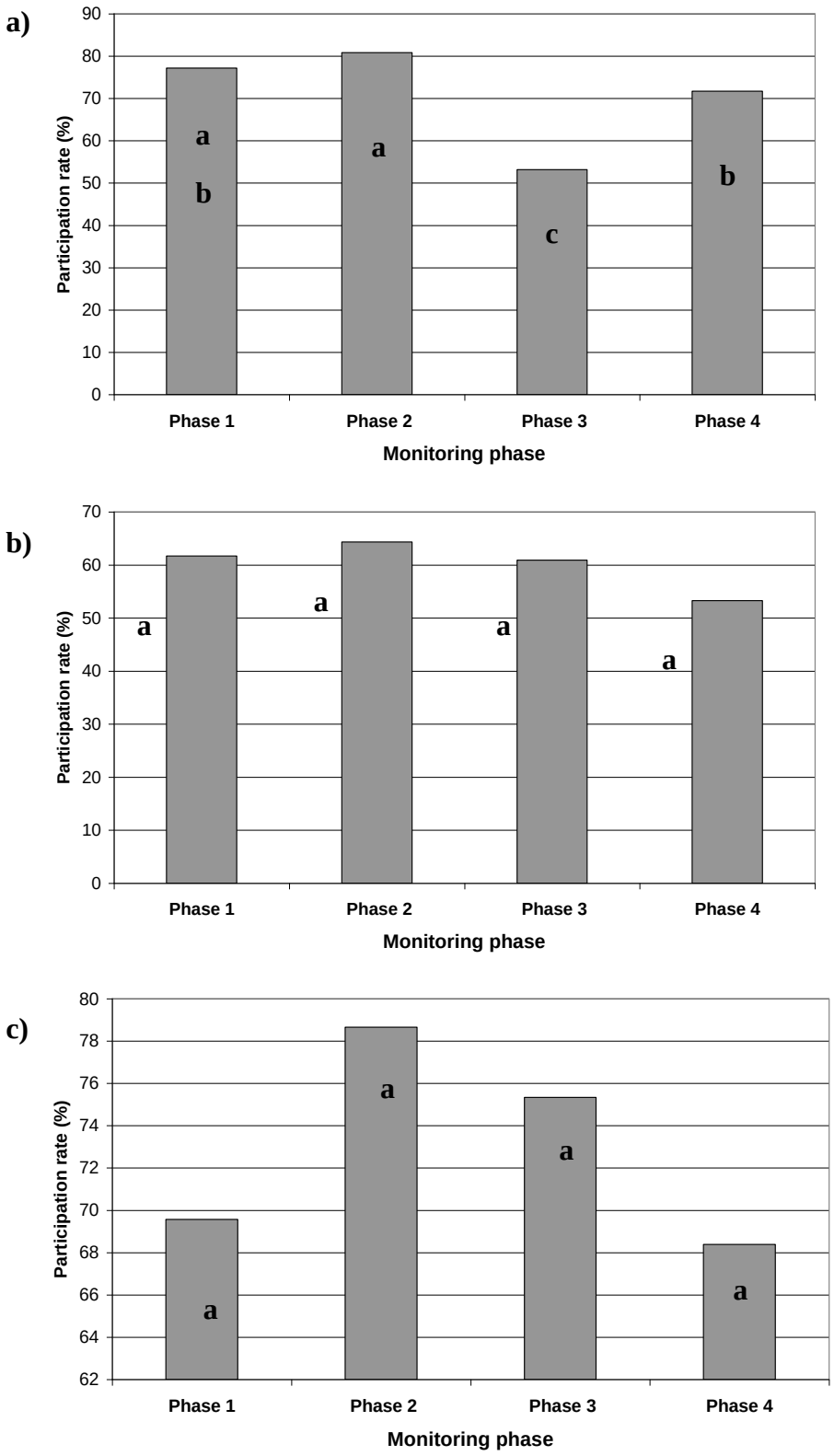


Figure 8.5.2 Participation rate for collection rounds for the four phases of the study in Ludlow, (a) Monday's round, (b) Tuesday's round, (c) Wednesday's round. (For each column labelled with the same letter there is no significant difference ($P<0.05$))

Table 8.5.4 P values for comparison of Monday's participation rate for the four phases of the study in Ludlow

	Monday Phase 1	***Monday Phase 2***	***Monday Phase 3***	**Monday Phase 4**
Monday Phase 1	-	>0.2	<0.001	>0.05
Monday Phase 2	-	-	<0.001	<0.05
Monday Phase 3	-	-	-	<0.001
Monday Phase 4	-	-	-	-

8.6 Comparison of participation and set out rates for Ludlow, Church Stretton and Craven Arms (Phase 4)

8.6.1 Ludlow

The set out and participation rates of all the households served by the weekly food waste collection scheme in Ludlow, Church Stretton and Craven Arms were determined in May 2010 (phase 4). A total of 5 collection rounds were operated in Ludlow, whilst collections in Church Stretton and Craven Arms consisted of 2 and 1 rounds respectively (Table 8.6.1).

Table 8.6.1 Timetable for data collection in Ludlow, Church Stretton and Craven Arms for phase four of the study

LUDLOW			
Week Commencing	**03/05/2010**	**10/05/2010**	**17/05/2010**
Monday	Round A	Round A	Round A
Tuesday	Round B	Round B	Round B
Wednesday	Round C	Round C	Round C
Thursday	Round D	Round D	Round D
Friday	Round E	Round E	Round E
CHURCH STRETTON			
Week Commencing	**03/05/2010**	**10/05/2010**	**17/05/2010**
Monday	Round A	Round A	Round A
Tuesday	Round B	Round B	Round B
CRAVEN ARMS			
Week Commencing	**03/05/2010**	**10/05/2010**	**17/05/2010**
Wednesday	Round C	Round C	Round C

Table 8.6.2 shows the number of households which were served by the weekly food waste collection scheme and were therefore monitored in this study. A significantly larger number of houses were served by the collection scheme in Ludlow (5277 houses) than in both Craven Arms (1025) and Church Stretton (2102). Ludlow had both the largest and smallest collection rounds, with 1406 houses included on Round B (Tuesday) and 475 houses included on Round E (Fridays).

The overall participation rates for Ludlow, Church Stretton and Craven Arms were 69%, 75% and 64% respectively (Figure 8.6.1) which were not significantly different (KW, P>0.05). The variation in the participation rate for the five different collection rounds in Ludlow during phase 4 is given in Figure 8.6.2. The participation rate for Tuesday's collection round was significantly lower than the participation rate of all the other four rounds (MW, P values

listed in Table 8.6.3); however there is no obvious explanation for this. The ACORN profile drawn up for the collection rounds indicates that the Monday round contained the highest proportion of residents that are 'hard pressed', Tuesday had the highest proportion of residents that are 'comfortably off' and Wednesday had the highest proportion of residents that are 'wealthy achievers' (MEL, 2008a). Previous studies have shown that the 'hard pressed' residents are least likely to recycle (MEL, 2008a).

Table 8.6.2 Number of houses monitored per collection round during phase 4 in Ludlow, Church Stretton and Craven Arms

	Sample size		
Collection round	**Ludlow**	**Church Stretton**	**Craven Arms**
Monday (round A)	1071	1099	-
Tuesday (round B)	1406	1003	-
Wednesday (round C)	1398	-	1025
Thursday (round D)	927	-	-
Friday (round E)	475	-	-
Overall	5277	2102	1025

Table 8.6.3 P values for comparison of participation rates of the five collection rounds in Ludlow in phase 4 of the study

	Monday	***Tuesday***	***Wednesday***	***Thursday***	**Friday**
Monday		<0.05	>0.3	>0.1	>0.4
Tuesday			<0.05	<0.005	>0.1
Wednesday				>0.05	>0.4
Thursday					>0.2
Friday					

The average set out rate for each collection round in Ludlow during phase 4 of the study is given in Figure 8.6.3. (Error bars display the standard deviation for the set out rate for each collection round). When each collection round is observed in isolation it can be seen that each had a small standard deviation indicating little significant difference between the set out rates for individual rounds during week 1, 2 and 3 (KW, $P>0.05$). The same trend is evident for the set out rates for all other collection periods (KW, $P>0.05$ for all collection days).

8.6.2 Church Stretton

The participation rates for the Monday (Round A) and Tuesday (Round B) collection rounds in Church Stretton were compared. The participation rates were 62.15% (Monday) and 64.01% (Tuesday) and therefore there was no significant difference between the rates for the two rounds during phase 4 of the study (KW, $P>0.5$).

The set out rate for Church Stretton's Monday collection round over the duration of the 3 week study is presented in Figure 8.6.4. The set out rate on Monday week 1 was significantly greater than that of week 2 (MW, $P<0.001$) and week 3 (MW, $P<0.05$). However, there was no significant difference between the set out rate for weeks 2 and 3 (MW, $P>0.05$), nor was between the set out rates on week 1, 2 or 3 for the Tuesday collection round (KW, $P>0.4$).

8.6.3 Craven Arms

Figure 8.6.5 illustrates the set out rates in Craven Arms over the three week period of the study. There is no significant difference between set out rate for week 1 and week 2 (TK-AP, Tukey 95% Confidence Intervals range from negative to positive, and pass through zero), and no significant difference between set out rate for week 2 and 3 (TK-AP). The set out rate for week 1, however, was significantly lower than that of week 3 (TK-AP). No comparison between participation rates for the collection rounds in Craven Arms could be made as there was only one collection round in this town.

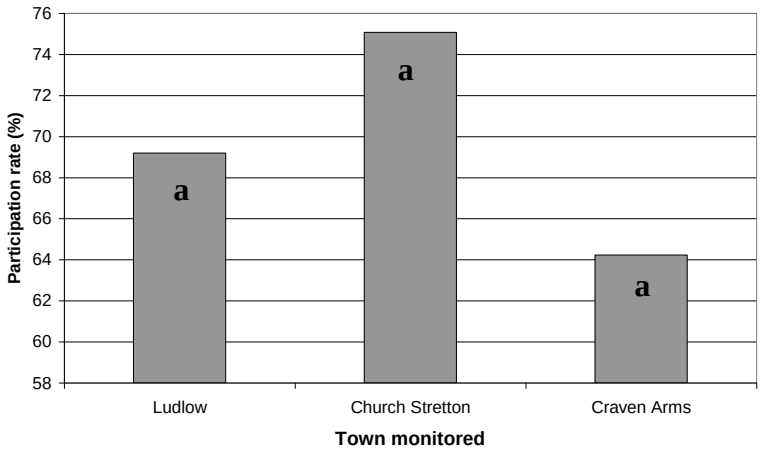


Figure 8.6.1 Overall participation rate for Ludlow, Church Stretton and Craven Arms during phase 4 of the study. (For each column labelled with the same letter there is no significant difference (P<0.05))

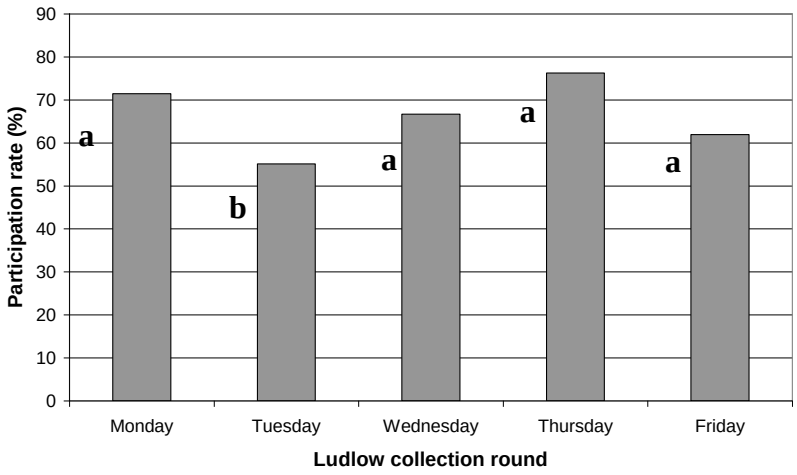


Figure 8.6.2 Participation rate for the different collection rounds in Ludlow during phase 4 of the study. (For each column labelled with the same letter there is no significant difference (P<0.05))

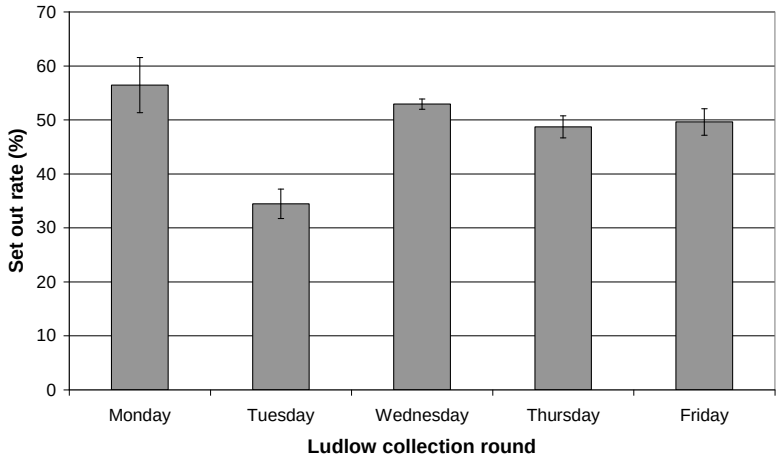


Figure 8.6.3 Average set out rate for the different collection rounds in Ludlow during phase 4 of the study. (Error bars show standard deviation)

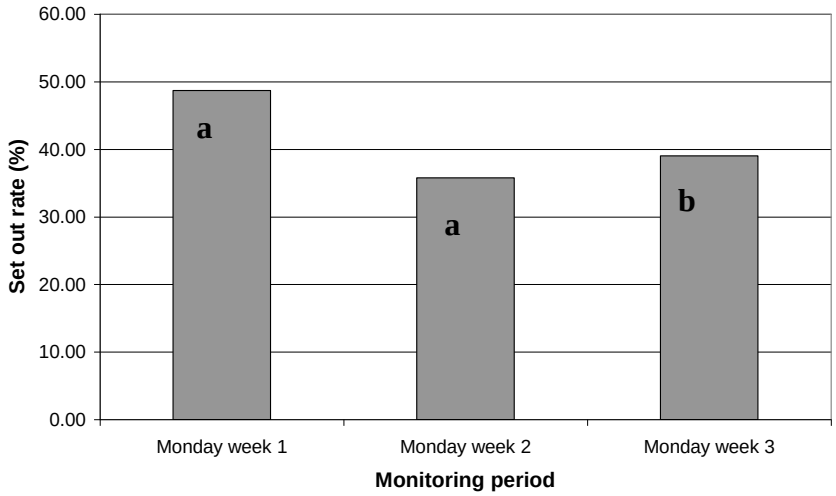


Figure 8.6.4 Set out rate for Monday's collection rounds in Church Stretton over the three weeks of the study. (For each column labelled with the same letter there is no significant difference (P<0.05))

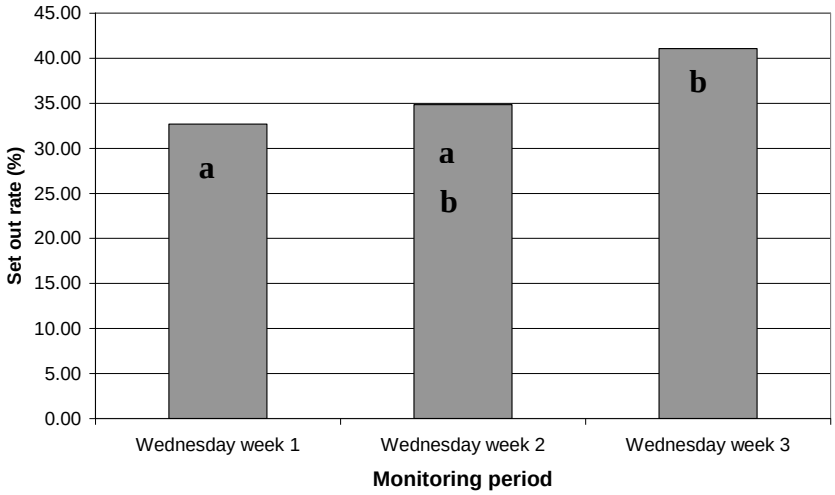


Figure 8.6.5 Set out rate for Wednesday's collection rounds in Craven Arms over the three weeks of the study. (For each column labelled with the same letter there is no significant difference (P<0.05))

8.7 Average waste per participating household

The average weight of food waste collected per household served and per participating household was calculated for collection rounds A-D (Monday – Thursday) for the Ludlow study (Table 8.7.1). Craven Arms, Church Stretton and the Ludlow Friday round were excluded from this analysis due to the co-collection of domestic and commercial waste on the same vehicle and therefore the weight of the waste derived from the domestic properties could not be accurately determined.

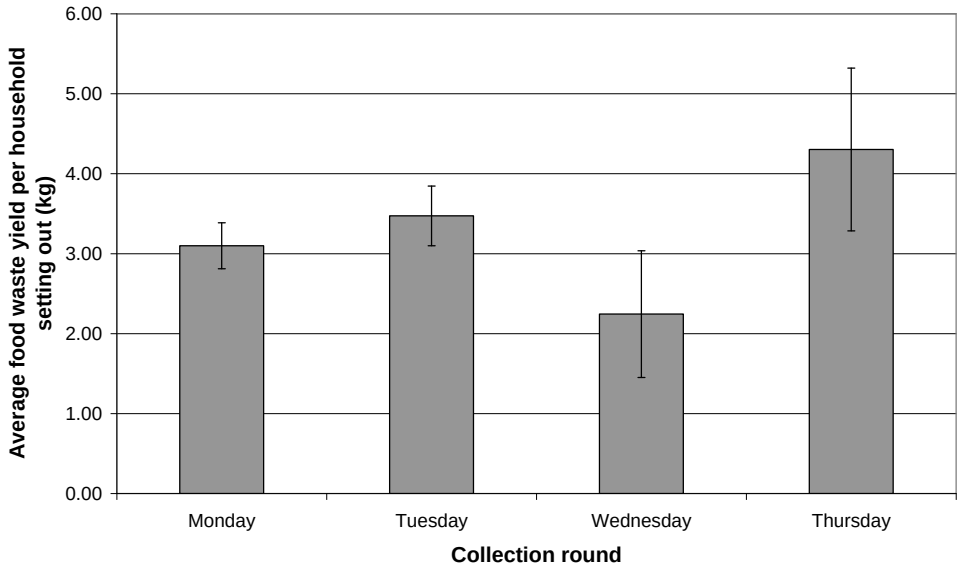


Figure 8.7.1 Average food waste collected per served household and participating household (Ludlow Monday – Thursday rounds only)

Table 8.7.1 Average food waste collected per served household and participating household (Ludlow Monday – Thursday rounds only)

Collection round	Food waste collected/ (kg)	Number of HH served	Average number of HH setting out	Average yield per served HH (kg/HH-week)	Average yield per HH setting out (kg/HH-week)
Monday	5,600	1071	604	1.74	3.10
Tuesday	5,040	1406	484	1.19	3.47
Wednesday	5,000	1398	740	1.19	2.24
Thursday	5,860	927	451	2.11	4.30

The error bars indicate the standard deviation in the food waste generation yields. There was very little variation in the generation rates for the Monday and Tuesday collection rounds. The error bars indicate a larger amount of variation in the yields generated in the Wednesday and Thursday collection rounds, however, there was no significant difference between the yields (ANOVA, $P<0.05$).

The average yield of food waste per household served (1.56 kg/HH-week) was inevitably considerably smaller than the average yield of food waste per participating household (3.27

kg/HH-week). The yield generated by the Thursday collection rounds was significantly greater than that generated by households on the Monday – Wednesday collection rounds.

Average household food waste yields determined by WRAP (WRAP, 2009) vary from 1.12 kg/HH-week (Luton) to 1.89 kg/HH-week (Mid Bedfordshire) (Table 8.7.2), which are significantly lower than the yields generated in the current Ludlow study are significantly higher. The WRAP (2009) study also determined the yield per participating household in Ludlow (in 2007) to be 2.10 kg/HH-week suggesting that the average yield increased throughout the duration of the trial. This contradicts anecdotal evidence suggesting that separate food collection schemes make householders more aware of their food waste generated (and its potential cost implications),householders therefore alter their purchasing habits thereby decrease food waste yields overtime (Joy Blizzard, LARAC, *personal communication*).

Table 8.7.2 Average food waste collected per household served per week in UK WRAP supported trials (Source: WRAP, 2009)

Local Authority	Average yield, kg/HH-week	Local Authority	Average yield, kg/HH-week
Belfast	1.09	Mid Beds	1.89
Croydon	1.64	Oldham	1.22
Guildford	1.70	South Shropshire	2.10
Luton	1.12	West Devon	1.48

8.8 Survey of attitudes and perceptions of the Ludlow food waste collection scheme

8.8.1 Background

In September 2007 an attitudinal survey was conducted in order to determine the perceived usage of the scheme and to ascertain residents' opinions and perceptions. The survey (commissioned by WRAP and conducted by EL) interviewed 600 respondents who were responsible (or jointly responsible) for waste disposal and recycling in their household. Respondents were identified according to their age and ACORN category in order to provide a sample which was representative of the population within the collection area.

8.8.2 Key results

A total of 88% of respondents claimed to use the service on every collection opportunity; 6% stated they used it sometimes; 5% never used it and 1% stated that they no longer used it (MEL, 2008a).

The number of respondents claiming to use the scheme on every available occasion (88%) is significantly higher than the participation rate (number of householders using the service on one or more occasions during a 3 week monitoring period) recorded in June and October 2007 (69% and 77% respectively; MEL, 2008b) and May 2010 (69%; Section 9.6.1.1). Exaggeration of claimed usage is widespread within the UK, and is evident in surveys within Denbighshire, Carmarthenshire and Rhondda Cynon Taf (MEL, 2011), and a number of other collection surveys within the UK (Keith Riley, Veolia, *personal communication*).

A total of 5% of residents within the Ludlow region claimed 'never' to use the service, with a further 6% using it 'sometimes'. The most common reason cited for non-participation was 'a

lack of material requiring disposal' (25% of respondents claiming never to use the scheme). Practical reasons, for example the collection of food waste is 'too messy', 'generates flies', 'attracts vermin' or 'generates an odour' were cited by 16% of Ludlow non-participants, with other residents claiming that they did not have enough space for the collection containers (4%), they home composted or used a home waste disposal system (5%). Similar conclusions were drawn by MEL in the Welsh 3 Counties trial (MEL, 2011).

A total of 88% of Ludlow residents reported that they were very satisfied with the collection scheme and had not experienced any problems. A total of 7% of respondents claimed that they had contacted the Local Authority for more information or to complain about the service (MEL, 2008a). The MEL (2011) survey reported that 75% of Welsh residents were satisfied with their collection scheme, with 20% reporting the need to contact the Council or Waste Contractors. South Shropshire District Council had consulted widely prior to the introduction of the scheme, and these results indicate that once rolled out, the scheme was generally trouble free. Both studies cited very similar behavioural (food waste generates odours, attracts vermin and flies) and situational (bags splitting, missed collections) problems as reasons why householders were not satisfied with the scheme.

In excess of 83% of the Ludlow respondents claimed that the weekly source segregated food waste collection scheme was better (83%) and easier to use (90%) than the collection of food waste in the alternate weekly wheeled bin system (MEL, 2008a).

A major driver of the WRAP 'Love Food, Hate Waste' campaign (www.WRAP.co.uk) was to raise awareness of the amount and cost of food waste generated by householders, and to encourage more responsible meal planning, purchasing and storage in order to decrease food waste generation. Anecdotal evidence from (Joy Blizzard, *personal communication*) is that separating food waste from residual waste highlights the amount generated and leads to a reduction in purchasing and alteration of eating habits (thereby resulting in a decrease in food waste generated). In contrast to this, 91% of respondents in the Ludlow survey (MEL, 2008a) and 87% of respondents in the Welsh survey (MEL, 2011) claimed that the separate collection systems had not changed the amount of food they purchased.

9 Comparison with participation rates in other UK Local Authorities

The participation rate for the weekly source separated food waste collection rounds in Ludlow, Church Stretton and Craven Arms recorded in May 2010 were 69%, 75% and 64 % respectively (Section 9.6.1.1) and are not significantly different (KW,P>0.05).

WRAP provided financial and technical support to 21 Local Authorities to carry out 2 year source separated food waste collections (2007 – 2009). Determination of participation rate was an important part of this research, and the average participation rates for a selection of these trials are listed in Table 9.1 (source; WRAP, 2009).

The participation rate for the Ludlow, Church Stretton and Craven Arms rounds compare very favourably with those of the other WRAP-funded schemes, and are significantly higher than those of a number of the trials. The Kingston upon Thames and Newtownabbey schemes were 'multiple occupancy - bring schemes' where householders were required to bring their food waste to a centralised collection area. It is well known that this genre of collection scheme attracts a lower participation rate than a kerbside collection scheme (Joy Blizzard, LARAC, *personal communication*).

Table 9.1 Average participation rates in weekly source separated food waste collection schemes (2007 – 2009) (Source: WRAP, 2009)

Trial area	*Participation rate / %*	*Trial area*	Participation rate / %
Kingston upon Thames	21.30	Preston	55.99
Newtownabbey	28.30	West Devon	66.44
Newcastle upon Tyne	43.95	East Devon	70.50
Belfast	45.60	Guildford	71.28
Luton	52.32	Croydon	71.45
Waveney	52.63	Mid Bedfordshire	71.48

The South Shropshire Biowaste Digester also receives waste from Newtown (Montgomeryshire) and Presteigne (Table 5.1.1; Figure 5.1.2). The participation rates within these two schemes were measured on an annual basis by the Waste Contractor (Cwm Harry Land Trust, CHLT) and were 70% (35 – 85%, n = 3 years) and 93% (90 – 98%, n =2) years respectively (David Clark, CHLT, *personal communication*). The participation rate in the Presteigne scheme is exceptionally high and is significantly higher than any of the schemes included in the WRAP survey (WRAP, 2009); however, it is believed that a public commitment to achieve a common goal is a significant factor in the participation rate. Presteigne's local Councillors and residents unanimously voted to work towards 'Zero Waste Community' status, whereby 'all discarded materials are designed to become resources for others. Products and processes are designed to systematically avoid and eliminate volume and toxicity of waste, conserve and recover resources and not to send any material to landfill or incineration' (Zero Waste Places). The collection and processing of food waste in an environmentally sustainable manner is considered to be critical to the implementation of Zero Waste, and therefore the scheme has a huge 'by-in' from the local community. The collection scheme is unique in that it is managed and staffed by local residents. The collection rounds are small (approximately 250 households per day), and one of the roles of the collection staff is to engage with the residents, both promoting the scheme and encouraging participation. It is believed that this has had a direct impact on the participation rate.

10 Ludlow commercial collection round

10.1 Background

The food waste collection scheme was extended to include commercial premises in Ludlow from January 2008 and in Church Stretton and Craven Arms from August 2008. These premises included food processing outlets, cafés, pubs, restaurants, hospitals, residential / care homes, shops and schools / colleges. Collections were free of charge, and were available up to 3 times per week. However, the standard collection frequency was once or twice per week and commercial premises had to justify the need for multiple collections to the Local Authorities Food Waste Officer.

Premises were supplied with a kerbside collection bin of a size suitable for their individual needs (between 25 – 240 litres), a 25-litre kitchen bin (identical to the household kerbside collection bins) and rolls 25-litre cornstarch biodegradable bags (available free of charge on request). Lockable kerbside bins were provided to premises with shared or open access bin storage in order to prevent contamination (Figure 10.1).

Figure 10.1 South Shropshire commercial food waste collection scheme

In Ludlow the collections were undertaken by Cwm Harry Land Trust using a small, dedicated vehicle. In Church Stretton and Craven Arms food waste was collected from the commercial premises at the same time as the domestic waste and was therefore collected in a bigger vehicle.

The collection scheme in Ludlow was undertaken within a dedicated vehicle; however the collection from commercial and domestic premises in both Church Stretton and Craven Arms was undertaken on the same round (using the same vehicle). The size of bins (and therefore bags) which were used by individual premises was determined by the amount of waste generated and varied from 7-litre – 25-litre bags. It was therefore not possible to accurately determine the origin of waste and therefore it was not possible to undertake compositional analysis on either waste stream.

The collection schemes in all three towns were offered to the premises free of charge. As such, the Waste Contractor was not obliged to quantify the amount of waste generated per premises or operate an RFID (radio frequency identification detection) system. In order to ascertain that the collection frequency and the bin sizes were appropriate for use, the Waste Contractor visually estimated the amount of waste presented on a monthly basis. However, these values were not determined on a regular basis and were only visual estimates and so were not considered reliable enough to present within this report

11 Compositional analysis data

11.1 Background

Data on food waste composition and characterisation within the UK and across the EU is fragmented; studies have utilised a wide variety of methodologies, resulting in little comparative data (Lebersorger and Schneider, 2011; Langley et al., 2010; Parfitt et al., 2010). Within the UK, WRAP has estimated the tonnage of potentially available food waste and has undertaken some large scale compositional analysis (WRAP, 2008a; 2009b). However, little research has been undertaken to determine the biogas potential and nutrient concentrations of these varying waste streams. Furthermore, quantification of contamination in waste is particularly pertinent to both AD operators and Local Authorities, yet little comparative, published research has been undertaken.

The aim of the current study was to determine and compare the composition of household source segregated food waste arising in collection schemes serving the South Shropshire

Biowaste Digester. The study specifically focussed on the fractions of waste which would significantly contribute towards biogas production, and to determine the genre and level of contamination. Waste audits were undertaken on multiple occasions and from a variety of rounds within specific regions to determine the variation in waste at a local and national scale. The physio-chemical composition of the material was also determined (Section 14).

11.2 Waste categorisation

There is not currently an International Standard method for conducting household food waste compositional analysis (Dahlen and Lagerkvist, 2008). WRAP has developed an extensive categorisation system containing 174 food types, combined into 13 major categories. This system was considered to be too complex and unnecessarily detailed for the purpose of the current study; however, the principles of the categorisation system were adopted, with some adaptations made to make the categories more pertinent to the focus of the research. Whether the waste was avoidable, unavoidable, partially consumed, wholly unused or its preparation state was irrelevant to this study and therefore was not considered. The waste categorisation system used in the current study (compared to that recommended by WRAP) is given in Table 11.1. (For further comparisons see also VALORGAS deliverable D2.1).

The WRAP system considers fruit, vegetables and salad materials separately; however, it is assumed that the biodegradability of these materials is similar. Therefore two categories were allocated: fruit and vegetables waste (cores, peelings, uneaten residues) and whole fruit and vegetables. Cereal was categorized separately out from pasta, rice and flour. A sub-category 'bones' was added to meat and fish. Although bones are excluded from many collection systems, however, they are included on those serving South Shropshire AD plant. Their biodegradability and biogas potential of bones is low, they can cause excessive wear and tear to the teeth of shredding and maceration equipment and furthermore they have been noted to form a significant proportion of 'grit' which settles in pipes, pumps and at the base of tanks. For these reasons bones are frequently rejected in the digestion pre-screening process (BiogenGreenfinch, standard operation procedures). An additional sub-category of 'large stones, seeds and fibrous materials' was added and 'eggs and egg shells' were excluded from the WRAP sub-category 'Dairy' for the same reasons. Desserts and cakes were removed from their own sub-category and added to bakery for simplicity on the basis that their biodegradability and biogas production is assumed to be similar. The early analytical work considered waste from the South Shropshire region (Ludlow, Church Stretton and Craven Arms). This material was very fresh (less than a week old), was delivered to the digester on the day of collection, and was not significantly compacted in transit. Therefore virtually all the components (even those of a 'dinner' or 'meal') could be separated out. Food waste derived from other areas (particularly Flintshire, Somerset and Ceredigion) had frequently been stored at waste transfer stations prior to delivery. This material was therefore considerably older and had started to decompose making identification of individual items within this waste significantly harder. For this reason an additional category (mixed meals) was added to these later analyses. 'Condiments, sauces, herbs and spices' was virtually impossible to distinguish from other waste and was therefore added to mixed meals where possible. All the waste analysed during the course of the project was delivered biodegradable bags, and therefore these were added as an additional sub-category.

As noted above, the degree of degradation significantly affects the ability to classify the waste. Therefore Lebersorger and Schneider (2011) recommend that all waste characterisation is undertaken within 2 days of collection. Within this trial, all waste was

analysed within 24 hours (frequently 12 hours) of delivery. None of the collection vehicles used compaction technology, and the majority of the analysis was undertaken during May and September in order to decrease decomposition due to high summer temperatures.

Table 11.1 Waste categorisation system used for categorisation project compared with recommended guidance from WRAP (WRAP, 2009)

WRAP Categorisation (WRAP, 2009)*	Greenfinch Categorisation	Example (Greenfinch categorisation)
1. Fruit 2. Salads 3. Vegetables	1. Whole fruit, vegetables and salads 2. Fruit, vegetable and salad peelings	Whole fresh fruit (apples, potatoes, carrots, lettuce, tomatoes, onions, dried fruit Vegetable peelings
4. Dried foods and powders	3. Pasta / rice / flour 4. Cereal	Cooked and uncooked pasta, rice, flour Cornflakes, muesli
5. Bakery	5. Bread and bakery,	Sliced, unsliced loaves, rolls, world breads (garlic bread, naan, tortilla) croissants, pastry, scones, hot cross buns
6. Meat and fish	6. Meat and fish	Pork, ham, bacon, beef, poultry, meatballs, mince, burgers, sausages, black pudding, fish (skin and flesh) fish fingers, crackling, shell fish
	7. Bones	Chicken bones, lamb / beef joint, shell fish shells, fish bones
7. Dairy	8. Dairy products	Cheese, butter, margarine, yoghurt
	9. Eggs + egg shells	Eggs, shells
8. Confectionary and snacks	10. Snacks, sweets, desserts and cakes	Chocolate, sweets, crisps, popcorn, biscuits, cereal bars, nuts, Danish pastries, cakes, cheesecake, trifle, fruit pie, crumble
9. Drinks	11. Tea bags and coffee granules	Tea bags, coffee granules, loose tea granules
10. Mixed foods	12. Mixed meals ** (included condiments, sauces, herbs)	Sugar, salt, herbs, spices, mayonnaise, tomato ketchup, stews, composite meals, mixed foods
11. Desserts	*(included within sweets, desserts and cakes)*	
12. Condiments, sauces, herbs and spices	*(included with mixed meals)*	
13. Oils and fats	*(butter included in dairy, liquid fats and oils not permitted in scheme)*	
14. Other food materials	13. Other food material	Baby foods,
	14. Non-food biodegradable waste	Flowers, leaves, tissues, paper, cardboard
	15. Biodegradable bags	Biodegradable waste
	16. Seeds and stones	Mango stones, sunflower seeds,
	17. Contamination	Plastic, tinfoil, elastic bands, cigarettes, hair, rubber, cork,

*Numbers in WRAP categorisation refer to the categorisation number in the WRAP system. Number in the Greenfinch categorisation column refers to the numbers in the current system.
**Category added to latter waste audits (not included in those undertaken in Ludlow, Church Stretton or Craven Arms (Section 8)

11.3 Methodology

Following each delivery, the waste was inspected by the AD Plant Operators and was then mixed using a front end loader. In order to obtain a representative sample, a total of 100 biodegradable bags were randomly selected from the load (where waste from an individual collection round was delivered in a number of loads, an equal number of bags were selected from each load). The date, source, total weight of the delivered load, and the total weight of the selected bags were recorded. The waste was transferred to the characterisation area and the weight of each of the bags was recorded to 0.1g (Adam Electrical, model CDW-3). Each bag was individually and carefully opened to both visually inspect for sharps and to avoid dispersion of light materials (e.g. dust, sand, cat litter, vacuum dust, hair, flour etc). Materials were divided into their respective defined categories and weighed to 0.1 kg. The nature of any 'non-food biodegradable materials', 'other food' and 'contamination' was recorded. A core team performed all the analyses in order to maintain consistency between the characterisation of different waste streams. Photographic evidence was recorded at all stages of the process.

11.4 Food waste composition analysis

Compositional analysis was undertaken on food waste derived from 7 schemes serving South Shropshire AD plant (Table 11.4.1). In order to obtain representative results, samples were taken from each individual collection round in South Shropshire (Ludlow, Church Stretton and Craven Arms) over a three week period. For all other sources samples were taken from one load collected on the same day of the week on 4 separate occasions.

Table 11.4.1 Sources of food waste, length of monitoring period and total number of food waste bags analysed in the compositional analysis

	Ludlow	*Church Stretton*	*Craven Arms*	*Flintshire*	*Presteigne*	*Ceredigion*	Somerset
Monitoring period / weeks	3	3	3	4	4	4	4
Number of sampling days	15	6	3	4	4	4	4
Total no. of food waste bags analysed	1500	600	300	400	400	400	400

The results of the food waste compositional analysis (expressed on a wet weight basis and normalised to 100%) are summarised in Figures 11.2.1a to g. The South Shropshire rounds did not include the category 'mixed meals' (Section 11.2). The composition of the waste from all 7 sources was very similar. The dominant waste stream at all sites was fruit and vegetable peelings (>50% of the total weight except at Presteigne which was 36.8%, Whole fresh fruit and vegetables comprised 8 – 10% of the total weight. In all of the areas except Somerset bread and bakery products were ranked second in the percentage composition of the food waste (10 – 12%); in Somerset bread and bakery products were ranked fourth (after fruit and vegetable peelings, whole fruit and vegetables and tea bags / coffee granules). The proportion of bread and bakery products may have been slightly enhanced due to their capacity to adsorb liquid (either included in the waste stream or generated during initial decomposition). The

food waste types which comprised the lowest percentage of the food waste weight varied between areas but included contamination, sweets and desserts, seeds and stones and 'other food material'.

There was no significant difference between the percentage composition of the food waste which was whole fruit and vegetables across the seven localities (ANOVA, $P>0.1$). The same trend was evident for meat and fish (ANOVA, $P>0.2$), dairy products (ANOVA, $P>0.3$), cereal (KW, $P>0.4$), tea bags, coffee granules (KW, $P>0.05$), sweets and desserts (KW, $P>0.3$), other food material (KW, $P>0.2$) and contamination (KW, $P>0.331$). The contamination contained within the food waste is discussed further in detail in Section 13.

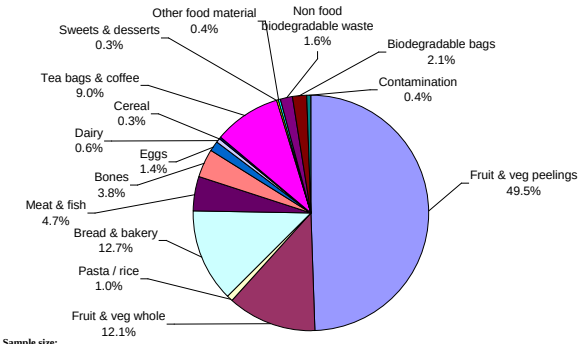
The proportion of the food waste which was composed of items such as meat and fish bones, eggs and egg shells and biodegradable bags is of interest to AD Operators as they are all items which can hinder the processing the food waste in anaerobic digestion. Interestingly, there were significant differences in the percentage of bones, eggs and eggshells and biodegradable bags between waste streams (Figures 11.2.8a-c).

Bones (from meat and fish) comprised between 2.9% and 5.8% of the total weight of the food waste characterised (Figure 11.2.8a). In the Somerset waste stream, bones comprised 7.8% of the total weight of the waste which was significantly higher than that of Ceredigion (MW, $P<0.05$), Craven Arms (MW, $P>0.05$) and Presteigne (MW, $P<0.05$). The percentage of the Flintshire waste which comprised bones (5.8%) was significantly higher than that of Ceredigion (MW, $P<0.05$), Craven Arms (MW, $P<0.05$) and Presteigne (MW, $P<0.05$). However, there was no significant difference between Ceredigion, Presteigne, Church Stretton, Craven Arms and Ludlow.

The percentage of food waste which comprised eggs and egg shells varied between 0.7% (Flintshire) and 1.4% (Ludlow). There was no significant difference between the percentage food waste comprising eggs between Ludlow, Church Stretton, Craven Arms, Presteigne, Ceredigion or Somerset; however Flintshire was significantly lower than in Ludlow (TK-AP), Church Stretton (TK-AP) and Craven Arms (TK-AP).

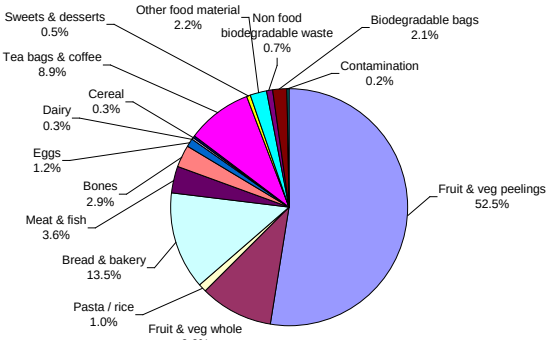
Biodegradable bags comprised between 4.3% (Presteigne) and 1.9% (Church Stretton) of the total food waste sample. As far as practically possible all particles of food were removed from the bags prior to weighing, however, the bags were weighed 'wet', and would have contained a small amount of moisture and residual food waste. The aim of this study was to determine the potential contribution of biodegradable bags to the rejects from the site and therefore this was justified. The percentage composition comprising biodegradable bags was significantly higher in Presteigne than in Ceredigion, Church Stretton, Craven Arms and Somerset (TK-AP). The proportion of biodegradable bags in Flintshire was significantly higher than Ceredigion, Church Stretton, Craven Arms and Ludlow (TK-AP; Figure 11.2.8.c)

The compositional analysis of the Ludlow waste stream is illustrated (proportionally) in Figure 11.2.2.



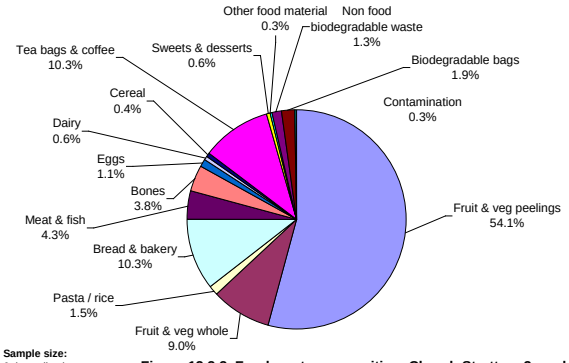
Sample size: 15 day collection 100 bags per day

Figure 12.2.1. Food waste composition, Ludlow, 3 week average / % by weight



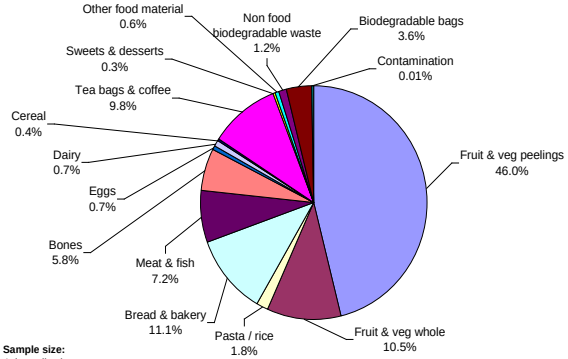
Sample size: 3 day collection 100 bags per day

Figure 12.2.2. Food waste composition, Craven Arms, 3 week average / % by weight



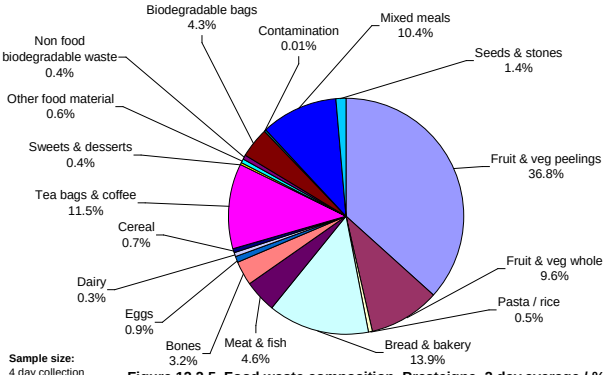
Sample size: 6 day collection 100 bags per day

Figure 12.2.3. Food waste composition, Church Stretton, 3 week average / % by weight



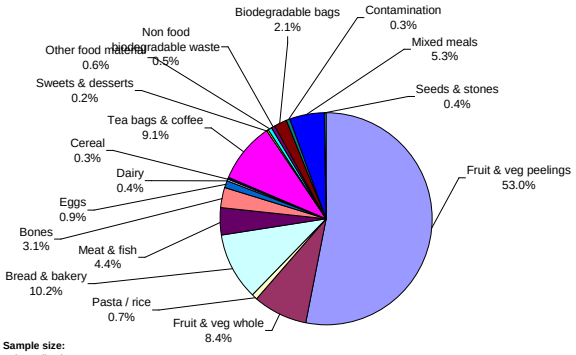
Sample size: 4 day collection 100 bags per day

Figure 12.2.4. Food waste composition, Flintshire, 1 day / % by weight



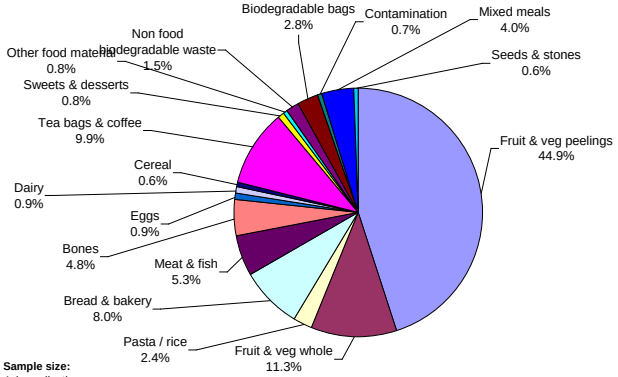
Sample size: 4 day collection 100 bags per day

Figure 12.2.5. Food waste composition, Presteigne, 2 day average / % by weight



Sample size: 4 day collection 100 bags per day

Figure 12.2.6. Food waste composition, Ceredigion, 4 week average / % by weight



Sample size: 4 day collection 100 bags per day

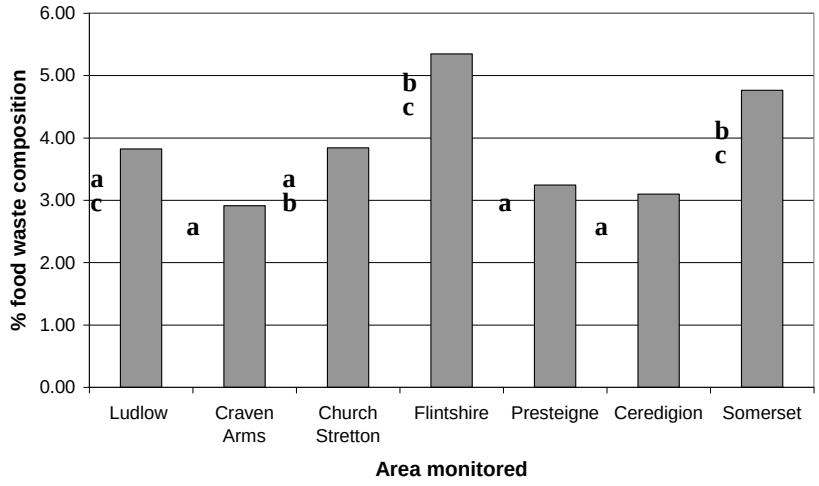
Figure 12.2.7. Food waste composition, Somerset, 4 week average / % by weight

Figure 11.2.1 Compositional analysis for Ludlow, Craven Arms, Church Stretton, Flintshire, Presteigne, Ceredigion and Somerset

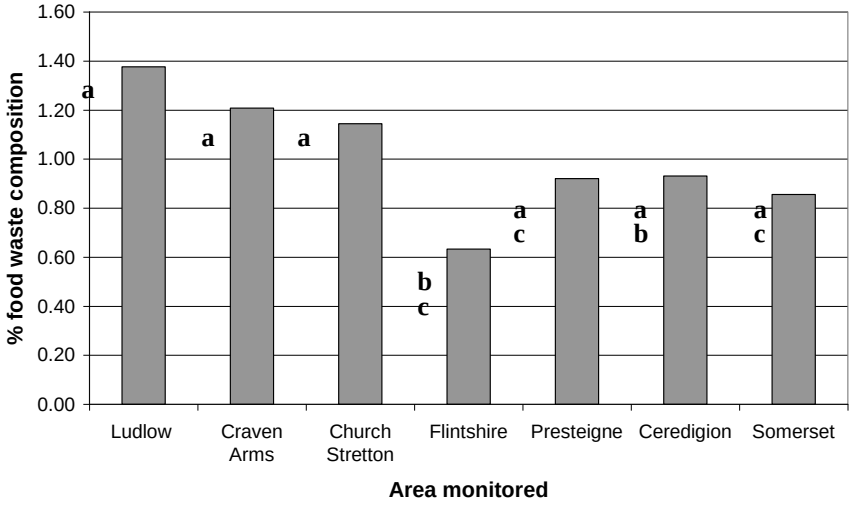
Figure 11.2.2 Compositional analysis of the Ludlow waste stream

This study provided an insight into the nature and properties of food waste as a feedstock for anaerobic digestion. The inclusion of bones, biodegradable bags and egg shells (Figures 11.2.10a-c) in feedstocks are of special interest to anaerobic digestion operators due to their potential to cause wear and tear to machinery, and their contribution towards grit and sedimentation in pipes and tanks (Section 12.2) which are both costly and time consuming to rectify. Large seeds and stones may have a similar effect, however they comprised a very small percentage of the total feedstock in all the sources of waste analysed as part of this study (<1%; Figures 11.2.1 – 12.2.8). Quantification of the relative proportions of such products in domestic and commercial food waste streams may facilitate negotiation of gate fees at appropriate levels to enable operators to take the necessary corrective action. The current analysis was conducted during May and June and therefore the effect of seasonal variation has not been taken into account, however such analysis would be beneficial and would warrant additional research.

a)



b)



c)

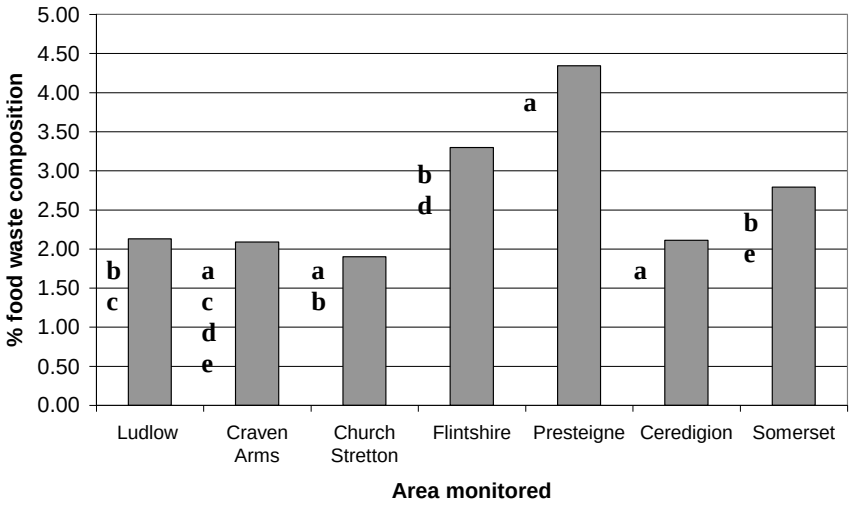


Figure 11.2.8 Percentage food waste composition for the seven areas for, (a) bones, (b) eggs, (c) biodegradable bags. (For each column labelled with the same letter there is no significant difference ($P<0.05$))

a) Bone

b) Biodegradable bags

c) Eggshells

Figure 11.2.10. Typical examples of material in domestic source separated food waste

12 Contamination

The mass of contamination in the food waste from all the sources was very low (<1%, measured by wet weight; Table 12.1). A similar compositional waste analysis study conducted during September 2010 on waste derived from households in 6 London Boroughs and the East of England indicated significantly higher rates of contamination. Contamination levels of 3.3%, 3.9% and 4.2% were recorded in waste from Surrey, Central Bedfordshire and Leatherhead respectively, whilst waste from Richmond and Ealing contained 4.9% and 5.6% contamination respectively (MTT, 2011;VALORGAS Deliverable 2.1).

Table 12.1 Percentage (by mass) of food waste streams comprising contamination and non-food biodegradable material

	Ludlow	Church Stretton	Craven Arms	Flintshire	Presteigne	Ceredigion	Somerset
% Contamination	0.4	0.3	0.2	0.01	0.01	0.3	0.7
% non-food biodegradable	1.6	1.3	0.7	1.2	0.4	0.5	1.5

Plastic, in the form of bags, film, wrapping and trays was the main constituent of the contamination in the South Shropshire AD plant study, with a small proportion of tinfoil. Plastic is relatively light (in comparison to food waste), and therefore it would be expected that plastic contamination would be a small percentage (by weight). The contamination from each round was photographed (Figure 12.1). These figures clearly demonstrate that the volume of plastic (and other contamination) was very small.

a)

b)

c)

d)

e)

f)

Figure 12.1 Examples of contamination from (a, b) Ludlow, (c) Church Stretton and (d) Craven Arms. Figure 12.1 (e) and (f) illustrate the typical contamination from 50 bags of waste derived from a London Borough
(Note: the photographs show all (not just a selection) of the products classed as contamination within the 100 / 50 bags sorted on one occasion from each source)

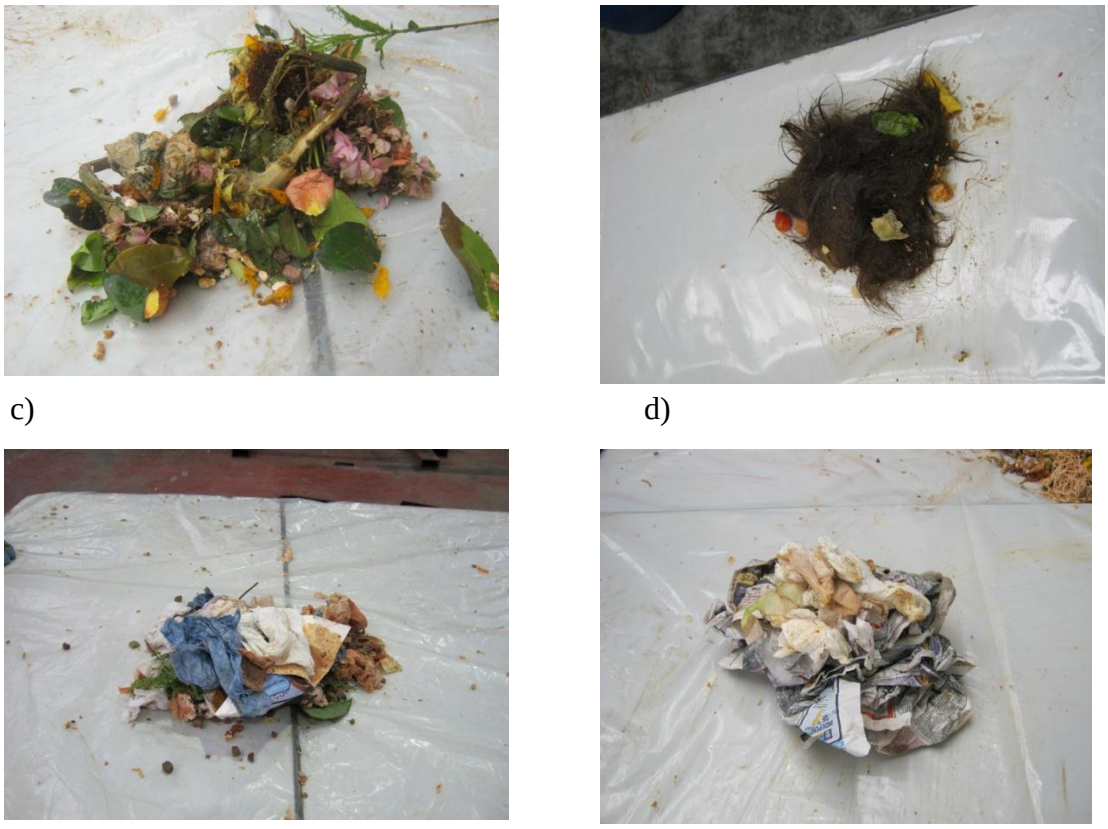
Examination of the 'heavies' knock out pot at South Shropshire AD plant indicates the presence of a surprisingly large amount of cutlery (knives, forks and spoons) and cooking utensils (particularly potato peelers and vegetable knives) in the waste stream. No evidence of such materials was found in any of the 4000 bags of waste found in the domestic waste streams suggesting that one of the main sources of this material might be the users of the commercial collection rounds.

The majority of the contamination was not considered to be 'malicious' deliberately included in the waste stream with the aim of causing damage. Instead, the majority of the contamination was associated with food products (i.e. plastic wrapped products passed their sell by date, yoghurts in pot, tinfoil wrapped food / sandwiches or products still with their labels attached.

Input supply agreements (between the AD operator and the waste supplier) often stipulate an acceptable level of contamination permitted within the waste stream; if this is exceeded then the waste may be rejected or a penalty imposed on the supplier. A figure of 5% is frequently used (Simon Musther, Commercial Manager, BiogenGreenfinch, *Personal Communication*). The current study has shown that 6 of the Local Authorities which supply South Shropshire AD plant have achieved contamination levels which are significantly below this level.

In addition to contamination, a small amount of non-food biodegradable material was identified (Table 12.1, Figure 12.2). This mainly comprised newspaper and tissues (permitted materials used by householders to wrap food waste), pet food, hair and flowers (household flowers not garden waste). There was no significant difference in the percentage of non-food biodegradable material between the sources of waste. One small bag of pet litter was identified (out of 4000 bags sorted), thereby indicating that householders do not use their food waste collection schemes to dispose of animal faeces.

a) b)



c) d)

Figure 12.2 Examples of non-food biodegradable waste from (a) Ludlow, (b) Church Stretton, (c) Ludlow and (d) Flintshire

13 Chemical and nutritional analysis

Monthly composite samples of food waste were analysed for their chemical and nutritional values (Table 13.1).

In order to obtain a representative sample of waste, small samples (500 g) of the shredded food waste were sampled from the conveyor belt at regular intervals throughout the day. These samples were frozen and accumulated with other samples to form a monthly composite sample. All samples were analysed for their chemical and nutritional value by Natural Resource Management (a UKAS accredited laboratory, UK) using their standard methodologies.

Table 13.1 Average nutritional value of composite samples of food waste

Elements	Concentration (mg/kg fresh weight)	Standard deviation
Total Nitrogen (N)	2888.89	567.83
Ammonium Nitrogen	1149.67	162.66
Total Phosphorus (P)	3339.56	660.68
Total Potassium (K)	9109.78	2029.55
Total Magnesium (Mg)	956.56	162.72
Total Sulphur (S)	1958.44	231.91
Tungsten (W)	0.13	0.07
Total Molybdenum (Mo)	0.33	0.18
Total Selenium (Se)	0.13	0.11
Total Cobalt (Co)	0.24	0.22
Total Nickel (Ni)	1.32	0.35
Total Zinc (Zn)	22.31	6.34
Total Iron (Fe)	415.89	161.34
Total Aluminium (Al)	278.44	96.68
Total Boron (B)	4.12	2.24

The concentrations of nitrogen, phosphorus and potassium were relatively high (on a fresh weight basis) suggesting that the food waste supplied into South Shropshire AD plant is suitable for the production of a beneficial plant fertiliser. The concentrations of these three nutrients were however variable throughout the year (as indicated by the standard deviation), showing the potential effect of seasonality. The current study also examined the concentrations of a variety of trace elements considered essential for successful food waste digestion (Defra WR1208, 2010). The concentrations of trace elements in the current study are in line with those expected in source segregated household food waste, and are similar to those reported by VALORGAS Deliverable 2.4 (Valorsul, 2012).

14 Conclusions

This study has compared and contrasted the characteristics of a variety of food waste collection schemes which supplied the digester during a 3-year period (2007 – 2010). Three municipal weekly source segregated collection schemes were considered in detail, examining the effect of scheme maturity on participation rate and public attitudes to the scheme. Compositional analysis was undertaken on the waste streams to determine the nature and properties of source segregated biowaste as a substrate for anaerobic digestion.

The key conclusions from the research are:

1. The introduction of a suitable collection scheme is integral to successful anaerobic digestion of source segregated food waste.
2. To facilitate the highest capture of food waste, a weekly separate collection scheme which uses small kitchen caddies and kerbside bins proved most successful.
3. The collection of co-mingled kitchen and garden waste in 240-litre wheeled bins produced a biowaste containing minimal food waste and a large amount of contamination.
4. Public engagement and perceived ownership of the scheme and treatment facility not only increased participation but also significantly reduced contamination.
5. The provision of biodegradable cornstarch bags is a useful tool to encourage participation, however it is not essential.
6. There was no clear evidence of seasonal variation in food waste generation.
7. WRAP or similar best practice guidance should be adopted in order to ensure that participation rate surveys are conducted which are scientifically and statistically robust.
8. There was no significant change in the participation rate of the Ludlow food waste collection scheme within the first 36 months of operation.
9. Public attitudinal surveys demonstrated that there was exaggerated perceived usage of the scheme, which indicated a participation rate 25% higher than the actual rate.
10. Compositional analysis indicated very low contamination rates (<1% by wet weight). Contamination was mainly in the form of plastic and tinfoil: it was not considered to be 'malicious', however, but was due to materials associated with food waste (e.g. plastic-wrapped food products).
11. The reject material from the plant contained cutlery and other cooking utensils; however, no evidence of such materials was found in any of the 4000 bags of food waste characterised and it is therefore assumed that the majority of these products arise from users of the commercial food waste collections.

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