Programme Area: Bioenergy

Project: Energy From Waste

Title: Initial Waste Assessment

Abstract:

This deliverable is number 2 of 3 in Work Package 1 and presents the initial results of waste sampling, including physical composition of waste materials and the detailed laboratory analysis. The report is intended to enable the reader to understand the main energetic waste flows over the initial 2 seasons of analysis of the project (November 2009 to January 2010 and February 2010 to May 2010). In all 4 seasons of sampling will be carried out. The information is based on the assessed sites only and at this stage only a preliminary attempt has been made to aggregate the derived results over the UK. The initial conclusions of the analysis undertaken for season 1 and 2 are presented in this report.

Context:

The Energy from Waste project was instrumental in identifying the potential near-term value of demonstrating integrated advanced thermal (gasification) systems for energy from waste at the community scale. Coupled with our analysis of the wider energy system, which identified gasification of wastes and biomass as a scenario-resilient technology, the ETI decided to commission the Waste Gasification Demonstration project. Phase 1 of the Waste Gasification project commissioned three companies to produce FEED Studies and business plans for a waste gasification with gas clean up to power plant. The ETI is taking forward one of these designs to the demonstration stage - investing in a 1.5MWe plant near Wednesbury. More information on the project is available on the ETI website. The ETI is publishing the outputs from the Energy from Waste projects as background to the Waste Gasification project. However, these reports were written in 2011 and shouldn't be interpreted as the latest view of the energy from waste sector. Readers are encouraged to review the more recent insight papers published by the ETI, available here: http://www.eti.co.uk/insights

Initial Waste Assessment

Report 1.2

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Executive Summary

This report is the second deliverable of work package 1, which is one of four work packages within the energy from waste project funded by the Energy Technologies Institute [ETI]. This is a flexible research project [FRP] and this deliverable presents the initial results of waste sampling, including physical composition of waste materials and the detailed laboratory analysis. The report is intended to enable the ETI to understand the main energetic waste flows over the initial 6 months (2 seasons) period. The information will be based on the assessed sites only and at this stage only a cursory attempt will have been made to aggregate the derived results over the UK The initial conclusions of the analysis undertaken for season 1 and 2 [November 2009 to January 2010 and February 2010 to May 2010 respectively] are presented in this report.

Further developmental work has been highlighted, including an established link with Defra, and is discussed in detail to show how the ongoing understanding of the UK waste materials will be enhanced. The initial agreement with Defra is that there will be a clear exchange of lessons learnt in linking standard industrial classifications [SIC] codes and data obtained from the respective projects currently in progress.

The MSW and C&I mixed waste streams consist of large amounts of different components which have the potential for energy recovery, such as paper, card, plastics, organics [food and green waste] and textiles. C&D waste consists largely of soils and aggregates, which are inert materials of no energy value.

The initial findings show that up to 70% of C&D wastes by weight is inert, which is material that is not biodegradable and is of no energy value.   The C&I wastes were observed to contain higher quantities of paper and card than MSW, which is due to the differences between the recycling targets and policies relating to these two waste streams. The C&I and MSW materials both contained large quantities of film plastic, which yielded the highest CV of all components analysed [39,000 kJ/kg].

Site [waste type]	Total annual waste [t]	Non-inert material Average CV [kJ/kg]	Total material Average CV [kJ/kg]
Blochairn [C&I]	61,400	12,524	9,611
Broxburn [C&I]	31,300	10,483	7,452
Elstow [MSW]	72,500	7,419	6,492
Kettering [C&D]	26,500	9,376	3,444

The potentially recyclable materials present in the residual wastes, in particular C&I, is of importance. The plastic materials contribute significantly to the CV of the overall material, and as the proportion of these materials are policy and economically driven, being able to understand future recycling trends would be important.

The level of pre-processing required for the use of waste materials as a fuel is dependent on the energy recovery technology and the associated tolerances. Therefore variability in the waste composition can be offset by adaptable processing of the waste to yield consistent fuels.

The on-going development of an image analysis tool to assess the composition of wastes is discussed in this report, including the schematic approach to analysing the images collected at each of the Shanks site. Further detail of this potentially rapid assessment tool is to be provided in the next deliverable, report 1.3.

Along with the initial conclusions reached from the sampling completed in seasons 1 and 2 a number of lessons were learned which have enabled a refinement of the waste sampling methodology. These changes will add significant value to the data collected as part of this project, providing a valuable and unique dataset from which a greater understanding of the energy potential of UK wastes can be achieved. Amendments include:

- A greater number of samples of individual components will be sent for laboratory analysis;
- MSW recycling material from Elstow to be added to the waste sampling strategy;
- An additional Shanks site [Aylesbury, Bucks] added to Season 3 to C&I materials;
- Approach further industrial representative and individual companies in order to access sector-specific datasets;
- Detailed analysis of the different plastics present in the C&I waste stream

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Figures and Tables

Cranfield UNIVERSITY

Glossary

CA- Civic amenity site [a site which contains bins for residual and recycling waste materials by which the public can dispose of household waste.]

C&D- Construction and Demolition

C&I- Commercial and Industrial

CV- Calorific Value [a measure of energy content]

DM- Dry matter [% of a sample that is not moisture (BS EN12879:2000)]

EfW- Energy from Waste. The process of generating energy, electricity and/or heat, from waste-derived materials.

ETI- Energy Technology Institute

HHW- hazardous household waste [batteries, engine oil, paint etc]

HWRC- Household waste Recycling Centres [as CA]

LOI- Loss-on-ignition [% of a sample that is determined to be organic under a controlled laboratory test (BS EN12879:2000)]

MSW- Municipal Solid Waste

RDF [refuse derived fuel]- a high calorific material obtained from the processing of mixed organic wastes. Consists largely of paper, card and plastics.

Recyclate- a recycled material

Recycling- the separation of waste materials either at source or at a bulking centre where materials are then diverted for treatment prior to reuse as a raw material commodity.

Residual wastes- typically black bag waste; what is left after recycling

SRF [Solid Recovered Fuel]- similar to RDF except produced to a set standard and classified in terms of CV, chlorine and mercury content.

Waste composition- the percentage by weight of plastics, wood, paper, etc.

Waste arisings- the quantity [tonnes] and type of waste being produced at a given location(s) within a specified time period

WEEE- waste electronic and electrical equipment

1. Introduction

There is a requirement to understand the arisings and composition of all wastes in the UK in order to understand the energy recovery potential of these materials. Report 1.1 highlighted the available data and identified the areas in which the data and level of understanding was limited; the waste streams which are not well understood were commercial and industrial [C&I] and construction and demolition [C&D]. Whilst it was found that large amounts of data exists for municipal solid wastes [MSW], this waste stream forms only 9% of the overall UK waste, whereas C&I and C&D are estimated to form 25 and 32% of the UK waste respectively. As outlined in Report 1.1 a sampling strategy has been developed to focus more on areas of lower understanding, but high energy potential. Therefore the waste sampling and site data collection has been prioritised on C&I wastes as these represent the arisings with the highest volume matched by highest calorific value where least information is known. This is illustrated in Table 1, which provides the energy, tonnage arisings and data quality for agricultural [Ag], mining and quarrying [M&Q], sewage sludges [SS], dredged materials [DrMt], municipal solid wastes [MSW], commercial [Com], industrial [Ind] and construction and demolition [C&D] wastes.

Table 1. UK waste arisings and data priorities for fuel analysis

Sector type vs data	Ag	M&Q	SS	DrMt	MSW	Com	Ind	C&D
	<1%	30%	<1%	5%	9%	11%	13%	32%
Energy	H	L	H	L	H	H	H	M
UK Arisings	L	H	L	M	M	H	H	H
Data Quality	M	M	H	L	H	L	L	M

Work package 1 aims to collect the available data on waste arisings and composition within the UK to then convert this in to a value of its fuel potential. The work draws information from a review of completed and ongoing waste studies plus a sampling programme of waste from UK sites. Expert advice has been sought from the Defra Waste Research and Evidence team in addition to input from the UK waste industry and process operators to guide the research design. Data has been drawn from a wide range of sources. In addition Shanks Waste Solutions Ltd., are providing access to their sites, company data and site specific samples and data. Appendix A provides further information on the process of data sharing with Defra, and Figure 1 shows how the data collected by Cranfield and Defra can be cross-linked and validated.

Figure 1. Validation process for C&I waste data

Data, such as arisings and composition, is drawn from 5x main sources including peer reviewed references, sector reports, industry specific data, operator data [Shanks] and direct sampling. These are highlighted in Figure 2. The specific Shanks sites were chosen as these represent typical mixed waste materials and provide access to a wide variety of waste stream-specific data.

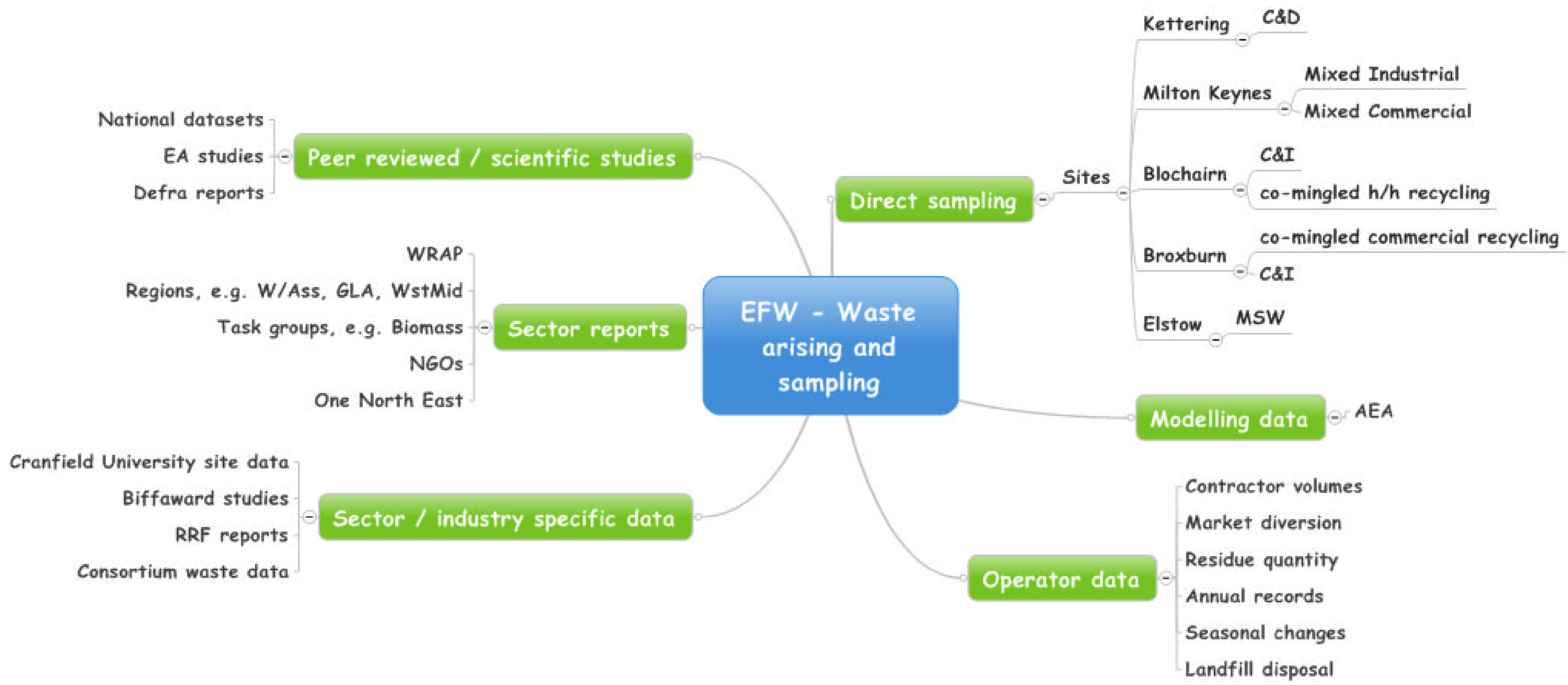

Figure 2. Data sources in WP.1

The objective of this work-package is to gain the best possible understanding of the energy potential of wastes, biochemical and/or thermo-chemical, across the UK. This information will then be used within the project to specify better the technology requirements for using waste as a fuel. In order to achieve this, the research method will extend the value of existing data to understand the properties of waste as a fuel. This is over and above the evidence collated for UK policy and regulatory development. It will then be used to guide the technology assessment and development priorities in the following work packages. Central to this is maximising the reliability of results to inform best value in monitoring and the later decisions within the technology assessment.

2. Aims and Objectives

2.1. Aims

This study aims to collate UK waste data from a number of sources, identify knowledge limitations and produce new data which enhances our understanding of UK wastes. The improved understanding of the wastes will subsequently allow the overall ETI project objectives to be met, which are to identify the next generation of technologies which can be used to generate energy from a wide variety of available waste materials.

2.2. Report requirements

It has been agreed previously that this report will provide-

- Executive summary
- Description of waste compositional and chemical analysis techniques employed
- Raw data collected
- Initial results for main energetic and volumetric data for assessed wastes
- Initial conclusions
- Confirmation or amendment of sampling and analysis regime for Seasons 3 & 4

Additionally this report will provide a discussion of the work going forward and will highlight how this will be achieved, and what will be delivered, for Report 1.3.

3. Existing Data

The availability of existing data for UK waste arisings was assessed for Report 1.1 in which a stakeholder's workshop was arranged to ensure that the project was making the best use of the available data.

A large number of sources of data were identified in Report 1.1, and through the findings of the workshop sector-specific data has also been collated. This information will be used to enhance the final conclusions that will be made in Report 1.3 and for the development of the UK waste map being produced in parallel to this project at Cranfield University.

Summaries of the UK waste materials are shown in Tables 2-6, including UK waste arisings, MSW composition, C&I composition and C&D composition. A comparison between the models developed for Report 1.1 and findings from a recent Defra report (project WR0119) are also shown.

Table 2. UK waste arisings ['000 tonnes]

	MSW[1]	C&I[2]	C&D	AGRICULTURAL[3]
ENGLAND	06/07.	06/07.		
North East	1,500	2,440		118
North West	3,938	7,532	10,793[4]	67
Yorkshire and Humberside	2,838	9,752		363
East Midlands	2,405	6,157		651
West Midlands	2,982	6,290		232
East	3,014	5,689	10,324[5]	495
London	3,997	7,337		18
South East	4,494	8,701		338
South West	2,859	4,760		304
TOTAL	28,027	58,658	89,600[6]	2,586
WALES	06/07.	06/07.		
TOTAL	1,785	3,573	12,167[7]	32
SCOTLAND	06/07.	06/07.		
TOTAL	2,134	8,093	11,804[8]	366
NORTHERN IRELAND	06/07.	06/07.		
Arc21	576			
NWRWMG	196			
SWAMP	282			
TOTAL	1,053	1,560	1,715[9]	28
UK TOTAL	33,000	71,884	115,286	3,012

[1] AEA models [Defra waste statistics]
[2] AEA models [Defra waste statistics]
[3] AEA models [Defra waste statistics]
[4] Beedell, J., C. Yates, et al. (2007). Study to fill the evidence gaps for construction, demolition and excavation waste streams in the North West region of England, Smiths Gore.
[5] Blackwell, M. (2008). East of England C&D waste arisings, BRE.
[6] Capita Symonds Ltd and WRc plc (2007). Survey of arisings and use of alternatives to primary aggregates in England, 2005: construction, demolition and excavation waste. London, Office of the Deputy Prime Minister.
[7] Environment Agency (2006). A survey on the arising and management of construction and demolition waste in Wales 2005-06. Cardiff.
[8] SEPA (2006). Construction and demolition wastes in Scotland, SEPA.
[9] Capita Symonds Ltd and WRc plc (2006). Survey of arisings and use of construction, demolition and excavation waste as aggregate in Northern Ireland in 2004/05 & 2005/06, Environment and Heritage Service.

Table 3. UK MSW composition [% weight] from AEA models [Report 1.1, Volume II]

	ENGLAND									WALES	SCOTLAND	NI
	North East	North West	Yorkshire and Humberside	East Midlands	West Midlands	East	London	South East	South West	Overall	Overall	Overall
Paper & card	18.9%	17.9%	19.7%	17.8%	17.7%	16.6%	15.8%	17.7%	15.4%	16.8%	20.0%	17.4%
Plastic film	5.9%	6.4%	6.0%	7.0%	6.2%	7.1%	5.4%	7.0%	6.6%	8.0%	4.6%	5.9%
Dense plastic	7.1%	7.6%	7.4%	8.2%	7.8%	8.3%	6.5%	8.3%	7.9%	4.8%	9.2%	6.3%
Textiles	3.7%	3.7%	3.7%	4.2%	3.8%	4.0%	3.4%	3.9%	3.9%	4.0%	3.4%	3.7%
Wood	3.8%	3.2%	3.0%	5.0%	4.7%	5.5%	5.0%	3.7%	5.3%	0.7%	5.2%	2.4%
Furniture	2.0%	1.5%	1.7%	2.3%	2.0%	2.2%	1.8%	2.3%	2.2%	2.1%	1.8%	2.0%
Other combustibles	8.0%	7.9%	8.5%	10.0%	8.7%	9.5%	7.4%	9.6%	9.2%	7.9%	7.9%	7.4%
Glass	4.3%	4.6%	4.1%	1.3%	5.0%	0.1%	3.9%	2.3%	0.6%	3.0%	5.4%	7.0%
Rubble (C&D waste)	0.1%	1.7%	1.2%	2.8%	1.5%	4.7%	3.4%	2.1%	2.0%	5.1%	0.5%	4.1%
Other non-combustibles	1.8%	2.0%	1.9%	2.2%	1.9%	2.2%	1.7%	2.1%	2.0%	2.0%	1.8%	1.8%
WEEE*	1.9%	1.7%	1.6%	1.9%	1.9%	1.9%	2.0%	1.5%	1.7%	1.5%	1.6%	1.4%
HHW#	0.6%	0.6%	0.6%	0.7%	0.6%	0.7%	0.5%	0.7%	0.6%	1.0%	0.1%	0.6%
Kitchen	26.2%	26.3%	27.0%	26.1%	24.2%	26.2%	24.7%	30.9%	30.0%	24.9%	27.2%	26.9%
Green waste	8.0%	6.8%	6.0%	2.8%	6.1%	3.6%	11.1%	0.9%	5.4%	11.6%	2.4%	5.6%
Fe metal	3.0%	2.9%	2.8%	2.2%	2.9%	2.1%	3.0%	1.7%	2.0%	2.3%	3.2%	2.8%
Non-fe metal	1.0%	1.1%	1.0%	1.0%	1.1%	0.9%	1.0%	0.8%	0.9%	0.9%	1.0%	1.1%
Fines	3.8%	4.1%	3.9%	4.5%	4.0%	4.5%	3.5%	4.5%	4.3%	3.4%	4.6%	3.8%

*WEEE- waste electrical and electronic equipment

#HHW- hazardous household waste

Recently a report was published by Defra which was a review of all MSW composition analyses in the UK (Resource Futures 2009). Table 4 provides a comparison between the collated MSW composition for the UK adapted from that report and the AEA models developed for the ETI energy from waste project[10].

Table 4. England MSW composition comparison

England MSW composition 06/07	AEA Model		Defra WR0119		Difference in Tonnes
Component	**Tonnes**	**%**	**Tonnes**	**%**	**%**
Paper & card	5,806,978	20.6	6,429,612	22.7	9.7
Plastic	2,706,165	9.6	2,831,585	10.0	4.4
Textiles	817,487	2.9	802,816	2.8	-1.8
Wood	1,240,325	4.4	1,056,748	3.7	-17.4
Furniture	394,649	1.4	379,783	1.3	-3.9
Other combustibles	1,719,542	6.1	1,605,239	5.7	-7.1
Glass	1,916,867	6.8	1,881,799	6.6	-1.9
Other non-combustibles	1,381,271	4.9	1,509,110	5.3	8.5
WEEE	563,784	2	620,566	2.2	9.1
Kitchen & other organic	5,722,410	20.3	5,546,611	19.6	-3.2
Green waste	3,946,490	14	3,989,782	14.1	1.1
Metals	1,212,136	4.3	1,217,335	4.3	0.4
Fines	761,109	2.7	469,127	1.7	-62.2
Total	**28,189,214**	**na**	**28,340,113**	**na**	**0.5**

It is evident from Table 4 that the variations between the two data sources is minimal, with the exception of fines, which is due to the two separate pieces of work both using data from WasteDataFlow[11] and existing waste composition data from the respective consultancies [AEA Technology and Resource Futures]. The differences arise from the compilation of all MSW composition studies carried out by various local authorities, which are reported in Defra WR0119, but not for the AEA models.

It should be noted that the wood waste arisings in Table 4 are higher than those reported in a recent study (Pöyry Forest Industry Consulting Ltd and Oxford Economics Ltd 2009). The reason for this is that the wood waste arisings quoted for MSW in that report was for wood received at civic amenity sites, and as such does not report the total wood waste arising in all household wastes.

The waste arisings by type is shown in Table 5 for the C&I waste stream. The waste type, category and business group are shown in Appendix B.

[10] ETI Work Package 1- Report 1.1, Volume 1, Appendix D

[11] WasteDataFlow is a web-based reporting system used by Local Authorities to report municipal waste collection and disposal data to central government

Table 5. C&I waste arisings by waste type [‘000 tonnes]

	England	Wales	Scotland	Northern Ireland
Chemicals	7,641	127	499	42
Metallic	2,961	333	394	113
Non-metallic	12,930	866	2,286	363
Discarded equipment	424	38	90	19
Animal & plant	3,842	400	714	165
Mixed	19,974	1,134	3,503	595
Common sludges	1,914	80	113	30
Mineral wastes	8,972	595	495	233
Total	58,658	3,573	8,093	1,560

The composition of the mixed [residual] waste material of C&I is shown in Table 6.

Table 6. Composition of C&I mixed waste [residual[12]] (SLR Consulting 2007)

	Composition (Wt %) of mixed waste stream
Paper and cardboard	32
Plastic film	7
Dense plastic	8
Textiles	2
Other combustibles	16
Glass	4
Other non-combustibles	6
Food/kitchen waste	13
Other organics	2
Metal	4
Household hazardous	1
WEEE	1
Fines	4
Total	**100**

Paper and card are more abundant in the residual C&I stream than the MSW material. This is due to the differences in the recycling schemes for these two waste streams; the MSW stream, household waste, is subjected, through local authorities, to tough recycling targets (Defra 2007). As a result the paper and card content of MSW is lower than that of C&I, and is likely to decrease further.

[12] Residual is typical black bag waste- which is general waste from commercial and industrial facilities. These wastes include that from catering and office areas within these facilities, which commonly resembles domestic waste. Recyclable materials are collected separately [i.e. source segregated] depending on the business type and location, therefore the residual waste is what is left following recycling.

4. Methods

Waste samples were taken from Shanks sites in England and Scotland, and will focus mainly on the C&I waste stream due to the lack of understanding. As outlined in Report 1.1 Volume 1, the sampling strategy was developed to suit the knowledge gaps. There are 5 sites which will be used for the waste compositional and sampling exercises, which will be visited twice per season. The Shanks site in Milton Keynes typically receives commercial and industrial streams separately, and so this site will equal 4 visits [2 visits per season; 2 sets of sample per visit]. Therefore a total of 12 site data sets per season will be produced.

Season 1 covers the period of November 2009 to January 2010; season 2 covers the period of February to May 2010. Season 3 will commence from end of May 2010 and be completed in July 2010. Finally Season 4 will start at the end of July 2010 and be completed at the beginning of September 2010.

For each site visit a detailed hand sort of the waste was carried out, along with 30 images for visual composition analysis. The results for the collected images are not discussed in this report and will be discussed in Report 1.3 due to the technique currently being under development. The methods for detailed sorting are described in Report 1.1 Volume 1, and are illustrated in detail in Appendix C. For each detailed sort there will be at least 1 representative sample sent to an external lab for proximate and ultimate analysis to determine properties such as moisture content, calorific value and elemental composition as detailed later. Therefore:

- 3x bucket loads from input waste material;
- Bags split and waste spread evenly- ≤50m^3 spread
    - 30x images for subsequent analysis
- 10-15x shovel loads of above spread for detailed sort- ~30-60kg [sub-set]
    - C&D materials typically ≥100kg;
    - Observations recorded for large/abundant/unusual items and a visual description of moisture content;
    - Photographs taken of site during sampling.
- Representative sample made up for lab analysis
    - From compositional analysis for site (mixed waste stream);
    - Single material samples, e.g. paper, card, plastics

An overview of the image analysis process is provided in Appendix D. This still under development, and so is subject to change.

A sample of around 10 kg is sent to the third-party laboratory. This sample is then dried at 105°C to determine the moisture content. The dried sample is then ground to <10 mm. A fraction of this homogenised material was then ground further to <1 mm for proximate and ultimate analysis.

The lab analysis will comprise of proximate and ultimate analysis, as shown in Table 7.

Table 7. Proximate and ultimate analysis

Method	Parameter	Principle of method
Moisture content [CEN/TS 15414]	Total Moisture %	A known mass of sample is dried at a nominal temperature of 105°C in an air atmosphere until constant mass is achieved and percentage moisture calculated from the loss in mass.
Ash content [CEN/TS 15403]	Ash %	A known mass of the sample is heated in air to 550ºC +/- 10 in 60 minutes and is kept at this temperature for a minimum of an additional 120 mins. The ash content is determined from the mass of residue remaining after incineration
Volatile matter [CEN/TS 15402]	Volatile Matter %	A known mass of sample is heated at 900ºC, out of contact with air for 7 minutes +/- 5 seconds. The volatile matter is calculated from the loss in mass of the sample. A deduction is made for the loss in mass due to moisture.
Gross and net CV [CEN/TS 15400]	Gross and Net Calorific Value kJ/kg	A known mass of sample is burnt in oxygen -enriched atmosphere within the calorimeter bomb. The heat released increases the temperature of the bomb and its surrounding water jacket. The calorimeter measures the temperature rise, makes the necessary corrections, calculates the heat release attributable to the combustion of the sample, and reports it as the calorific value of the sample in kJ per kg
Carbon [CEN/TS 15407]	Carbon %	A known mass of sample is burnt in oxygen. The combustion gases are passed over suitable reagents to assure complete oxidation and removal of undesirable by-products such as sulphur, phosphorus and halogen gases. The oxides of nitrogen are converted to molecular nitrogen and residual oxygen is removed in the reduction tube. The concentrations of carbon dioxide, water vapour and nitrogen gas are measured by thermal conductivity cells. The instrument uses the concentration of these gases together with the sample weight to give a direct readout of the percentages of carbon, hydrogen and nitrogen.
Hydrogen [CEN/TS 15407]	Hydrogen %	
Nitrogen [CEN/TS 15407]	Nitrogen %	
Oxygen [by difference]	Oxygen %	Oxygen content is calculated by difference, i.e. $100-\sum\%C+\%H+\%N$
Sulphur [CEN/TS 15407]	Sulphur %	A known mass of sample is incinerated at 1350ºC in an oxygen- enriched atmosphere. The sulphur in the sample is converted to sulphur dioxide and is measured by an infrared cell. The measured quantity is converted into a percentage
Chlorine [CEN/TS 15408]	Chlorine %	A known mass of the sample is oxidized by combustion in a bomb containing oxygen under pressure. Chlorine-containing compounds are converted to chlorides which are absorbed and/or dissolved in an absorption solution (water or KOH 0,2 M solution); analysis of Cl by ion chromatography

Along with the mixed waste materials and the individual components of waste, the above lab analysis will also be applied to other materials of potential interest from the waste sites. These can typically include street sweepings, fines and light materials [removed by a windshifter].

5. Results

The composition and analytical data for waste materials assessed in seasons 1 and 2 are shown in Tables 7 and 8. All proximate and ultimate analysis was undertaken by TES Bretby unless otherwise stated. There is significant variation across the waste streams and seasons, which is to be expected due to the varying nature of waste.

It was not possible to sample Elstow in season 1 and Blochairn [x1] and Broxburn [x2] in season 2 due to adverse weather conditions. The implications of this are that we collected no data on general MSW in season 1 and less data for C&I materials from Scotland in season 2. Whilst not ideal, this presents little problem as this data will be captured in seasons 3 and 4 also, and can be validated against existing literature.

The adjusted CV [Tables 8 & 9] is calculated from the quoted CV values and reduced to allow for inert materials. This was done as part of the analysis by Marchwood Scientific, and so an adjustment calculation was not necessary.

Table 8. Composition and detailed analysis of waste materials in Season 1

		Season 1								
	Site-	Blochairn	Blochairn	Broxburn	Broxburn	Kettering	Milton Keynes	Milton Keynes	Milton Keynes	Milton Keynes
	Sample type-	Co-mingled hh recycling	Mixed C&I	Mixed commercial recycling	Mixed C&I	C&D	Mixed commercial	Mixed commercial	Mixed industrial	Mixed industrial
	Date-	08/12/2009	09/12/2009	04/01/2010	05/01/2010	25/11/2009	23/11/2009	24/11/2009	23/11/2009	24/11/2009
Physical Composition (% weight)	Paper	50.3	24.7	40.3	24.5	3.9	13.8	23.0	4.4	8.8
	Card	20.0	10.4	27.7	15.9	2.8	15.4	19.8	7.4	20.8
	Wood	0.0	0.0	0.0	0.0	17.7	13.2	6.8	42.9	33.5
	Metals	3.4	13.5	1.3	6.1	4.1	0.1	11.9	9.7	4.2
	Glass	3.5	0.3	0.0	4.3	0.0	12.7	0.4	0.3	0.1
	WEEE	0.0	0.3	0.0	0.0	1.7	0.1	1.8	1.8	0.1
	Textiles	4.3	0.0	0.0	8.8	0.3	0.1	5.4	1.1	1.3
	Dense Plastics	12.3	9.2	12.7	7.9	1.8	3.9	9.4	26.5	5.8
	Plastic Film	1.4	28.5	14.2	9.2	2.5	8.3	9.4	2.8	4.0
	Organic Fines	4.9	12.5	3.9	20.7	0.0	32.0	11.9	2.9	8.5
	Inert/Agg/Soils	0.0	0.6	0.0	2.6	65.1	0.6	0.4	0.2	12.6
Proximate	Total Moisture %	38.7	9.1	24.6	27.7	26.7	31.3	47.8	52.7	71.9
	Ash %	15.2	21.7	14.6	9.4	5	9.5	13	16	11
	Volatile Matter %	42.6	65	58.6	54.5	58.7	52.7	37.8	25.9	14.5
	Gross Calorific Value kJ/kg	9,132	15,331	11,439	12,015	13,045	12,039	7,495	7,477	3,461
	DAF Calorific Value kJ/kg	19,821	22,146	18,803	19,113	19,107	20,352	19,111	23,890	20,240
	Net Calorific Value kJ/kg	7,589	14,035	10,014	10,483	11,519	10,479	5,799	5,728	1,468
	Adjusted Gross CV kJ/kg	**8,504**	**13,079**	**11,295**	**10,456**	**3,798**	**10,432**	**6,417**	**6,582**	**2,870**
	Adjusted Net CV kJ/kg	**5,549**	**10,516**	**7,119**	**7,452**	**3,030**	**7,462**	**3,817**	**4,616**	**912**
Ultimate elemental analysis (%)	Carbon %	23.54	37.17	30.73	31.02	32.05	30.3	20.08	19.03	7.65
	Hydrogen %	2.74	4.95	3.78	3.92	3.99	3.65	2.42	2.5	0.84
	Nitrogen %	0.21	0.53	0.2	0.27	0.21	0.21	0.14	0.26	0.88
	Oxygen %	19.6	26.4	26	27.6	32	25	16.5	9.4	7.7
	Sulphur %	0.04	0.18	0.05	0.06	0.06	0.05	0.02	0.1	0.06
	Chlorine %	0.04	0.12	0.04	0.1	0.09	0.04	0.06	0.09	0.08

Table 9. Composition and detailed analysis of waste materials in Season 2 [*denotes samples analysed by Marchwood Scientific]

		Season 2							
	Site-	Blochairn	Elstow	Elstow	Kettering	Kettering*	Milton Keynes*	Milton Keynes*	Milton Keynes*
	Sample type-	C&I	MSW [general]	MSW [general]	C&D	C&D	Mixed commercial	Mixed industrial	Mixed industrial
	Date-	01/04/2010	25/02/2010	17/03/2010	18/03/2010	04/05/2010	04/05/2010	04/05/2010	05/05/2010
Physical Composition (% weight)	Paper	17.5	4.7	12.7	0.1	0.0	19.5	3.9	2.9
	Card	15.8	3.0	2.1	5.3	0.0	11.4	6.3	37.9
	Wood	0.9	2.7	0.3	39.4	14.3	0.0	45.5	31.8
	Metals	4.7	6.4	1.2	2.1	2.0	1.4	0.8	5.0
	Glass	0.0	5.7	4.4	0.1	4.0	4.8	0.0	0.0
	WEEE	0.4	5.1	0.0	0.0	0.0	0.0	0.0	0.0
	Textiles	9.0	7.1	11.5	4.1	0.0	5.2	18.5	2.0
	Dense Plastics	9.0	14.5	3.6	5.5	11.6	11.0	10.4	2.3
	Plastic Film	15.0	19.9	18.0	4.2	0.0	15.7	3.7	9.6
	Organic Fines	21.4	22.2	37.0	0.0	0.0	31.0	0.6	8.5
	Inert/Agg/Soils	0.0	0.0	0.0	39.2	66.1	0.0	5.7	0.0
	Misc. Comb	6.4	8.8	9.2	0.0	2.0	0.0	4.7	0.0
Proximate	Total Moisture %	23.6	53.4	40.9	11.5	17.4	23.7	12.1	11.0
	Ash %	13.4	9.3	12.5	53.2	37.2	10.0	4.6	8.2
	Volatile Matter %	56	33.1	40	35.2	44.9	36.4	75.6	73.6
	Gross Calorific Value kJ/kg	12,490	7,491	10,773	7,836.0	**8,955**	**14,657**	**14,778**	**15,015**
	Net Calorific Value kJ/kg	11,013	5,690	9,147	7,233.0	**8,320**	**13,621**	**13,655**	**13,960**
	Adjusted Gross CV kJ/kg	**11,849**	**6,205**	**10,167**	**4,592**	n/a	n/a	n/a	n/a
	Adjusted Net CV kJ/kg	**8,707**	**4,541**	**8,443**	**3,859**	n/a	n/a	n/a	n/a
Ultimate elemental analysis (%)	Carbon %	32.01	18.51	23.24	13.93	17.2	35.2	41.1	42.5
	Hydrogen %	4.14	2.28	2.88	1.44	0.4	3.2	4	4.3
	Nitrogen %	0.4	0.3	1.0	0.7	2.5	1.5	1.1	1.3
	Oxygen %	26.4	16.2	19.4	18.6	78.4#	59.5#	53.5#	51.8#
	Sulphur %	0.1	0.1	0.1	0.7	0.5	0.3	0.1	<0.1
	Chlorine %	0.2	0.1	0.3	0.3	1.0	0.3	0.2	0.1

#calculated by deduction [Marchwood Scientific method]

5.1. Physical composition

Generally the recyclable content of mixed waste materials, MSW and C&I, is quite high. For instance the paper content of MSW and C&I vary between 4.7% [Elstow MSW, Season 2] and 24.7% [Blochairn C&I, Season 1]. The paper observed in the wastes was mostly office paper and newspaper, with the remainder consisting of tissue and packaging. There are varying quantities of drinks bottles, which are included in the dense plastic category; these are perhaps the easiest material to recycle currently within the residual waste streams.

The paper and card content of the MSW stream, sampled at Elstow, is much lower than that presented from the waste flow modelling in Report 1.1 [shown in Table 4]. This is highly likely to be due to a recycling scheme in the area with a high capture rate of these materials, thus lowering the proportion of paper and card in the general MSW stream. As a result, the sampling of the Shanks-collected recycled MSW materials should be added to the sampling strategy.

The paper and card content of mixed C&I wastes (Blochairn and Broxburn) varies from 30-40%, and is comparable to the paper and card content (32%) of mixed C&I reported in Table 6 (SLR Consulting 2007). The dense plastic content is also similar, with 8% observed in the SLR study whereas at the Shanks sites it was observed to be between 8-9%. However the plastic film content observed at the Shanks sites is approximately twice that observed in the SLR study, whereas the plastic film content of the Milton Keynes industrial wastes (sampled separately from commercial wastes) is around the same value, or less than, the proportion observed by SLR. Likewise the commercial waste from Milton Keynes contains a higher proportion of film plastics. Therefore it can be concluded that commercial premises, such as retail and offices, produce greater quantities of film plastics than industrial sectors; due to the increased numbers of refuse sacks used and a greater quantity of packaging waste.

The household and commercial recycled materials [Blochairn 08/12/09 and Broxburn 04/01/10 respectively] both contain large quantities of paper, which is to be expected from a waste collected via local authority recycling rounds. The higher net CV for commercial recycled material is likely to be due to the significantly higher film plastic content, and also as this material has lower moisture content. As is shown in Table 9, the net CV of film plastic is higher than that of dense plastic.

Plastic film, which includes carrier bags and packaging wastes, made up a large proportion of the mixed C&I and MSW materials [9.2-28.5% in season 1 and 15-19.9% in season 2]. The commercial waste stream at Milton Keynes contained 8.3-9.4% in season 1 and 15.7% in season 2. These materials are high volume materials; they are lightweight and take up a high proportion volume-wise of the waste materials. These materials are not readily recycled, which explains the high presence of these materials in the waste streams sampled. The future presence of film plastics in residual wastes streams is important when considering the fuel potential of these wastes since film plastics are very high CV materials [39,000 kJ/kg as shown in Table 9]. The removal of film plastics from the waste stream would subsequently result is a significant decrease in the CV content, and as a result the thermal energy recovery value, of the overall waste.

5.2. Sample analysis

The moisture content of wastes is shown to vary largely, with an average value of 35%, however an industrial sample from Milton Keynes contains 71.9% moisture. This is a very high result, though the waste material contained large amounts of wood material [42.9% w/w] which was observed to be very wet when the site was visited. This is likely to be influenced by the adverse weather conditions at the time. This sample also indicated a very low net CV value. This is due to the high moisture content of the waste, the higher inert content [12.6%] than other industrial and C&I samples and also due to the relatively low dense and film plastic content [5.8 and 4% respectively].

As the moisture content impacts on the net CV of the waste materials caution is required when considering these materials as potential fuels. Wastes of higher moisture content would require drying prior to use as a fuel and, in cases where grinding and pre-sorting are required, increase the costs of preparing the material prior to energy recovery. Therefore consideration could be given to waste containers and the collection schemes, including the collection vehicles used, to prevent the addition of rain water to the material before arrival at the treatment facility.

From the ultimate analysis it can be observed that a relatively high gross CV coincides with high carbon content. This is to be expected, however the net CV is calculated using moisture, hydrogen, oxygen and nitrogen content, therefore a high carbon content will not result in a high net CV.

The highest chlorine content was observed for the C&D waste collected at the Kettering site on 04/05/10. It was observed, on this occasion, that the C&D waste consisted largely of materials resulting from a house being demolished. Therefore the waste contained a large amount of wooden door frames and aggregate material [soil and brick]. However in the waste there was also a quantity of dense plastics which consisted largely of PVC window frames; these results in the chlorine content of 1%, which is roughly 10 times that of all other waste analysed.

Table 10. Detailed analysis of individual components and separated materials

	40-200mm Windshifter Kettering 18/1/09	**0-40mm Windshifter Kettering 18/11/09**	**0-6mm Fines Kettering 18/11/09**	**Textiles 05/2/10**	**Wood 05/02/10**	**Dense Plastics 05/02/10**	**Paper/Card 05/02/10**	**Film Plastic 05/02/10**
Total Moisture %	22.9	21.4	20.4	3.5	6.2	5.7	5	2.9
Ash %	18.6	45.9	68.9	13.3	2.4	1.5	13.2	5.4
Volatile Matter %	52.8	37.3	16.7	75	76.1	89.6	72.4	91.6
Gross Calorific Value kJ/kg	11,336	9,057	2,181	20,670	18,935	35,180	15,602	41,321
DAF Calorific Value kJ/kg	19,380	27,700	20,380	24,840	20,720	37,910	19,070	45,060
Net Calorific Value kJ/kg	9,969	7,812	1,316	19,297	17,614	33,110	14,403	39,057
Carbon %	29.26	23.99	5.19	48.65	46.84	71.2	39.35	78.54
Hydrogen %	3.59	2.65	0.6	5.51	5.39	10.24	4.85	13.22
Nitrogen %	0.39	0.85	0.26	3.51	0.58	0.24	0.35	0.4
Oxygen %	24.8	4	3.3	25.2	38.5	11	37.2	<0.1
Sulphur %	0.41	1.23	1.34	0.37	0.04	0.07	0.06	0.02

Chlorine %	0.19	0.01	0.08	0.05	0.03	0.09	0.02	0.03

Paper and card yield the lowest net CV [14,400 kJ/kg] of the analysed waste components. These are also present in relatively high proportions in the C&I fractions shown in Tables 8 and 9. As paper and card are commonly recycled (especially for MSW streams) consideration should be given to the benefits of recycling this material and the potential impacts on the fuel value of the overall waste stream.

The film and dense plastic materials indicate a significantly higher net CV [39,000 and 33,000 kJ/kg respectively] than the other components. Film plastic, however, is not commonly source-segregated for recycling collections. The chlorine and sulphur content of these plastic streams are not higher than other materials, and so further consideration should be given to the environmental emissions resulting from the use of these materials as a fuel, as they may not be too unfavourable.

5.3. Site waste arisings

The quantity of specific waste materials arriving at each of the sampled Shanks waste sites is shown in Figure 3. Milton Keynes is not shown due to the site only operating for 3 months during 2009.

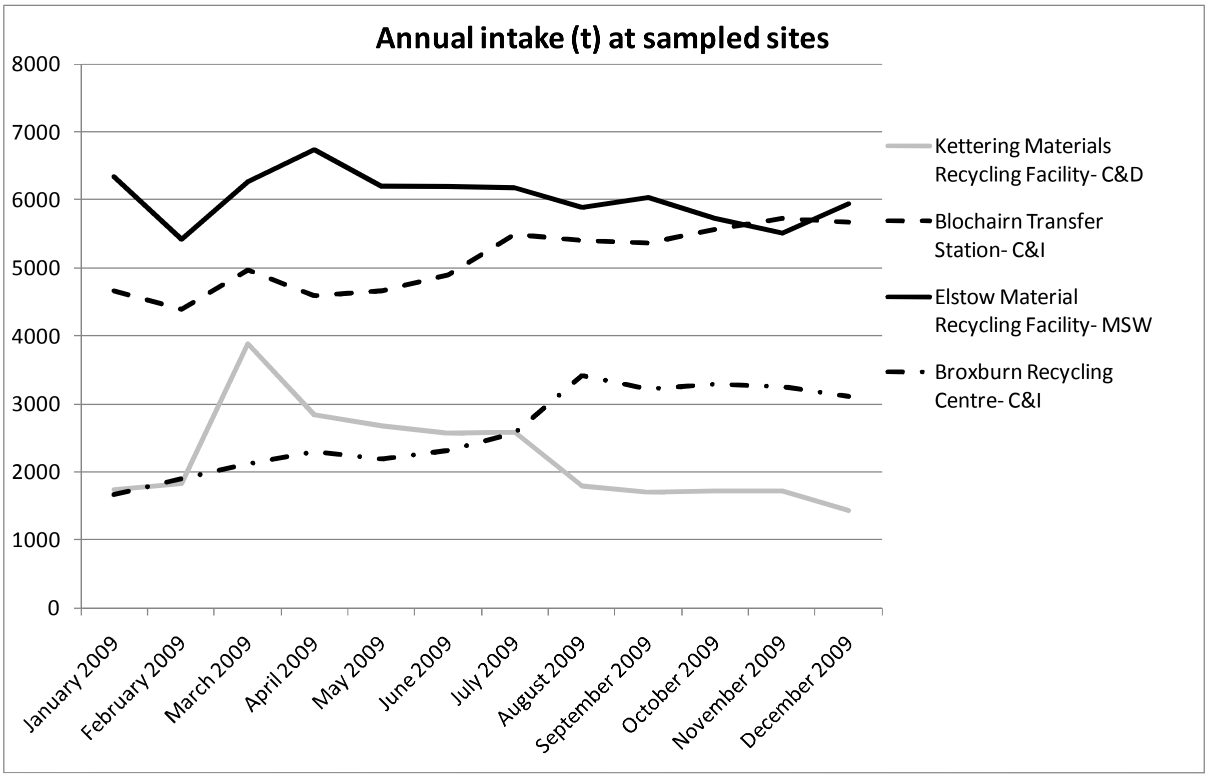

Figure 3. Quantity of specific waste materials arriving at sampled Shanks sites.

Waste arisings are variable, as is the composition, and this is shown in Figure 2. A number of factors can explain the fluctuations and growth in waste arriving at the sites, such as adverse weather [flooding and snow], site building work, changes in contracted collections, economic impacts etc. For example, over the winter period there was a relatively low quantity of C&D waste arriving at the Kettering site, this could be due to the snowfall in the area causing a backlog of materials at the construction sites, resulting in a very sudden increase in March.

The fluctuations in quantities and composition of waste arriving are a result of seasonal and economical changes. These are a risk, however are an acceptable risk since waste is variable, and are inherently associated with the design of energy from waste facilities. The risk of composition changes can be addressed through pre-processing of waste and bulking of the refined fuel. For example, if a waste contains between 5-10% metal then efficient removal of this through a material recycling factory [MRF] would refine the waste material as a fuel. The level of pre-processing required for the use of waste materials as a fuel is dependent on the energy recovery technology and the associated tolerances; a higher level of pre-processing required results in a high cost, and possibly a higher quantity of waste material [i.e. inert from C&D wastes]. Therefore variability in the waste composition can be offset by adaptable processing of the waste to yield consistent fuels.

Based on the quantities of waste arriving at each of the Shanks wastes sites, and using an average of the calorific content of these materials, an estimate can be made of the potential energy value of these materials. This is summarised in Table 11.

Table 11. Total annual energy potential for each material sampled at each site

Site [waste type]	Total waste [t]	Non-inert material Average CV [kJ/kg]	Total material Average CV [kJ/kg]	Total CV per annum [GJ]
Blochairn [C&I]	61,400	12,524	9,611	590
Broxburn [C&I]	31,300	10,483	7,452	233
Elstow [MSW]	72,500	7,419	6,492	471
Kettering [C&D]	26,500	9,376	3,444	91

The net CV for C&D wastes throughout seasons 1 and 2 is low, which is expected due to the very high content [65.1, 39.2 and 66.1%] of inert materials [aggregate]. Whilst the net CV content of the non-inert material is comparable to other waste streams the inert fraction [aggregate, glass and metals] accounts for up to 72% of the waste material. Therefore a significant amount of material would need to be removed from the waste prior to use as a fuel, resulting in subsequent disposal/handling costs of the inert materials.

6. Future work

6.1. Knowledge development

The image analysis technique is currently being developed based on the findings of previous research undertaken at Cranfield University, and the results for all seasons will be presented in Report 1.3. This will provide a more in-depth understanding of the variation in composition and the reliability of waste sampling methodology, as the sample size will be much larger. It also provides an innovative method of gaining a much larger sample set without having to physically sort through the waste material, which is time consuming and disruptive to site operations. This is currently being developed through an applied research project at Cranfield University [invention disclosure form, INF, pending].

In order to build a more complete picture of UK waste materials the third party analysis will involve a more comprehensive analysis of individual waste components for seasons 3 and 4. This will allow a more detailed analysis of the physical sort data in terms of estimated energy content, and which components yield a higher calorific value in mixed waste streams. This could be used to develop a model in which the changes in waste material CV can be calculated as the proportion of each component of waste is varied.

A major driver behind the use of certain materials as a fuel is the commodity value. This is the financial benefit of separating a specific waste component for reuse. Certain components, such as specific plastics, provide a financial incentive to the waste treatment operator. However if the market value of the recyclate was to drop or the energy value was to increase due to technological advance, then the ongoing separation of that recycled material may no longer be profitable and as a result would remain in the mixed waste stream, available as a fuel. Ongoing research at Cranfield University is assessing the composition of each type of plastic [e.g. high density polypropylene, HDPE] in C&I mixed wastes, and comparing the energy value with commodity value.

Cranfield University have had discussions with Defra to explore the benefits of developing a synergy between the waste data collection and the C&I survey that Defra are currently undertaking. A document, agreed by Defra, detailing the method and benefits of such an arrangement is provided in Appendix A.

6.2. Amendments to data collection methodology

Due to a contractual change at the Shanks Kettering site, the industrial and commercial streams received at the Milton Keynes transfer station are no longer delivered and stored separately. Therefore for seasons 3 and 4 the sampling at the Milton Keynes site will be C&I mixed wastes, rather than two separate streams.

The following changes will add extra value to current data collection and understanding of the fuel potential of waste materials-

- A greater number of samples of individual components will be sent for detailed laboratory analysis, providing a clear understanding on variability from waste samples. This is not possible without using replicate samples;
- MSW recycling material from Elstow to be added to the waste sampling strategy, and will completed at the same time as one of the scheduled visits to Elstow;
- An additional Shanks site [Aylesbury, Bucks] has been added to Season 3 to cover additional development requirements [image analysis and plastic composition] and will focus on mixed C&I materials;
- Approach further industrial representative and individual companies in order to access sector-specific datasets;
- Detailed analysis of the different plastics present in the C&I waste stream

These amendments are aimed at enhancing the data collected as part of this project, providing a valuable dataset from which a greater understanding of the energy potential of UK wastes can be achieved.

6.3. Key insights and lessons learned

Based on the findings of this work to date, including previous reports, several key points can be raised regarding the future steps that would enhance the understanding of UK waste arisings.

- Understanding of recycling trends, such as increased recycling rates in C&I waste streams and the shift of recycling rates in MSW. There is a notably higher proportion of recyclable material present in mixed C&I wastes, and as such there could be a decrease these materials in the future;
    - Driven by economic factors, government and local authority level targets;
    - Using the known factors to estimate future recycling trends;
    - Estimate the effects of changes in recycling levels on the composition of residual wastes, moisture content and net calorific value;
- Rapid assessment tools- the image analysis method is showing potential as an alternative method of monitoring waste composition. Additionally analytical methods developed at Cranfield University could be utilised in understanding the biogenic carbon content of heterogeneous waste materials, which is useful for the allocation of renewable obligation certificates [ROCs];
- Sector data for C&I wastes- it would be valuable if all wastes arriving at the transfer stations could be allocated, proportionately, to specific SIC codes. This would allow a greatly improved understanding of the mixed residual wastes collected. An alternative to this would be a large scale waste composition study which collects waste samples from pre-specified locations, such as retail, catering, education etc;
    - Could be linked to economical changes for each sector;
    - And waste minimisation strategies specific to different sectors.

A number of key findings have been outlined in this report, however a number of areas require further work which could be addressed in future projects which could provide the resources and timescales necessary.

7. Conclusions

The objective of this report is to describe the initial results for assessed wastes in terms of composition and energetic content; the initial conclusions from the compositional and volumetric data and to discuss the further analysis for seasons 3 and 4. Also to use the knowledge gained to identify opportunities to enhance the data collection as the project progresses.

The initial results have been presented, and the initial conclusions are that the waste composition for all streams is variable within reasonable limits. Capturing this variation throughout this work package is a priority, and the further development opportunities and amendments to the current data collection methodology aim to provide a greater understanding of this variation. Further consideration to the variability of the waste materials will be applied in Report 1.3.

As is shown in Table 10 C&I wastes have yielded the highest net CV (allowing for moisture content), and based on the existing understanding of C&I arisings (Table 2) it can be concluded that C&I wastes have the highest potential for use as an energy material. The C&D waste stream contains such a large quantity of inert aggregate material that the net CV is much lower than that of C&I and MSW materials.

The potentially recyclable materials present in the residual wastes, in particular C&I, is of importance. The plastic materials contribute significantly to the CV of the overall material, and as discussed in section 6.3, being able to understand future recycling trends would be important.

Further work has been identified based on the lessons learned from seasons 1 and 2. This includes an additional sample of source segregated recycled material collected from households (co-mingled recycling) to validate the low paper and card content observed in general MSW. The requirement to undertake a detailed analysis of each waste component has also been identified, which will add significant value to the overall data generated from the site sampling.

In addition to the site sampling the image analysis technique is being further developed to understand the extent of variability. Data will also come from other important sources including Defra as discussed previously and from sector-specific companies and representatives.

8. References

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Appendix

A. Waste data link with Defra

Data collection process and summary of analysis – Work Package 1

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Context

Work package 1 aims to collect the best available data on waste arisings and composition within the UK to then convert this in to a value of its fuel potential. The work draws information from a review of completed and ongoing waste studies plus a sampling programme of waste from UK sites. Expert advice has been sought from the Defra Waste Research and Evidence team in addition to input from the UK waste industry and process operators to guide the research design. Data has been drawn from a wide range of sources. In addition Shanks Waste Solutions Ltd., are providing access to their sites, company data and site specific samples and data.

The objective of this work-package is to gain the best possible understanding of the energy potential of wastes, biochemical and or thermo-chemical, across the UK. This information will then be used within the project specify better the technology requirements for using waste as a fuel. In order to achieve this, the research method will extend the value of existing data to understand the properties of waste as a fuel. This is over and above the evidence collated for UK policy and regulatory development. It will then be used to guide the technology assessment and development priorities in the following work packages. Central to this is maximising the reliability of results to inform best value in monitoring and the later decisions within the technology assessment.

Data is drawn from 5x main sources; peer reviewed references, sector reports, industry specific data, operator data [Shanks] and direct sampling, Figure 1.

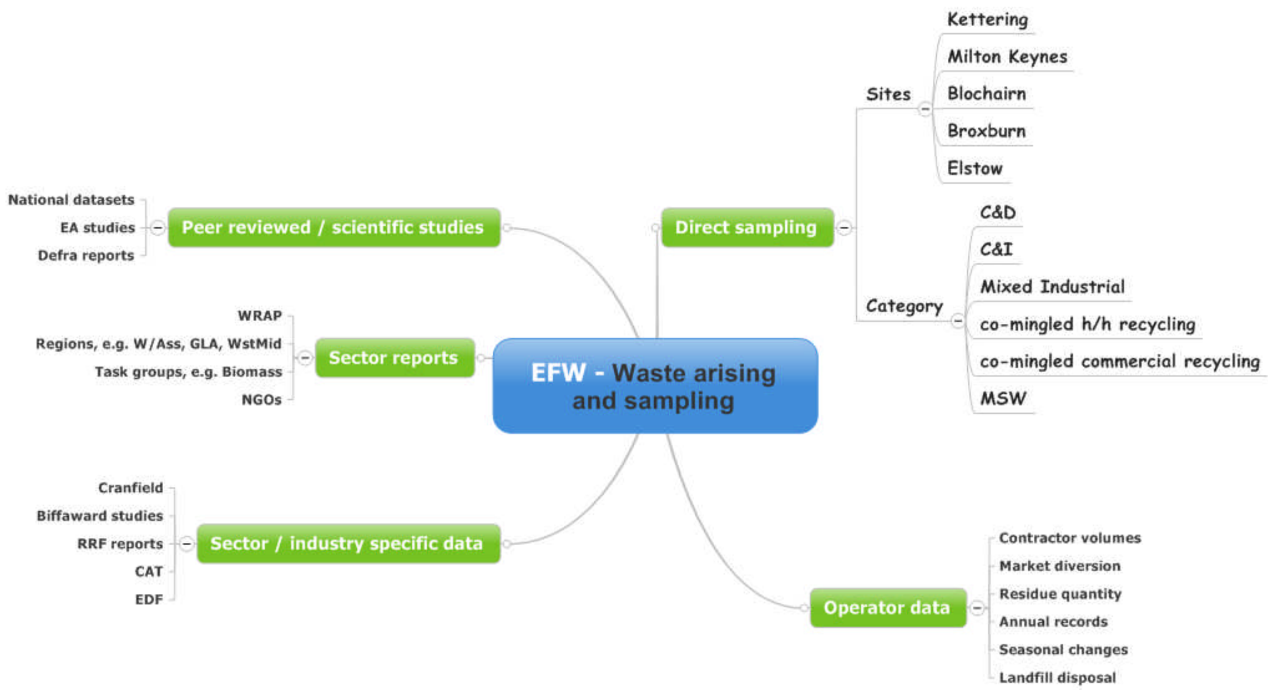

Figure 1 Data sources in WP.1

Waste sampling and site data collection has been prioritised on commercial and industrial waste as this represents the arisings with the highest volume matched by highest calorific value where least information is known.

Sector type vs data	Ag	M&Q	SwS	DrMt	Hsld	Com	Ind	D&C
	<1%	30%	<1%	5%	9%	11%	13%	32%
Energy	H	L	H	L	H	H	H	M
Volume	L	H	L	M	M	H	H	H
DataQu	M	M	H	L	H	L	L	M

Figure 2 UK waste arisings and data priorities for fuel analysis

Two key stages are introduced within work package to maximise the data value; image analysis to maximise the number of samples available on waste data that can be collected, and data integration with existing sources. These approaches are included to provide the most reliable and best value outcome from the study that meet necessary time constraints of project reporting.

Image analysis

Evidence from previous work indicates that the manual sorting of waste can provide a close determination of lab analysis[1]. This technique has been further developed to use digital photo images of waste to calculate the manually sorted composition of wastes. The method developed matches the analysis of waste images with manual sorting to calculate the total composition. The cross-comparison of these techniques is used firstly to calculate and adjust for errors and then to validate the method. Taking this approach significantly increases the volume and quality of data generated across the site visits whilst also enabling future analysis to progress rapidly with an ongoing monitoring of results to calibrate the method.

Data integration

Work package 1 uses differing data sources to extend existing knowledge of data flows to provide an analysis of fuel potential. This is undertaken by linking information on arisings by; sector [SIC codes], total waste tonnages [commercial data and national reports] and industry & waste type reports [WRAP] to extend knowledge about commercial and industrial (C&I) waste arisings.

In addition, Defra working in partnership with the London Waste and Recycling Board (LWaRB) and the South West region is commissioning a survey to obtain data from businesses in England on waste arisings and management in 2009. The aim of this work is to determine the total tonnage of C&I waste produced in England in the calendar year 2009, broken down by broad business sectors and material types, and to identify management methods for each waste stream.

These data sources will be integrated by matching known tonnages of waste by sector (using SIC codes) with compositional analyses for corresponding sectors. This provides an “origin by waste type by weight/tonnage” dataset. Existing sources in addition to the forthcoming Defra data will be used to extend these site specific analyses to other locations.

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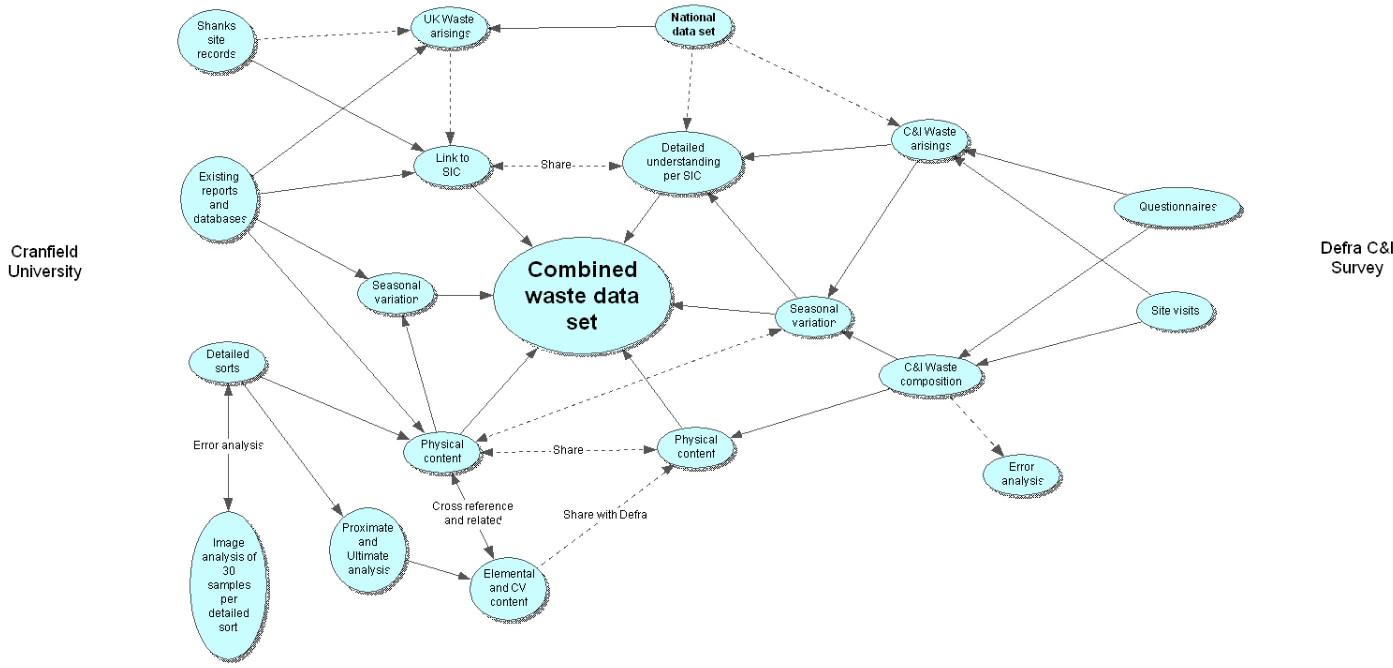


Figure 3 Data types and flow within WP.1

Defra intend to use the standard Substance Oriented Classification (SOC) in recording waste types (see Table 2 in the appendix), which is an aggregation of European Waste Catalogue (EWC) codes used in the 2002/03 survey. This will allow a direct link to be made between the compositional analyses with an associated fuel value or range. The Defra study stratifies the sample by 12 business sectors shown in Table 2 in the appendix.

Sample detail

Waste samples will be taken from Shanks sites in England and Scotland, and will focus mainly on the C&I waste stream due to the lack of understanding. There are 5 sites which will be used for the waste compositional and sampling exercises, which will be visited twice per season. The Shanks site in Milton Keynes typically receives commercial and industrial streams separately, and so this site will equal 4 visits (2 visits per season; 2 sets of sample per visit). Therefore a total of 12 site data sets per season will be produced.

For each site visit there will be a detailed hand sort of the waste, along with 30 images for visual composition analysis. For each detailed sort there will be at least 1 representative sample sent for lab analysis. Therefore:

- 3x bucket loads from input waste material;
- Bags split and waste spread evenly- ≤50m^3 spread
    - 30x images
- 10-15x shovel loads of above spread for detailed sort- ~30-60kg (sub-set)
    - C&D materials typically ≥100kg;
    - Observations recorded for large/abundant/unusual items and a visual description of moisture content;
    - Photographs taken of site during sampling.
- Representative sample made up for lab analysis

- From compositional analysis for site (mixed waste stream);
- Single material samples, e.g. paper, card, plastics

The lab analysis will comprise of proximate and ultimate analysis, and so will determine the following:

- Moisture content
- Volatile matter
- Gross and net CV
- Carbon
- Hydrogen
- Oxygen
- Nitrogen
- Sulphur
- Chlorine
- Ash fusion temperatures

Along with the mixed waste materials and the individual components of waste, the above lab analysis will also be applied to other materials of potential interest from the waste sites. These can typically include street sweepings, fines and light materials (removed by a windshifter).

Summary

Overall WP.1 provides a new and more detailed understanding of the UK waste composition and potential as a fuel. This is built by extending manual sorting on site and integrating data from multiple sources including that provided by Defra. The latest Defra study provides a new and updated understanding of C&I waste which when combined with compositional and fuel analysis makes both valuable data sets into a unique analysis.

The results within work package 1 are drawn from a comprehensive knowledge of waste arisings by SIC which will then be matched with the comprehensive composition analysis being undertaken. This is then shared with Defra to further extend the breadth and depth of value of data quality enhancing the research of both parties. This data sharing includes the elemental and CV data for mixed wastes, and the individual components. WP.1 generates data on the waste composition as well as the proximate/ultimate analysis which is not available in the research literature at this level. Alongside this it compiles a large volume of existing data. In addition, company specific data from a number of sites is included. WP.1 will benefit from the larger sample size produced within the Defra study which is designed to gain a stronger understanding of C&I waste composition and tonnage. Information on energy content, which does not form part of the Defra work, will be collated by the ETI project and extended to make best use of the Defra study thus maximising the data value and benefit to both research parties. This will provide a uniquely comprehensive and detailed analysis of the fuel potential from waste in the UK.

B. C&I SIC groups and waste categories

Sector no.	Description	SIC(2007) groups
Industrial sectors		
1	Food, drink & tobacco	10.1 – 12.0
2	Textiles / wood / paper / publishing	13.1 – 18.2
3	Power & utilities	19.1 – 19.2, 35.1 – 36.0
4	Chemicals / non-metallic minerals manu.	20.1 – 23.9
5	Metal manufacturing	24.1 – 25.9
6	Machinery & equipment (other manu.)	26.1 – 33.2
Commercial sectors		
7	Retail & wholesale	45.1 – 47.9
8	Hotels & catering	55.1 – 56.3
9	Public administration & social work	84.1 – 84.3, 86.1 – 88.9
10	Education	85.1 – 85.6
11	Transport & storage	49.1 – 53.2
12	Other services	58.1 – 82.9, 90.0 – 96.0

Table 1 Defra sample stratification

SOC Group	SOC Sub-Group	EWC-Stat code
Chemical wastes	Spent solvents	1.1
	Acid, alkaline or saline wastes	1.2
	Used oils	1.3
	Spent chemical catalysts	1.4
	Chemical preparation wastes	2
	Chemical deposits and residues	3.1
	Industrial effluent sludges	3.2
Healthcare wastes	Health care and biological wastes	5
Metallic wastes	Metallic wastes	6
Non-metallic wastes	Glass wastes	7.1
	Paper and cardboard wastes	7.2
	Rubber wastes	7.3
	Plastic wastes	7.4
	Wood wastes	7.5
	Textile wastes	7.6
	Waste containing PCB	7.7
Discarded equipment	Discarded vehicles	8.1
	Batteries and accumulators wastes	8.41
	WEEE and other discarded equipment	8.2, 8.43
Animal & vegetable wastes	Animal waste of food preparation and products	9.11
	Animal faeces, urine and manure	9.3
	Animal & vegetal wastes	9 excl. 9.11 & 9.3
Mixed (ordinary) wastes	Household and similar wastes	10.1
	Mixed and undifferentiated materials	10.2
	Sorting residues	10.3
Common sludges	Common sludges (excluding dredging spoils)	11 excl. 11.3
	Dredging spoils	11.3
Mineral wastes	Combustion wastes	12.4
	Contaminated soils and polluted dredging spoils	12.6
	Solidified, stabilised or vitrified wastes	13
	Other mineral wastes	12.5
	Construction and demolition wastes	12.1
	Asbestos wastes	12.2
	Waste of naturally occurring minerals	12.3
*Non-wastes**	*Virgin timber*	
	Blast furnace slag	

Table 2 SOC and EWC code classifications

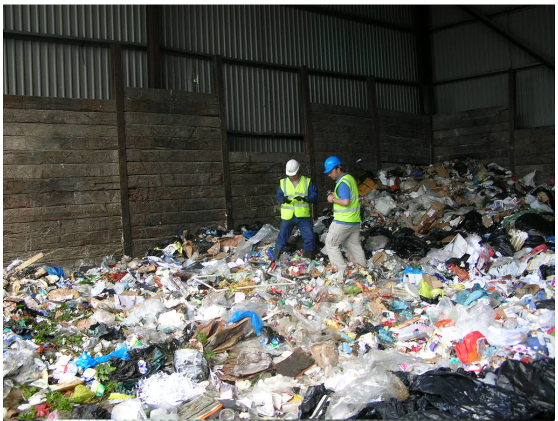
C. Waste sampling methodology

A Shanks site operator uses a wheel loader to spread the waste from the appropriate waste stream on the floor of a suitable reception area.

Approximately 50m^3 of waste from randomly selected collection routes is spread to a depth of ~20cm.

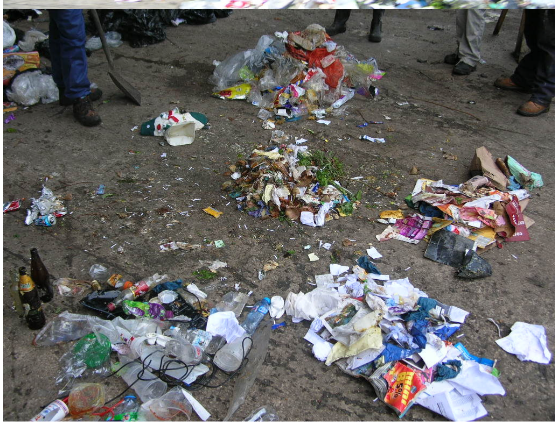
The waste is manually removed from back bags (and other packaging) so that the waste materials can be visually inspected.

30 digital photo images are captured of a 1m x 1m quadrant on the surface of the waste.



The location of the quadrant images is randomly selected by “blind throwing” the quadrant. Care is taken to avoid duplicating similar imaging locations.

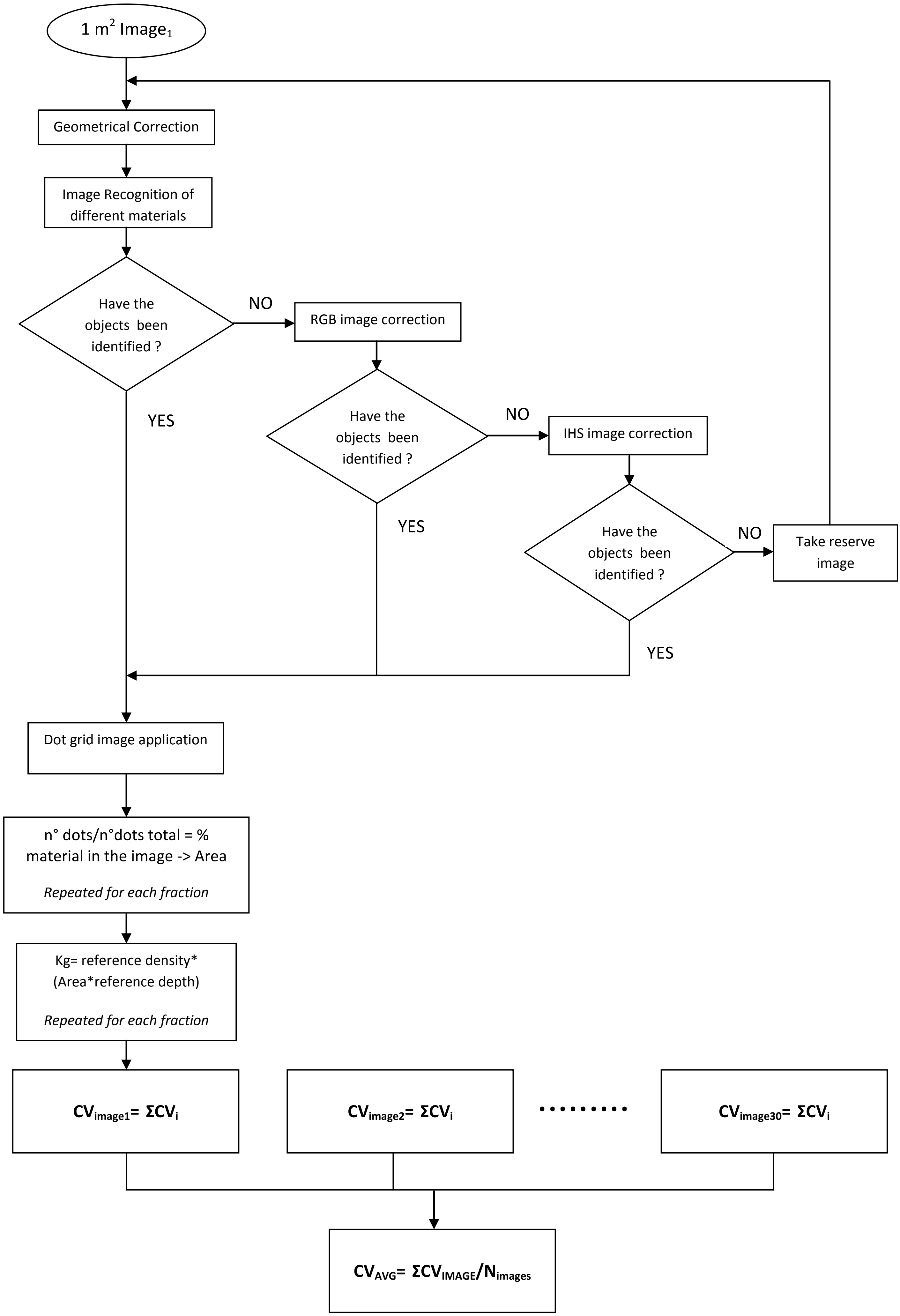
10 to 15 shovel loads of the overall waste stream are collected into a separate sub-pile. Due to the difficult in shovelling large waste materials, some shovel loads are manually gathered. The aim is for the sub-pile to be broadly representative of the materials and their relative proportions in the main waste stream. This sub-pile is manually sorted into its constituent materials as per the project categorisations. Each of the constituent material piles are weighed individually.



The constituent materials are co-combined and mingled into the sub-pile. A sample of this sub-pile, representative of the main waste stream, is collected into a sealed vessel for further laboratory analysis.

Further notes are taken of any irregular, large or other noteworthy items in the waste stream.

D. Image analysis process


1 m² Image1
Geometrical Correction
Image Recognition of different materials
Have the objects been identified ?
NO
RGB image correction
YES
Have the objects been identified ?
NO
IHS image correction
YES
Have the objects been identified ?
NO
Take reserve image
YES
Dot grid image application
n° dots/n°dots total = % material in the image -> Area
Repeated for each fraction
Kg= reference density* (Area*reference depth)
Repeated for each fraction
CVimage1= ΣCVi
CVimage2= ΣCVi
CVimage30= ΣCVi
CVAVG= ΣCVIMAGE/Nimages