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

VALORGAS

Project acronym: **VALORGAS**
Project full title: **Valorisation of food waste to biogas**
Grant agreement no.: 241334

D2.4: Case study for collection schemes serving the Valorsul AD plant

Due date of deliverable: Month 25
Actual submission date: **Month 25**

Project start date: 01/03/2010 Duration: 42 months

Lead contractor for this deliverable
VALORSUL SA – Valorização e Tratamento dos Resíduos Sólidos das Regiões de Lisboa e do Oeste

Revision [0]

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Lead contractor
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Revisions
Changes from version [0] consist of the addition of a list of names of the key individuals involved in preparing the report

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D2.4: Case study for collection schemes serving the Valorsul AD plant

1 Introduction

The work described in this Deliverable Report concerns the aspects/main characteristics of the selective food waste collection schemes that were implemented by Valorsul SA in partnership with the municipality shareholders of the company. The report also presents the results from the analysis (physical and chemical composition) of this food waste that is selectively collected from restaurants, canteens, wholesale and retail markets and others in the municipalities of Lisbon Area.

2 Valorsul SA

Valorsul SA is the company responsible for the treatment of the Municipal Solid Waste (MSW) produced in Lisbon, of approximately one million tonnes per year. It covers a population of 1.5 million inhabitants. To deal with one fifth of the MSW produced in the country, Valorsul has eight Collection centres, six transfer stations, two Material Recovery Facilities, one Anaerobic Digestion plant, one Incineration plant, one Bottom Ash Processing and Recovery plant, and two landfills.

Valorsul SA was given the mission of promoting actions that contribute to assuring sanitation and welfare of the population, namely:

a) The processing of MSW adjusted to the real needs of the municipalities, in quantitative as well as qualitative respects, in accordance with applicable national and EU regulations;

b) The promotion of the necessary actions in order to implement a proper policy of MSW management, namely regarding reduction and recovery of recyclables;

c) Cost control, efficiently and rationally using the available means in their activities.

According to the national waste management policy, the recovery of waste must be maximised either as energy or through recycling. The guidelines given by the EU were based on the following principles: waste minimisation; recovery of waste through separate collection, sorting and recycling; energy recovery and, finally, safe disposal of the waste produced.

Keeping this in mind, Valorsul SA has established an Integrated Waste Management System to take care of the MSW produced in its intervention area (Figure 1).

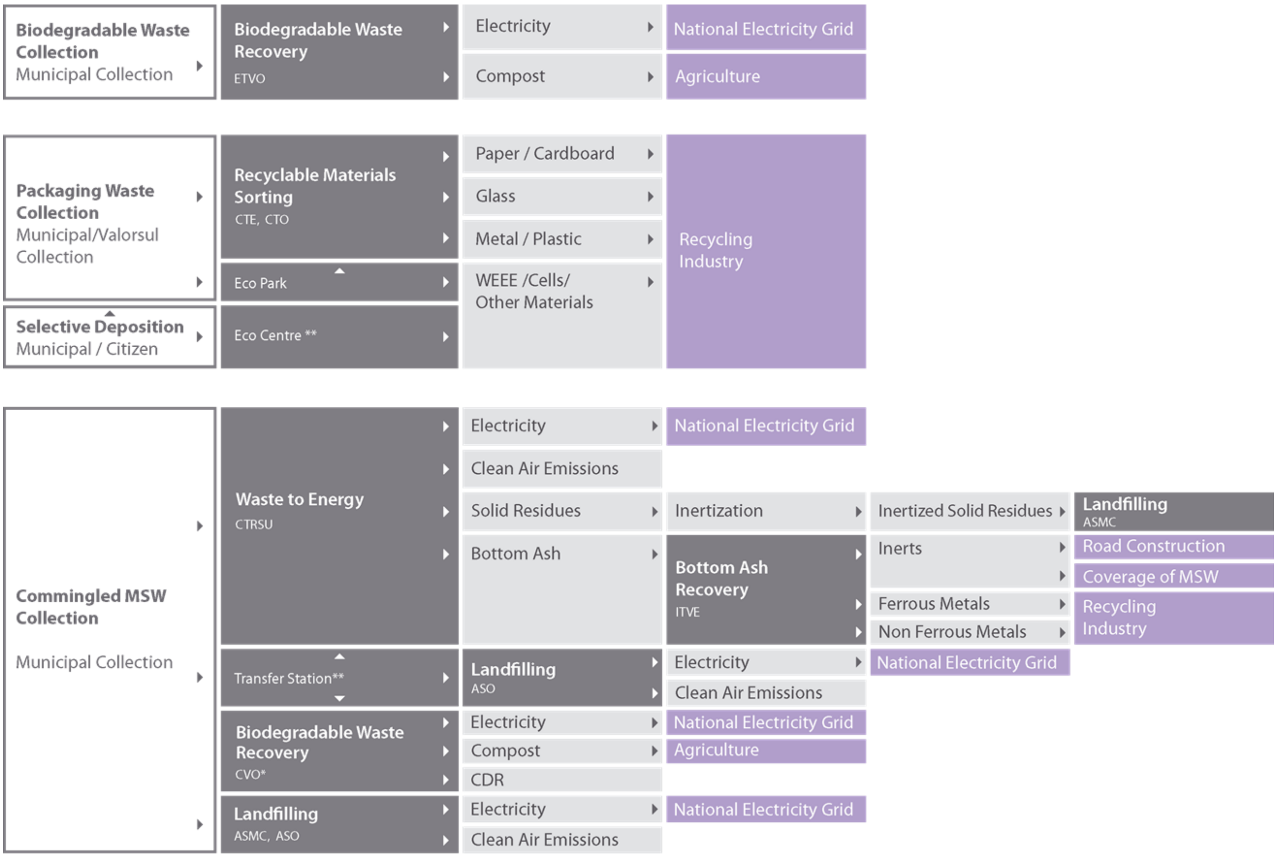


Figure 1. Valorsul's Integrated Waste Management System

2.1 Valorsul AD plant - Process Description

The Organic Fraction of MSW is selectively collected (SC-OFMSW) in restaurants, hotels, and supply and retail markets, amongst other big producers of this kind of waste in the municipalities of the Lisbon Area.

The Anaerobic Digestion plant (Estação de Tratamento e Valorização Orgânica, ETVO) of Valorsul was designed to process 40,000 tonnes of SC-OFMSW per year, with a planned increase of capacity to 60,000 tonnes per year in a second phase. Concerning compost and electrical energy, the plant design foresees, respectively, 16 kg tonne^{-1} and 285 kWh tonne^{-1} of waste processed. The waste that arrives at the plant is discharged to two different lines, depending on the level of contaminants. The process consists of a wet two-stage thermophilic anaerobic digestion process. After the digestion step, the organic suspension is dewatered and pre-composted in 5 tunnels with forced aeration, and post-composted in windrows in a covered area. The final compost is refined by passing through a sieve and a densimetric table to remove contaminants.

Valorsul SA opted for a separate collection system as the anaerobic digestion process requires a high-quality biodegradable waste as raw material. It also allows the production of better quality compost. Figure 2 presents a picture of the AD plant and the process flow diagram.

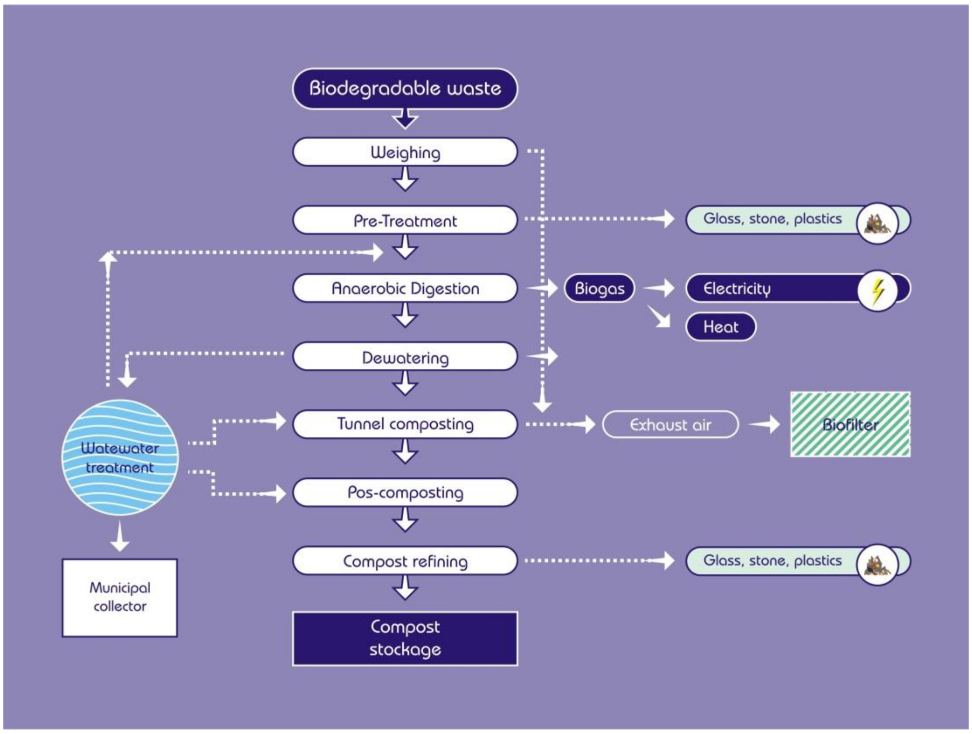


Figure 2. AD plant and process flow diagram.

3 Collections

3.1 Large producers - SC-OFMSW

As reported by Vaz *et al*. (2011) the separate collections currently serve 2547 participating establishments (large producers, SC-OFMSW) and 1988 households (SS-OFMSW), at the locations shown in Figure 3. The participating establishments were chosen by the municipalities who are responsible for the collection. The selection was based on the identification of high density areas in terms of OFMSW production, in order to ensure the collection of large quantities within small distances. Information on the sources of organic waste and types of collection is summarised in Table 1.

Table 1. Source of SC-OFMSW and type of collection

Population (3 municipalities)	Lisbon Loures Amadora
(Total producers – Figure 4)	~2565 collection points/large producers: Lisbon Municipality - 1871 Loures Municipality - 531 Amadora Municipality – 163 ~276 domestic buildings in 3 locations
Targeted material (e.g. general organic wastes, domestic food waste only, food waste and packaging, general organic wastes)	Organic waste separately collected on large producers like restaurants, canteens, markets, supermarkets and others. There are also two collection circuits [b] that include household waste.
Organisation operating collection	Municipalities of Lisbon, Amadora and Loures/Odivelas and private companies
Collection type (e.g. individual household, communal bins)	Communal bins - standard 1000, 660, 340, 240, 140, 90 litre Households bins: standard 120 litre (In both cases only bins are provided, not bags)
Material type	Separate collection of the organic fraction of MSW (SC-OFMSW)
Collection frequency	Daily (one circuit on Sundays)
Type of vehicle used	15 m^3, waste collection vehicles with double lifting system and compaction
Local and national regulations affecting collection and disposal	Protocols signed between Valorsul and the Municipalities to ensure the municipality is responsible for separate collection of organic waste. Contract signed with private companies (like EGEO and MARL - Lisbon Wholesale Market). There is no national/local regulation that requires separate collection: the decision was made by Valorsul.

Sources	**Responsible for collection**	**2007**	**2008**	**2009**	**2010**
Municipal collection	Amadora	1900	1953	2057	2073
	Lisbon	18931	19294	19780	19293
	Loures/Odivelas	2000	2556	2546	2494 [a]
Private entities	Lisbon Wholesale Market and other private operators	9299	10645	10298	12034
Total (tonnes)		32129	34448	34680	35893

AD Reception	**Type of Waste**	**Collection Schedule**
Wet line	Waste with lower contaminants (includes markets, canteens) – defined by contract as < 5% average	13h00 - 21h00
Dry line	Waste more contaminated (mainly restaurants, supermarkets) – defined by contract as < 11% average	23h00 - 07h00

[a] (includes SS-OFMSW from 1988 households)
[b] circuit: defined route a vehicle travels to collect from X waste organic producers

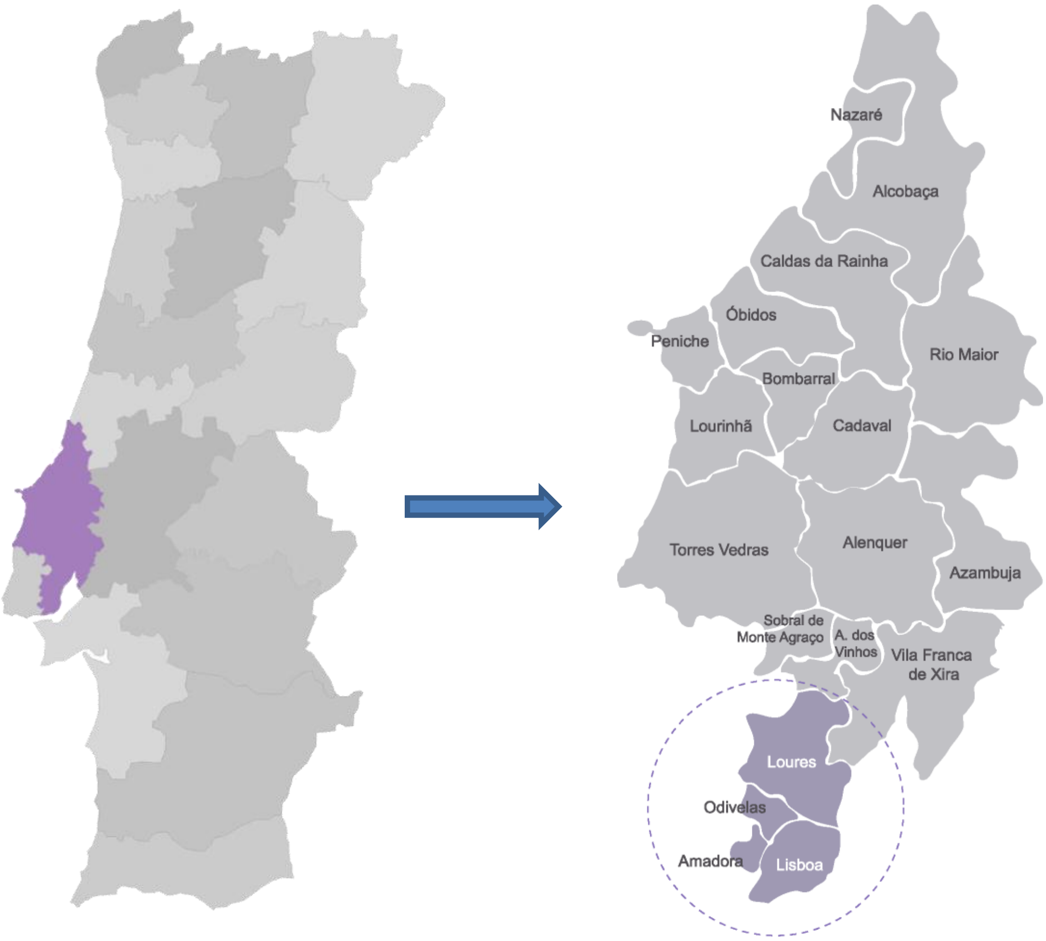


Figure 3. Map of the region

Before beginning the collection, Valorsul conducted a communications campaign called '+ Valor' (meaning '+ Value' in Portuguese) using a range of strategies with the aim of instructing producers about the kind of waste to be disposed of, and of obtaining information on their main concerns and any particular needs. To act as an incentive and support, the Programme includes the offer of containers and periodic washes, and the supply of information, as well as daily collections from Monday to Saturday. There is also a telephone help line for the producers. In terms of the kind of waste to be disposed, the producers are asked to include/exclude, in a specific container, the following:

- **Include**: Solid waste (vegetables, bread, meat, fish, eggs, cakes and desserts, confectionery/snacks, tea bags and fruit peel) and paper napkins.
- **Exclude**: Liquid residues; packages; cups, knives, forks, spoons, baking and aluminium foil papers; plastic bags; cigarette ends; textiles.

Figure 5 presents examples of the type of posters that were delivered to the producers with the waste deposition instructions (Torres *et al.*, 2007).

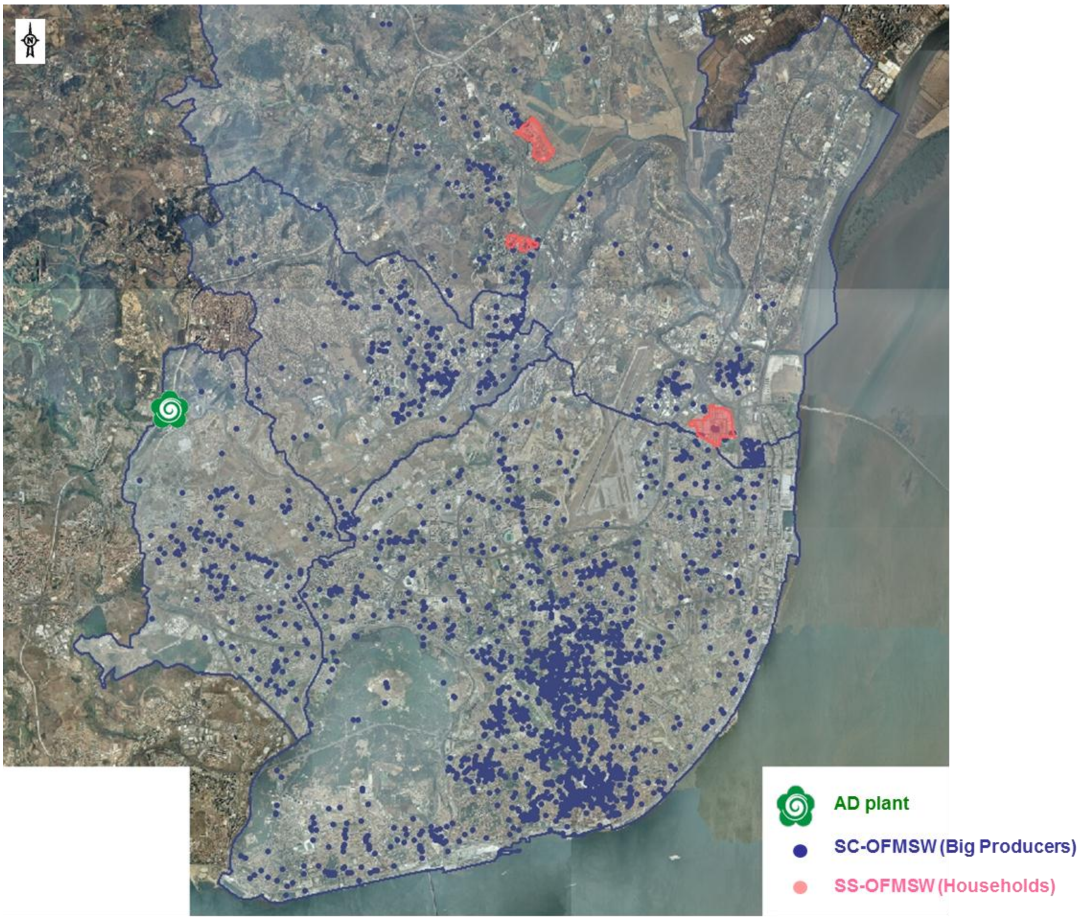


Figure 4. Locations of SC-OFMSW and SS-OFMSW producers

Figure 5 . Poster with waste deposition instructions.

3.1.1 Amadora

Amadora is a city and municipality in Portugal, in the northwest of the Lisbon Metropolitan Area. The city and municipality population is 175,872 in eleven *freguesias* (parishes). Amadora is a satellite city of Lisbon, one of the smallest Portuguese municipalities (24 km^2), but one of the most populous. With an area of 23.77 km^2, it is the most densely populated municipality of Portugal. It is also a major residential suburb of the capital, and the landscape is dominated by large apartment blocks and some industry (Figure 6).

Figure 6. Amadora (Wikipedia, 2011)

Information on the sources of organic waste and types of collection in Amadora is summarised in Table 2.

Table 2. Sources of OFMSW in Amadora – collection scheme characteristics.

Circuit	Type of producer	Collection Points	Total collection points	Duration (H:min)	Distance (km)	OFMSW quantities (kg/producer-day)	OFMSW quantities (tonne/day)
Amadora North	Canteens	41	87	02:52	67	43.73	3.80
	Markets	4					
	Restaurants	19					
	Supermarkets	23					
Amadora South	Canteens	43	76	02:41	64	43.73	3.32
	Markets	2					
	Restaurants	11					
	Supermarkets	20					
Amadora Saturday	Canteens	12	83	02:53	69	43.90	3.64
	Markets	6					
	Restaurants	25					
	Supermarkets	40					

From Table 2 it can be seen that there are no significant differences between the type of circuits, in terms of producer type and the quantities of SC-OFMW collected by producer-day (~44 kg producer^{-1} day^{-1}). The Saturday circuit collects from a mixture of producers on the North and South circuits. Because Amadora's SC-OFMW is mainly from canteens the quality is usually good, and for that reason this food waste is usually processed in the 'wet' line.

In terms of fuel consumed data collected in 2010 reflects a diesel consumption of 8050.25 L and a natural gas consumption of 17986.73 m^3.

SC-OFMSW collection circuits in Amadora are shown in Figure 7 which includes 3 circuits, 6 days per week (Monday to Saturday).

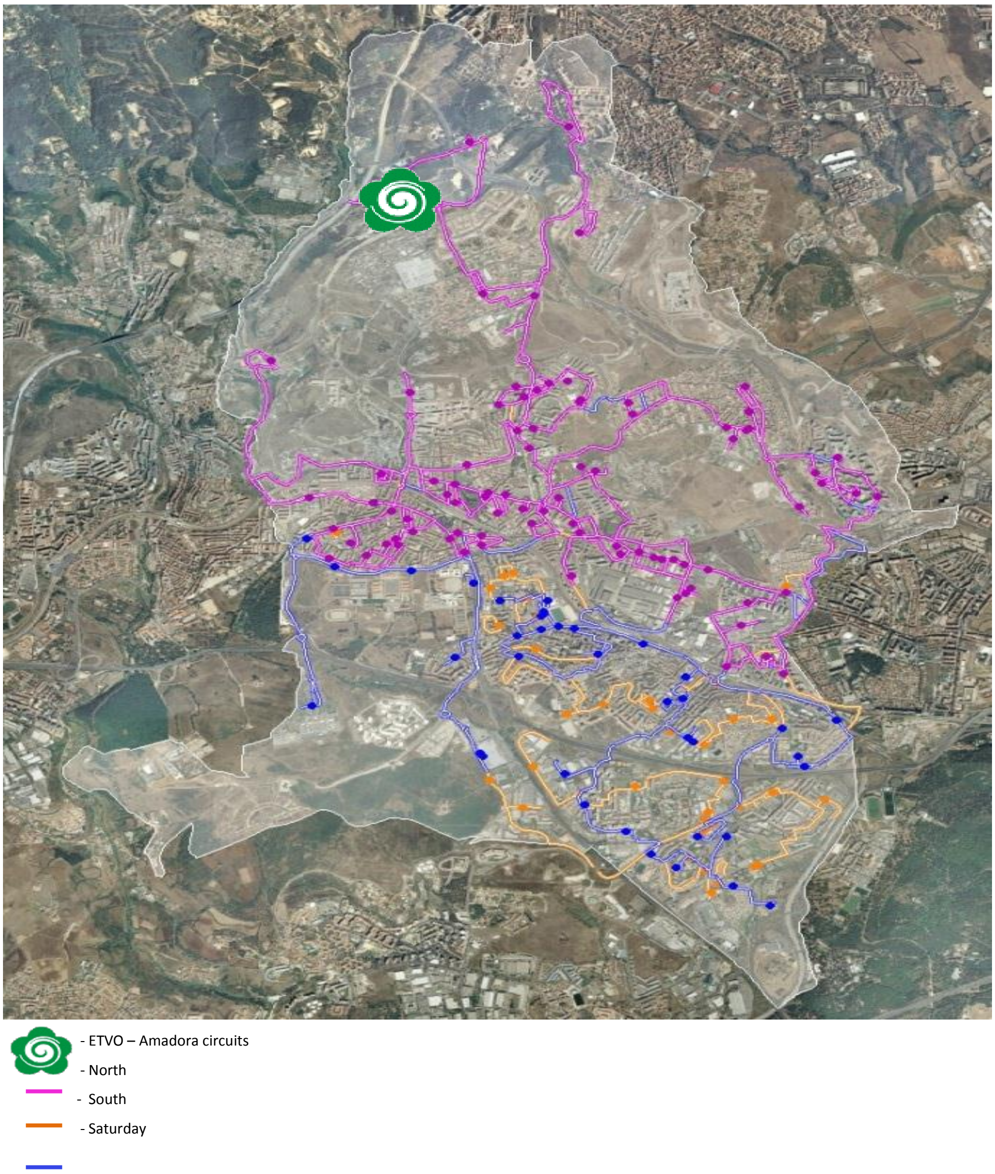


Figure 7. SC-OFMSW collection circuits in Amadora.

3.1.2 Lisbon

Lisbon is the capital city and largest city of Portugal with a population of 547,631 within its administrative limits on a land area of 84.8 km^2. The urban area of Lisbon extends beyond the administrative city limits with a population of 3 million on an area of 958 km^2 making it the 9th most populous urban area in the European Union. About 2,831,000 people live in the Lisbon Metropolitan Area (which represents approximately 27% of the population of the country). Information on the sources of organic waste and types of collection is summarised in Table 3.

Table 3. Sources of OFMSW in Lisbon – collection scheme characteristics

Circuit	Type of producer	Collection Points	Type	Total collection points	Duration (H:min)	Distance (km)	OFMSW quantities (kg/producer-day)	OFMSW quantities (tonne/day)
O0101	Canteen	57	wet	68	02:48	103	40	2.72
	Markets	2						
	Restaurants	5						
	Supermarkets	4						
O0201	Canteen	22	dry	177	05:12	111	18	3.19
	Restaurants	152						
	Supermarkets	3						
O0202 (only sundays)	Canteen	13	dry	130	05:50	133	39	5.07
	Restaurants	116						
	Supermarkets	1						
O0203	Canteen	38	dry	188	05:51	154	29	5.452
	Markets	3						
	Restaurants	144						
	Supermarkets	3						
O0301	Canteen	32	dry	144	05:12	131	17	2.448
	Restaurants	104						
	Supermarkets	8						
O0302	Canteen	21	dry	170	05:13	188	31	5.27
	Markets	4						
	Restaurants	142						
	Supermarkets	3						
O0401	Canteen	67	wet	75	03:36	113	39	2.93
	Markets	2						
	Restaurants	3						
	Supermarkets	3						
O0501	Canteen	53	dry	218	05:48	151	26	5.67
	Restaurants	159						
	Suermarkets	6						
O0601	Canteen	27	dry	250	05:41	141	26	6.50
	Markets	1						
	Restaurants	211						
	Supermarkets	11						
O0602	Canteen	42	dry	276	05:59	147	25	6.90
	Restaurants	227						
	Supermarkets	7						
O0701	Canteen	64	wet	77	03:29	101	53	4.08
	Markets	4						
	Restaurants	4						
	Supermarkets	5						
O0801	Canteen	65	wet	85	03:32	108	39	3.32
	Markets	4						
	Restaurants	8						
	Supermarkets	8						
O0802	Canteen	43	dry	184	05:24	140	29	5.34
	Restaurants	135						
	Supermarkets	6						

From Table 3 it can be seen that the collection implemented by Lisbon Municipality includes 13 circuits distributed between 'wet' and 'dry' circuits. The 'wet' circuits include food waste from big producers, mainly from canteens and markets: by definition this waste is of a higher quality (fewer contaminants, higher moisture) than the waste from the 'dry' circuits and for that reason is more suitable for processing in the wet line. Nevertheless, the quality of the circuits is controlled during the physical characterisation campaigns to validate whether the name of the circuit corresponds to its destination (usually wet circuit = wet line, but not always).

Another conclusion is that the 'wet' circuits usually collect more waste per producer-day, average value 43 kg producer^{-1} day^{-1}, than the 'dry' circuits (average value 5 kg producer^{-1} day^{-1}). These differences are related to the type of producer. In fact, in the markets and canteens the quantities of food waste collected per producer are higher than the quantities collected in restaurants (more predominant in 'dry' circuits). Therefore, the number of producers is also superior in the 'dry' circuits as well as the circuit duration.

SC-OFMSW collection circuits in Lisbon are shown in Figures 8 and 9 and result in 13 circuits distributed in two groups (4 'wet' and 9 'dry' circuits), 7 days per week (only one circuit on Sundays).

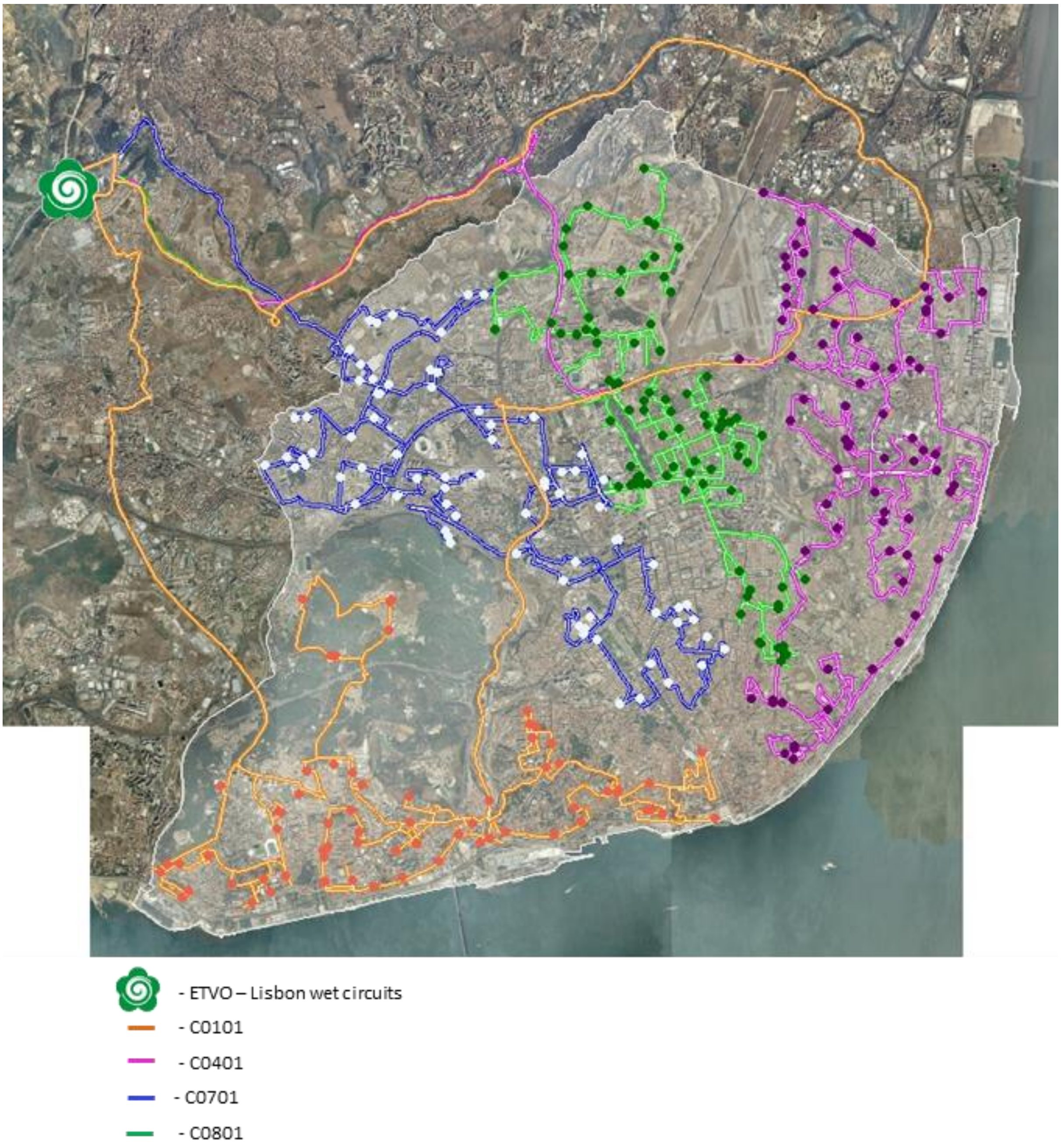


Figure 8. SC-OFMSW collection circuits in Lisbon ('wet' circuits).

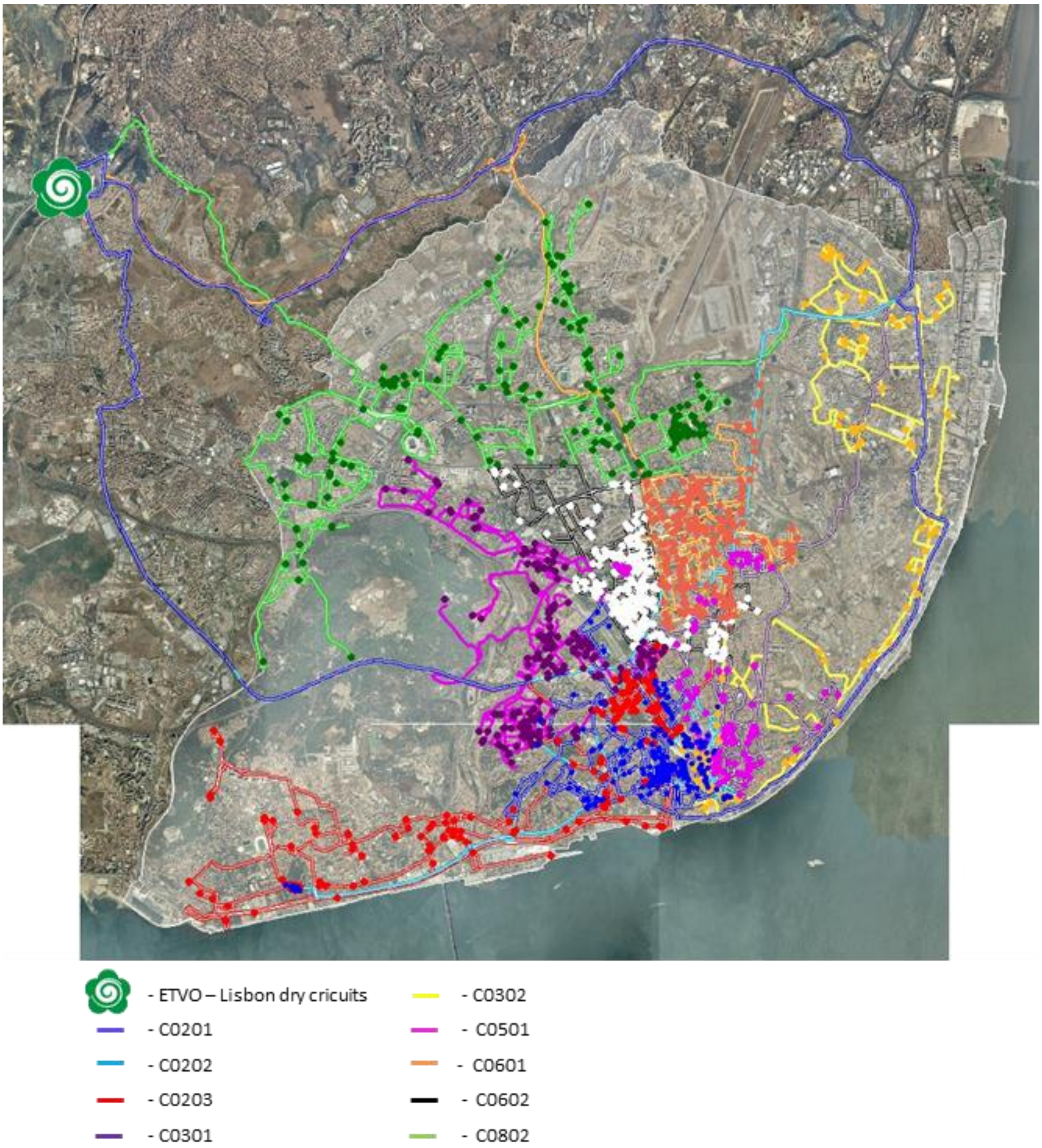


Figure 9. SC-OFMSW collection circuits in Lisbon ('dry' circuits)

In terms of fuel consumed in food waste collections, data collected in 2010 reflects a diesel consumption of 133872 L and a natural gas consumption of 177600 m^3.

3.1.3 Loures

Loures is a municipality to the north of Lisbon. It occupies an area of 169 km² with 18 parishes and has about 200,000 inhabitants (2001). The municipality is basically divided in three areas: the rural part to the north (the parishes of Lousa, Fanhões, Bucelas, Santo Antão do Tojal and São Julião do Tojal); the urban part to the south (Frielas, Loures and Santo António dos Cavaleiros); and the urban-industrial to the east (Apelação, Bobadela, Camarate, Moscavide, Portela de Sacavém, Prior Velho, Sacavém, Santa Iria de Azóia, São João da Talha and Unhos). Information on the sources of organic waste and types of collection is summarised in Table 4.

Table 4. Sources of OFMSW in Loures – collection scheme characteristics.

Circuit	Type of producer	Collection Points	Total collection points	Duration (H:min)	Distance (km)	OFMSW quantities (kg/producer-day)	OFMSW quantities (tonne/day)
R01	Canteens	53	220	07:48	183	13	2.86
	Markets	1					
	Restaurants	150					
	Supermarkets	16					
R02	Canteens	35	401	05:56	140	9	3.61
	Domestic	238					
	Markets	2					
	Restaurants	119					
	Supermarkets	7					
R03	Canteens	39	186	04:44	133	12	2.23
	Domestic	38					
	Markets	2					
	Restaurants	105					
	Supermarkets	2					

Table 4 shows significant differences between the type of circuits and this fact is related to the type of producer, namely that household collection contributes lower quantities of OFMSW collected by producer-day (~9 kg producer^{-1} day^{-1}), compared to OFSMW quantities collected in R1 (~13 kg producer^{-1} day^{-1}).

These circuits are distributed between the 'dry' line and 'wet' line. Despite the considerable amount of door-to-door (household) collection points the OFMSW that incomes to the plant is not as good in terms of quality as was expected, due to the percentage of plastic film (bags) which is considerable.

SC-OFMSW and SS-OFMSW collection circuits in Loures are shown in Figure 10 which results in 3 circuits, 6 days per week.

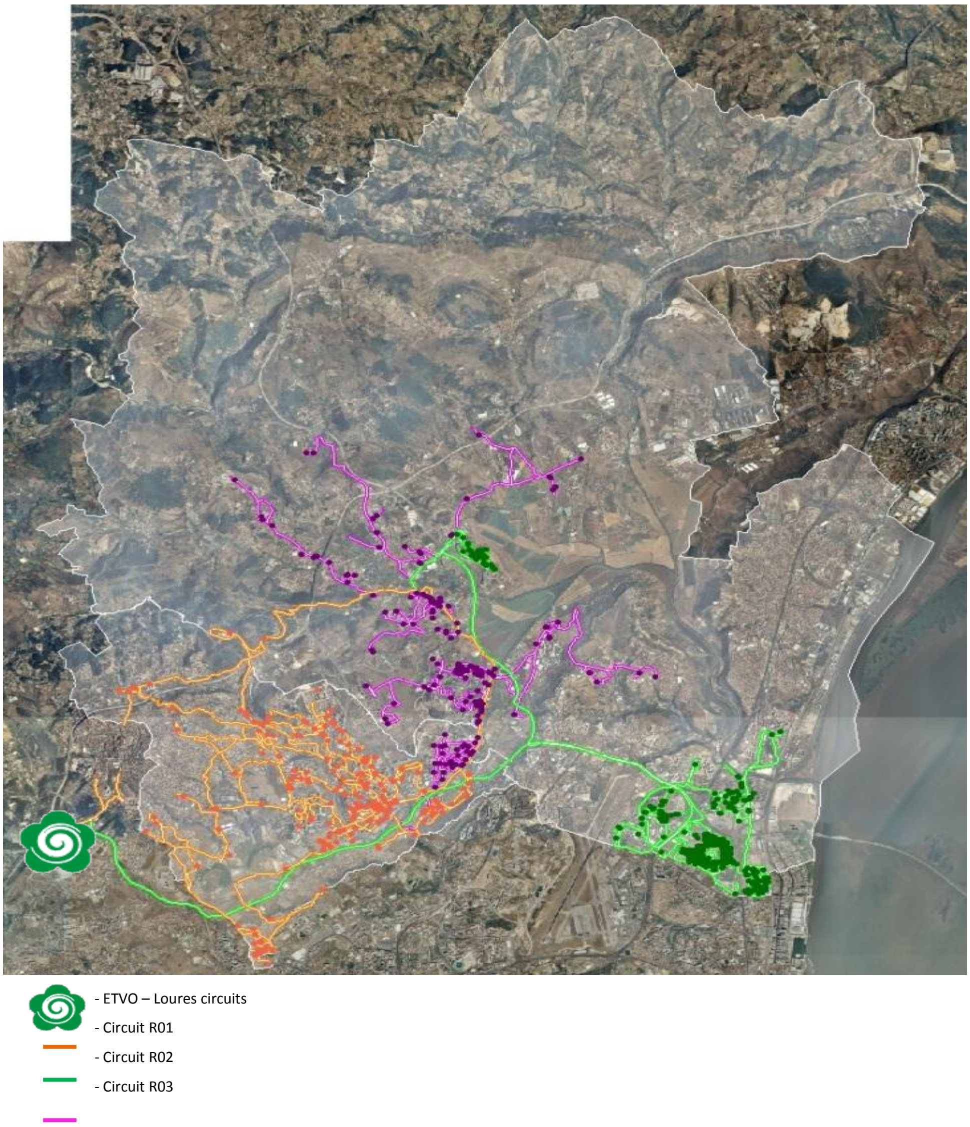


Figure 10. SC-OFMSW collection circuits in Loures.

Referring to the two existing circuits that receive SS-OFMSW (mixed with SC-OFMSW)**,** more detailed information is presented in section 2.2. This type of waste is included in Loures circuits R2 and R3. The SS-OFMSW from R2 circuit belongs to Portela (Loures). This SS-OFMSW (Portela) covers a major area compared with SS-OFMSW from R3 (Quinta do Infantado) which is in a new neighborhood where collections only started recently and for that reason are not fully operational.

In terms of fuel consumed in food waste collections data collected in 2010 reflects a diesel consumption of 42622.73 L.

3.1.4 Urban Density

Table 5 shows the urban density in terms of number of establishments per km^2. These figures were calculated by circuit and by average values. In order to calculate the circuit areas the Base Reference Geographical Information (BGRI) methodology from the National Institute of Statistics was applied. The BGRI is a geographic referencing system, supported by orthophotomaps in digital form, that divides the areas of each parish in small territorial units for statistics. These areas are identified in Figure 11.

Table 5. Number of establishments per km^2

Municipality	Circuit	m^2	km^2	Producers	Collection points/km^2	Average per municipality
Amadora	Norte	2,846,345	2.85	87	30.57	24.55
Amadora	Sul	3,553,067	3.55	76	21.39	
Amadora	Sábado	3,828,032	3.83	83	21.68	
Lisboa	CO0101	7,484,332	7.48	68	9.09	59.13
Lisboa	CO0201	1,460,453	1.46	177	121.20	
Lisboa	CO0203	2,878,547	2.88	188	65.31	
Lisboa	CO0301	1,165,859	1.17	144	123.51	
Lisboa	CO0302	2,319,372	2.32	170	73.30	
Lisboa	CO0401	8,629,774	8.63	75	8.69	
Lisboa	CO0501	3,854,879	3.85	218	56.55	
Lisboa	CO0601	2,208,439	2.21	250	113.20	
Lisboa	CO0602	3,075,983	3.08	276	89.73	
Lisboa	CO0701	5,254,679	5.25	77	14.65	
Lisboa	CO0801	7,759,721	7.76	85	10.95	
Lisboa	CO0802	7,884,556	7.88	184	23.34	
Loures	R01	4,625,046	4.63	220	47.57	55.39
Loures	R02	3,487,684	3.49	401	114.98	
Loures	R03	5,746,145	5.75	186	32.37	
Loures*	R02	2,913,435	2.91	163	55.95	
Loures*	R03	5,676,587	5.68	148	26.07	

* without door-to-door collection

From Table 5 it can be seen that Lisbon, when compared with Loures and Amadora, presents a high discrepancy between circuits with respect to the number of establishments per km^2 because it includes a larger area with different topographical characteristics (historic neighbourhoods, downtown restaurants and also suburbs with a lower urban density). In terms of average values Lisbon collection presents a ratio about ~59 establishments per km2 followed by Loures with ~ 55 and Amadora with ~25.

Table 6 summarises some of the key parameters for the collections that can be used in collections modelling being carried out as part of the VALORGAS project.

Table 6. Summary of SC-OFMSW results for 2010

2010	Amadora	Lisbon	Loures
Circuits (no.)	2 week (1 weekend)	13	3
Team	1 driver, 2 roadmender	1 driver, 2 roadmender	1 driver, 2 roadmender
Schedule	14:00-20:00	13:00-20:00 ("wet circuits"); 23:00-05:00 ("dry circuits")	23:00-06:00
Breaks	-	no breaks	1 hour
Fuel	17986,73 m^3 NG; 8050,25 L Diesel	177600 m^3 NG;133872 L Diesel	42622,73 L Diesel

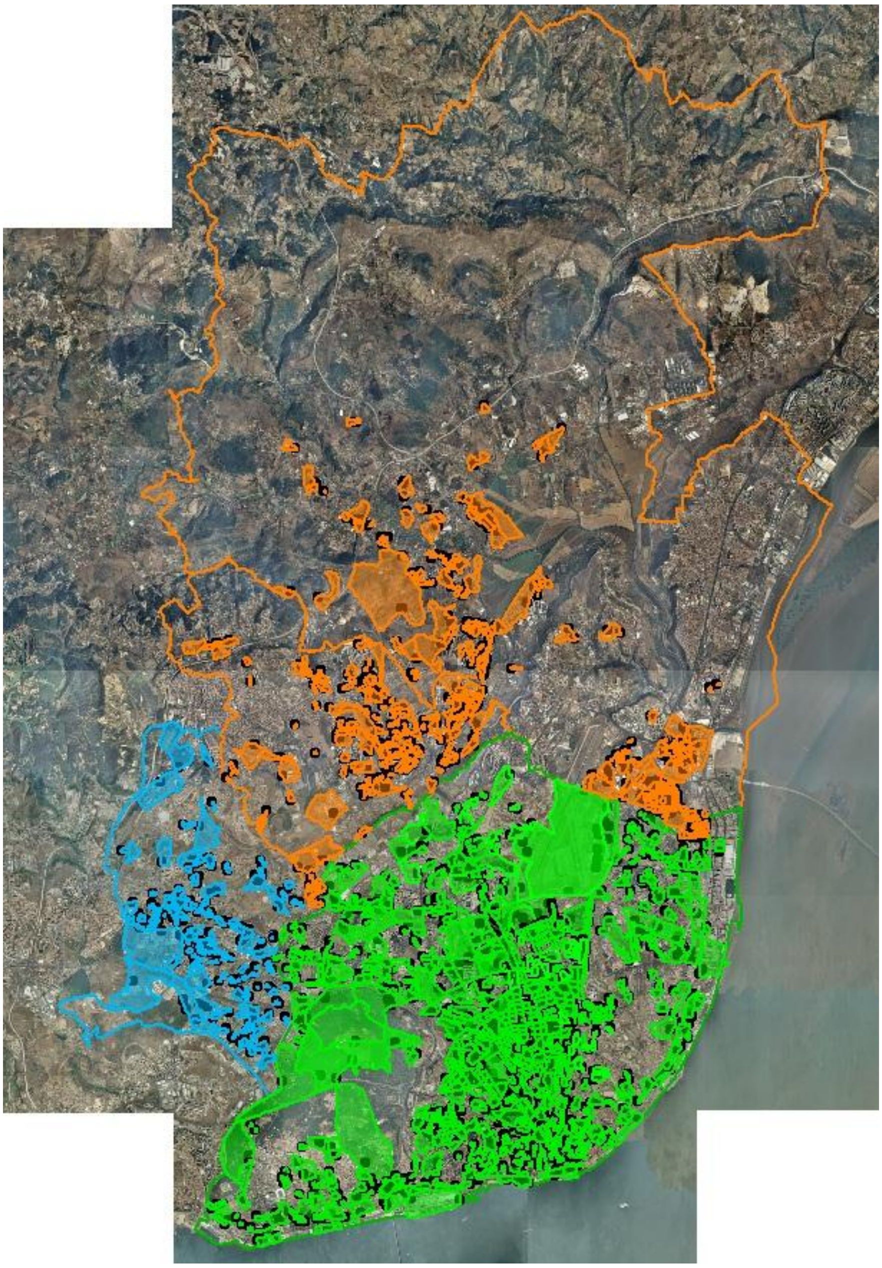


Figure 11. Area calculation based on the BGRI methodology.

3.2 Household collections - SS-OFMSW

3.2.1 Portela's SS-OFMSW collection – main characteristics

'Portela' is a noun literally meaning 'entryway'. In the 1960s, this parcel of land, formerly occupied by farms, was intensively urbanised in the form of symmetrically ordered blocks of twelve-floor buildings with a rounded shopping area in the centre. Portela airport in Lisbon is named after Portela for its close proximity to this parish, formally created in 1985. It offers elementary to high school and sports facilities. (Victor, 2008).

In terms of area, Portela occupies 0.95 km^2 and has 15,441 inhabitants (highest density population of the municipality of Loures 16,254 inhabitants km^{-2}, which represents more than twice the population density in the municipality of Lisbon (6673 inhabitants km^{-2}) (Victor, 2008).

The age structure in Portela is characterised by a high percentage of potentially active population, between 15 and 64, which represents about 77%, higher than the national average of 68%. Consequently, the percentages of young people (0 to 14 years) and old people (aged 65 years) at 13% and 10% respectively, are below the national average of 16% and 16.4%. Regarding the level of education among the population, Portela is distinguished by a large percentage of residents with higher education, equal to 40.8%, well above the national average value of 10.6%. It is also characterised by a low number of individuals with an basic educational level (1st, 2nd and 3rd cycles) and a high number of individuals with secondary and high school education. The average size of private households is 3.02 persons, mostly consisting of three individuals (27%), followed by families with 4 and 2 members (26% and 25%, respectively) (Victor, 2008).

The study area consists of ~ 238 multifamily buildings located primarily in high-density residential buildings. Some of these buildings (the main ones around the shopping center) have a central place inside the building where the bins from the door-to-door collection are kept. There are also other building types where 120-litre bins serving a number of properties (e.g. apartments) are placed outside as can be seen in Figure 12.

Waste is collected daily: each property has an individual bin, but biodegradable plastic bags are not provided. The information about the type of materials to be disposed is as reported above. The waste is transported in 15 m^3 refuse collection vehicles with compaction.

Figure 12. Type of buildings in Portela (Victor, 2008).

The decision to include this residential area in the Program + Valor, along with the collection of big producers, was mainly related to the typology of urbanisation, namely the existence of buildings of high population density with conditions for storage of individual deposition equipment for mixed waste collection and for the recyclables collection (packaging materials, paper, glass and plastics + metals).This decision was also related to the fact that the resident population already had well-established habits of waste separation, which was reflected in the high door-to-door recyclables collection rates. In fact, the collection of paper and card began in 1996, glass and plastics+metals collection started in 1999 and the amounts of these recyclables collected per inhabitant are double the average values registered in Loures/ Odivelas (56.9 kg person^{-1} year^{-1} in comparison with 27.8 kg person^{-1} year^{-1} in 2006) (Victor, 2008).

Another factor in the decision was the content of organic matter present in the waste collected from Portela area which represented about 39%, according to data from characterisation campaigns (Victor, 2008).

Figure 13 shows the area in Portela covered by this organic matter door-to-door collection.

Figure 13. Area covered by SS-OFMSW in Portela. (Victor F., 2008).

Besides the support provided by Valorsul, at the level of deposition equipment (bins), vehicles collection and information materials, the program + Valor also involved a close collaboration between the Loures municipality and the parish of Portela. The communication strategy for the implementation of the project had support from the person selected as responsible/coordinator, who helped giving information to residents so that everyone could access it quickly. For the separation of the SS-OFMSW, domestic containers (28 and 16 litres) were provided for kitchen purposes (Figure 14).

a) 120-litre bins with informational materials

b) Individual bins with informational materials

Figure 14. Collection system facilities in Loures.

4 Waste Characterisation

4.1 Sample preparation and categories classification

Physical characterisation of SC-OFMSW from the entities belonging to the '+ Valor' programme, municipalities and private companies, is performed in order to ensure the quality of organic waste delivered to the Anaerobic Digestion plant of Valorsul and to prevent the input of toxic substances in the biological process. Sorting was implemented according to the classification system developed by Valorsul, based on the DGQA (1989) (Figure 15**)** and ADEME methodologies (MODECOM, 1997 and 1998). The sampling was stratified by the type of circuit (different municipalities or private collection). Among each stratum, the load for characterisation was randomly selected.

The physical characterisation of SC-OFMSW takes place in a specific compartment in the

AD plant. The selection of vehicles to be characterised is based on the following criteria:

i. Ensuring the quality of SC-OFMSW, to minimise the level of contaminants through the assessment of the constituents incorrectly discharged. Accordingly, contracts were made with the various entities responsible for the collection where contamination limits were defined, otherwise penalties could be applied (rejection of the waste and payment of costs, including proper treatment and transport to the final destination). These entities are regularly informed of the physical composition of the waste collected by the circuit, in order to correct deposition mistakes from the respective producers;

ii. Based on the results of the contaminant levels per circuit, it is possible to decide the distribution of waste through the two processing lines ('wet' and 'dry' lines);

iii. To detect possible toxic substances that could interfere with the biology of the process, like detergents for example. The waste that presents a higher level of contamination and lower moisture content, mainly from restaurants and supermarkets, is discharged in the 'dry' waste pre-treatment line, that has a more extensive pre-treatment, while the residues of superior quality, with lower contaminant levels and with a higher moisture content, are discharged into the 'wet' line (canteens and markets).

iv. Bearing in mind the above criteria, the characterisation of a particular circuit is adjusted in order to ensure representativeness.

For the compositional analysis of large producers (SC-OFMSW) 95 samples were characterised in 2010, and a further 45 samples were characterised between January and February 2011.

Referring to SS-OFMSW producers (households), five samples of source segregated household waste only were taken from one of two collection rounds serving domestic properties. The first sample was taken in the first week of February 2011, and the remaining samples on four consecutive days in the following week (see also Deliverable D2.1).

In both cases the selected load was discharged from the collection vehicle and mixed using a wheel loader. A sub-sample of ~250 kg was then taken by quartering the mixed sample which was then sorted by hand on a sorting table with individual components weighed to ±0.01 kg (ADAM scales, Milton Keynes, UK).

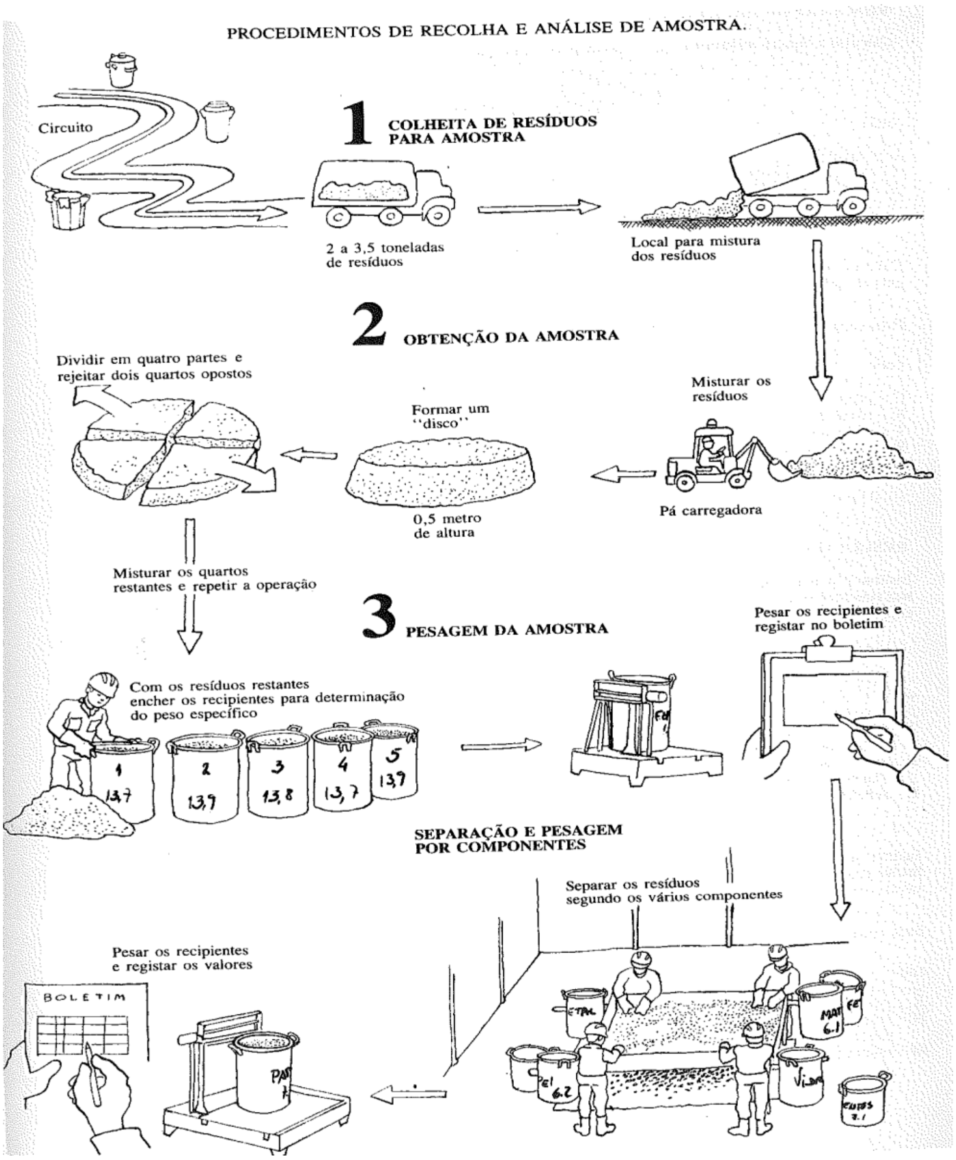


Figure 15. – Collection and analysis procedure according to DGQA methodology (1989).

Sorting of SC-OFMSW was performed according to the classification system developed by Valorsul (Table 7), based on the DGQA (1989) and ADEME methodologies (MODECOM, 1997 and 1998). The sampling was stratified by the type of circuit (municipalities or private collection). Among each stratum, the load for characterisation was randomly selected

The classification of SS-OFMSW was carried out using a modified version of the Valorsul system, in which Group 1 (Putrescible Waste) was subdivided into additional categories based on those used in the WRAP (2008) studies. The original WRAP (2008) classification is based on 174 separate types of food waste, including individual types of fruit and vegetables. These 174 food waste types are then summarised in 13 main categories. In the SS-OFMSW it was possible to identify 12 of these, and the categories used are shown in Table 8. The mapping between the different categorisation systems used is presented in deliverable D2.1 'Compositional analysis of food waste from study sites in geographically distinct regions of Europe'.

Table 7. SC-OFMSW Physical Characterisation. Categories Classification.

Group 1 – Putrescible Waste	Food	
	Others	
	Fines	<20mm
Group 2 – Paper/Cardboard	Paper	
	Cardboard	Packaging
		Non packaging
Group 3 - Contaminants	Plastic	Film
		Bottles
		Other plastics
	Glass	Packaging
		Non packaging
	Metals	Ferrous
		Non Ferrous
	Composites	
	Textiles	
	Health care textiles	
	Combustibles	Wood
		Others
	Incombustibles	Inerts
	Special Waste	Bones
		Others

Table 8. SS-OFMSW Physical Characterisation. Categories Classification.

Group 1 – Putrescible Waste		
Vegetables		
Fruit		
Salads		
Mixed Foods		
Meat and fish		
Bakery		
Dairy		
Dried Food		
Drinks		
Condiments		
Confectionery and desserts		
Other		
Group 2 – Paper/Cardboard	Paper	
	Cardboard	Packaging
		Non packaging
Group 3 - Contaminants	Plastic	Film
		Bottles
		Other plastics
	Glass	Packaging
		Non packaging
	Metals	Ferrous
		Non Ferrous
	Composites	
	Textiles	
	Health care textiles	
	Combustibles	Wood
		Others
	incombustibles	Inerts
	Special Waste	Bones
		Others

4.2 Physico-chemical analysis

Although full physico-chemical characterisation of the food waste samples was not part of this deliverable, preliminary characterisation was carried out as part of deliverable D2.1 and is included here to provide information in support of the compositional analysis.

Based on the physical characterisation process described above the composition (percentage) of the various components of the sample of 250 kg (meat, fish, vegetables, fruits, paper / cardboard, etc.) is obtained. From these percentages, laboratory samples of approximately 2.5 kg are composed representing the initial sample (250 kg) composition. These samples are kept cold and delivered within 24 hours to an accredited external laboratory, in order to prevent degradation. Information on the parameters and the analytical methods used is given in Annex A.

5 Results and discussion

5.1 Compositional analysis – results from waste characterisation campaigns

The modified methodology could not be applied to the SC-OFMSW because a considerable part of this material is composed of cooked meals, making the components more difficult to distinguish and the categories less suitable. Both the SS-OFMSW and the SC-OFMSW are collected in compaction vehicles, and as the waste was sorted after delivery to the plant this also made it difficult to identify items. Experience obtained during the trial suggested that the WRAP (2008) categories are more suitable for pre-collection sorting or sorting of waste that is collected without compaction.

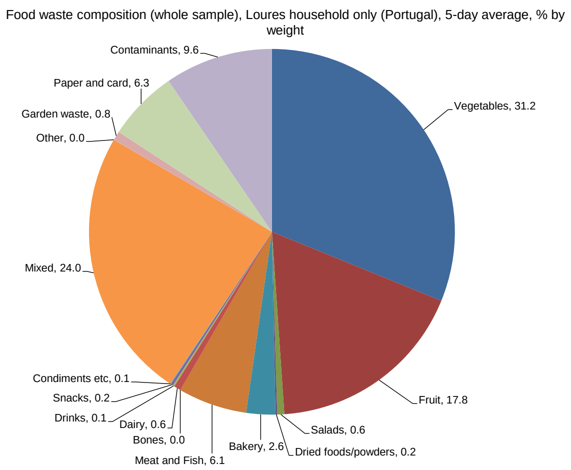
The same conclusions were drawn by Lebersorger *et al.* (2011) in their work on a methodology for determining food waste in household waste, where it is noted that, based on the comments of other authors, each sample should be sorted within 2 days from the sampling day in order to avoid food degradation and difficulties in identifying components. These authors also mentioned that identifying individual waste components from a sample taken from a collection vehicle is more difficult and inaccurate because the process of mixing and compaction in the collection vehicle decreases particle size and increases contamination of individual waste components.

5.1.2 Household - SS-OFMSW

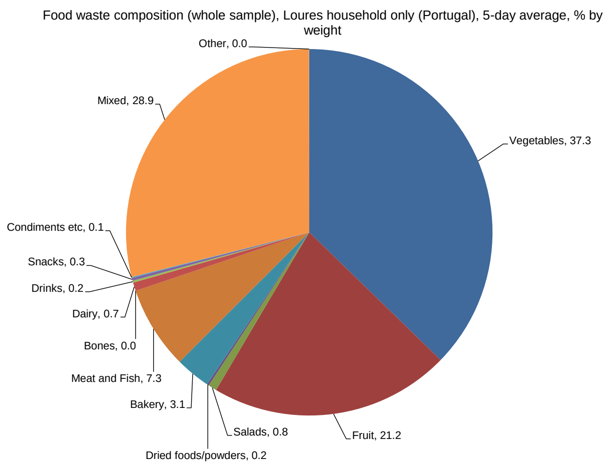
Table 9 presents the results of sorting of 5 days' waste from the domestic properties on collection round R2 in Loures, Portugal. Figure 16 shows the data normalised to 100% on a wet weight basis, both in total and for food waste only, while Figure 15 shows the sorting process and output. These results are also presented in Deliverable D2.1, but are included here for completeness.

Table 9. Waste compositional analysis for daily collection from households in Loures

	% wet weight	08/02/2011	15/02/2011	16/02/2011	17/02/2011	18/02/2011	Average	Max	Min
G1 - Putrescibles	Vegetables	28.6	30.3	25.3	37.8	33.8	31.2	37.8	25.3
	Fruit	23.5	22.1	10.5	20.5	12.2	17.8	23.5	10.5
	Salads	1.0	0.5	0.9	0.3	0.4	0.6	1.0	0.3
	Dried foods/powders	0.0	0.1	0.4	0.1	0.1	0.2	0.4	0.0
	Bakery	1.5	4.9	2.0	2.3	2.2	2.6	4.9	1.5
	Meat and Fish	5.8	5.2	6.5	4.7	8.3	6.1	8.3	4.7
	Bones	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dairy	0.3	1.0	0.6	0.7	0.5	0.6	1.0	0.3
	Drinks	0.1	0.3	0.0	0.2	0.1	0.1	0.3	0.0
	Snacks	0.3	0.5	0.0	0.2	0.0	0.2	0.5	0.0
	Condiments etc	0.0	0.0	0.0	0.3	0.0	0.1	0.3	0.0
	Mixed	22.7	18.6	33.9	18.4	26.3	24.0	33.9	18.4
	Other	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
G2 - Garden waste	Garden waste	0.7	2.0	0.0	0.2	1.0	0.8	2.0	0.0
G3 - Paper & cardboard	Paper	5.8	5.3	7.4	4.7	5.5	5.7	7.4	4.7
	Card - packaging	0.3	0.3	1.2	0.2	0.4	0.5	1.2	0.2
	Card - non-packaging	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.0
G4 - Contaminants	Plastic - film	6.9	5.6	6.7	5.4	5.4	6.0	6.9	5.4
	Plastic - bottles	0.0	0.1	0.5	0.1	0.4	0.2	0.5	0.0
	Plastic - polystyrene	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
	Plastic - other	0.3	0.8	0.9	0.3	0.5	0.6	0.9	0.3
	Glass - packaging	0.1	0.4	1.1	0.4	0.6	0.5	1.1	0.1
	Glass - non-packaging	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Ferrous metals	0.4	0.1	0.3	0.1	0.3	0.2	0.4	0.1
	Other Metals	0.2	0.3	0.2	0.1	0.2	0.2	0.3	0.1
	Composites	0.4	0.5	0.4	0.3	0.4	0.4	0.5	0.3
	Textiles	0.4	0.0	0.3	0.1	0.3	0.2	0.4	0.0
	Sanitary textiles	0.6	1.0	0.3	2.4	0.7	1.0	2.4	0.3
	Combustibles - wood	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Combustibles - other	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0
	Incombustibles	0.0	0.0	0.0	0.0	0.3	0.1	0.3	0.0
	Special - packaged organic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Special - other	0.02	0.0	0.04	0.04	0.0	0.0	0.0	0.0
Total (%)		100.0	100.0	100.0	100.0	100.0	100.0	-	-
Food waste (% of total)		**83.7**	**83.5**	**80.3**	**85.6**	**83.9**	**83.4**	-	-
Weight of sample (kg)		**255.0**	**252.9**	**283.7**	**253.5**	**252.9**	**259.6**	**283.7**	**252.9**



a) Whole sample



b) FW only

Figure 15. Food waste composition from Loures households, Portugal (5-day average)


a) Waste as received


b) Hand sorting on sorting table


c) Vegetable waste


d) Sorted fractions

Figure 16. Sorting process for characterisation of waste from Loures households

The SS-OFMSW sample included a proportion of 'Paper and card' (6.3% of total weight) and a very small amount of 'Garden waste' (0.8%). The main contaminant was plastic bags (6.0%): as biodegradable bags are not provided in this scheme, this represents a considerable input of contamination and a reduction in the potential for energy recovery from the biodegradable plastic. The remaining contaminants (plastic bottles, polystyrene foam and other plastics, glass, metals, composites, textiles, combustibles and special items - see Figure 15) made up around 3.6% of the total weight, indicating that the degree of contamination without taking into account plastic bags was reasonably low. The sorters reported finding batteries in the collected sample on two separate occasions.

On a food waste only basis the average total for the combined categories 'Vegetables', 'Fruit' and 'Salads', corresponding to the combined 'Fruit and vegetable waste' and 'Fruit and vegetables (whole)', was 59.2%. The category 'Mixed meals' made up 27.2% of the food waste component, possibly reflecting the fact that the waste was delivered by a compacting vehicle.

Figure 17 shows the variation between collection days for the food waste categories, and again suggests that day-to-day variation at a small scale may be as significant as any regional or seasonal variations.

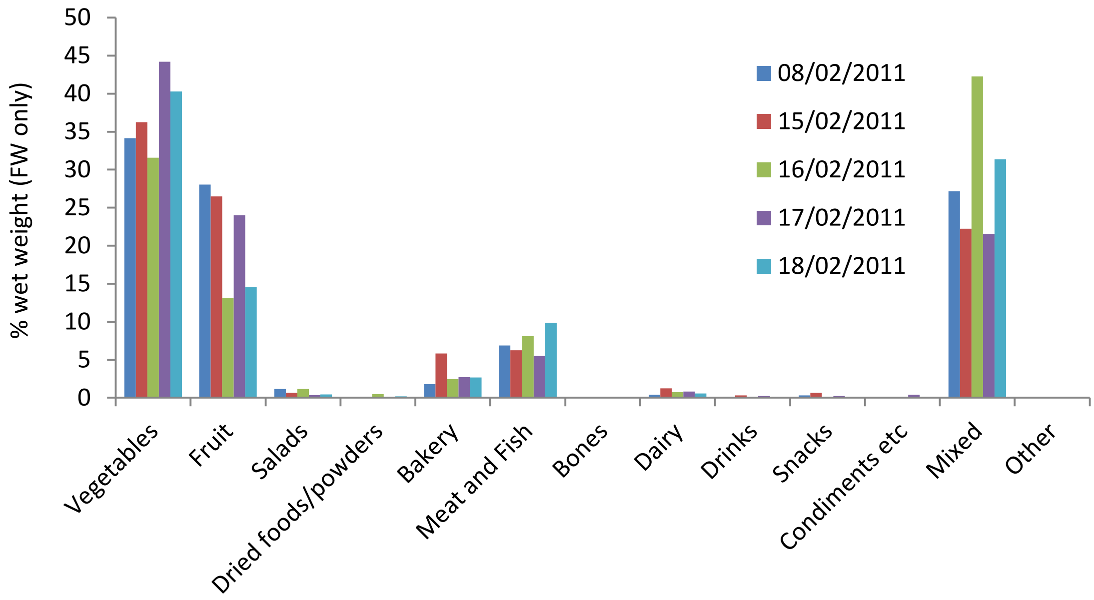


Figure 17. Variability in materials from Loures household collections (food waste only)

5.1.3 Large producers - SC-OFMSW and comparison with SS-OFMSW

Table 10 shows the results of compositional characterisation of SC-OFMSW, with those from the 2011 SC-OFMSW collections for comparison. The waste delivered to the plant after separate collection from large producers consisted of ~82% organic material, ~7% paper and cardboard and ~11% contaminants. Plastic materials (plastic bags) were the main contaminants and represented ~8% in large producers. These results were similar to values found in previous years: in 2006 and 2007 the organic content was the same, but the paper and card component was slightly higher and other contaminants slightly lower (Vaz *et al.*, 2008).

Table 10. Waste characterisation results for SC-OFMSW using Valorsul categorisation

Component	Large producers 2010			Large producers 2011			Household 2011		
(%WW)	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min
Food	68.3	89.4	39.7	73.5	94.7	53.5	83.4	85.6	80.3
Other organic	0.2	2.8	0.0	0.1	2.0	0.0	0.8	2.0	0.0
Fines < 20mm	13.4	56.8	5.4	8.5	16.0	0.0	0.0	0.0	0.0
Paper and Card	6.9	15.3	1.7	7.2	15.9	0.4	6.3	8.6	4.9
Plastic	8.1	13.3	0.6	8.2	16.2	0.3	6.8	8.1	5.9
Glass	0.7	2.7	0.0	0.5	1.6	0.0	0.6	1.2	0.1
Metals	0.5	1.9	0.0	0.4	1.4	0.0	0.4	0.6	0.1
Composites	0.3	1.3	0.0	0.4	1.8	0.0	0.4	0.5	0.3
Textiles	0.3	1.7	0.0	0.2	2.6	0.0	0.2	0.4	0.0
Sanitary textiles	0.1	3.4	0.0	0.1	2.4	0.0	1.0	2.4	0.3
Combustibles	0.4	4.2	0.0	0.1	0.6	0.0	0.1	0.1	0.0
Incombustibles	0.1	2.1	0.0	0.1	1.0	0.0	0.1	0.3	0.0
Special Waste	0.7	9.8	0.0	0.8	5.9	0.0	0.0	0.0	0.0
Total	100.0	-	-	100.0	-	-	100.0		

The results are also similar to those reported by Ansorena *et al.* (2011) for large producers in Gipuzkoa, Spain where the organic fraction made up 82% using the same categories as defined by Valorsul. The Spanish study found a fraction of cellulose absorbent (8.2%) in waste from large producers, which was included in the Organics category. This material was not identified as a significant component in the organic waste from the Lisbon area, and in terms of Valorsul's classification is included in the paper and cardboard fraction. These differences are probably related to food consumers' habits (in this case possibly to the higher consumption of fried foods and 'tapas' in Spain, and the consequent utilisation of cellulose-based absorbent to remove the excess of oil).

Tables 11, 12 and 13 below summarise the information for SC-OFMSW in terms of organics and contaminants content. The organic fraction includes food, other organic, fines < 20 mm and paper and card components; the contaminants fraction includes all the remaining components. The values for large producers in 2010 and 2011 were weighted by the relative amounts delivered to the plant by each type of circuit (different municipalities or private collection), as the sampling was stratified. Appendix B presents the statistical formulas behind the calculation. The confidence interval is calculated on the basis of a 95% confidence level either for large producers or household ones. The relative precisions obtained can be considered quite good, well below the upper bound of 20% recommended by the European Commission (2004).

Table 11. Waste characterisation results for SC-OFMSW: average and confidence interval, precision

Fraction (%WW)	Large producers 2010		Large producers 2011		Household 2011	
	Weighted Ave +/- Conf. Int.	Relative precision (%)	Weighted Ave +/- Conf. Int.	Relative precision (%)	Weighted Ave +/- Conf. Int.	Relative precision (%)
Putrescible	88.8+/-1.8	2.0	89.2+/-1.2	1.4	90.4+/-1.1	1.2
Contaminants	11.2+/-1.8	16.0	10.7+/-1.2	11.4	9.6+/-1.1	11.6

There are strong similarities between the waste selectively collected from large producers and from households. The large producers show a wider range of values in each category, reflecting the different business types but also the quality of source separation at each organisation. On average the household waste contains slightly less plastic and a slightly higher fraction identifiable as food waste; but in general the profiles for large producers and households suggest that there is unlikely to be any significant difference between these two waste streams as feedstocks for anaerobic digestion.

Despite the informational materials and assistance offered by '+ Valor' programme, the SS-OFMSW collections contained a relatively high proportion of contaminants compared to levels reported elsewhere. The levels of contamination in SC-OFMSW are similar to those found in other studies, and show considerable variation. Cecchi et al. (2003) reported the percentage of compostable materials in municipalities around Milan as 93.0- 99.7%, smaller than the range reported here. The SS-OFMSW characterisation found almost no garden waste. This reflects the fact that the waste comes from domestic properties in an urban environment. The same low levels of green waste were found in the SC-OFMSW because this biodegradable waste comes from commercial establishments.

Table 12. Summary results for characterisation of SC-OFMSW carried out in 2010

Physical Characterization RO 2010			Municipalites											
			Amadora			Lisboa -Dry circuits			Lisboa - Wet circuits			Loures		
			Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max
Group 1 – Putrescible Waste	Food		80.5	71.6	89.4	67.3	55.6	76.0	69.9	62.4	78.4	70.6	63.3	82.1
	Others		0.7	0.0	2.8	0.1	0.0	1.4	0.2	0.0	1.1	0.4	0.0	1.4
	Fines	<20mm	8.1	5.4	10.9	9.7	5.5	17.8	11.6	6.5	19.3	9.1	5.9	12.5
			89.3	**82.5**	**94.9**	**77.1**	**67.2**	**84.7**	**81.7**	**74.2**	**87.1**	**80.0**	**71.0**	**88.3**
Group 2 – Paper/Cardboard	Paper		3.9	1.9	7.3	7.8	4.2	12.8	5.9	2.6	11.3	7.4	1.4	12.8
	Cardboard	Packaging	0.2	0.0	0.4	1.2	0.1	2.7	1.1	0.1	2.9	1.2	0.1	3.3
		Non packaging	0.0	0.0	0.1	0.1	0.0	0.5	0.1	0.0	0.2	0.1	0.0	0.2
			4.1	**2.2**	**7.3**	**9.2**	**5.8**	**15.3**	**7.0**	**3.1**	**13.9**	**8.7**	**4.3**	**15.1**
Group 3 - Contaminants	Plastic	Film plastic bags	5.2	1.4	9.0	7.9	3.8	10.7	6.4	4.1	10.2	6.9	3.7	9.2
		Bottles	0.2	0.1	0.5	0.6	0.0	1.2	0.3	0.1	1.2	0.4	0.1	0.9
		Other	0.7	0.6	1.1	1.4	0.4	3.1	1.2	0.5	2.8	1.1	0.6	1.4
			6.1	**2.3**	**9.6**	**9.8**	**5.0**	**13.3**	**7.9**	**5.9**	**11.5**	**8.4**	**5.2**	**11.0**
	Glass	Packaging	0.0	0.0	0.1	1.1	0.1	2.6	0.4	0.0	1.5	0.8	0.3	1.3
		Non packaging	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.0	0.1	0.0	0.0	0.1
			0.0	**0.0**	**0.1**	**1.2**	**0.1**	**2.7**	**0.4**	**0.0**	**1.6**	**0.8**	**0.3**	**1.4**
	Metals	Ferrous	0.1	0.0	0.3	0.7	0.2	1.5	0.2	0.0	0.5	0.4	0.0	0.7
		Non Ferrous	0.0	0.0	0.1	0.2	0.0	0.8	0.1	0.0	0.2	0.2	0.0	0.6
			0.1	**0.0**	**0.3**	**0.9**	**0.3**	**1.9**	**0.2**	**0.0**	**0.7**	**0.5**	**0.0**	**1.1**
	Composites		0.1	0.1	0.2	0.5	0.2	1.3	0.3	0.1	0.7	0.4	0.1	0.9
	Textiles		0.0	0.0	0.0	0.5	0.0	1.7	0.3	0.0	1.6	0.2	0.0	1.0
	Health care textiles		0.0	0.0	0.0	0.2	0.0	0.9	0.0	0.0	0.4	0.4	0.0	1.9
	Combustibles	Wood	0.0	0.0	0.0	0.1	0.0	0.5	0.1	0.0	0.4	0.1	0.0	0.4
		Other	0.1	0.0	0.4	0.1	0.0	0.2	0.1	0.0	0.4	0.1	0.0	0.2
	Incombustibles	Inerts	0.1	0.0	0.3	0.3	0.0	0.9	0.1	0.0	0.5	0.1	0.0	0.4
	Special Waste	Organic packages	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	4.1	0.0	0.0	0.0
		Bones > 25 cm	0.0	0.0	0.0	0.3	0.0	4.1	1.5	0.0	5.4	0.0	0.0	0.0
		Other	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2
			0.3	**0.1**	**0.5**	**1.8**	**0.4**	**6.5**	**2.7**	**0.4**	**6.9**	**1.6**	**0.3**	**3.5**
		Total Contaminants	**6.6**	**2.8**	**10.1**	**13.7**	**9.1**	**20.7**	**11.3**	**8.2**	**15.7**	**11.3**	**6.9**	**14.1**
		Nº of samples	6			29			14			13		

Physical Characterization RO 2010			VALORSUL						EGEU PRIVATE			TRATOLIXO PRIVATE			MARL - PRiVATE			2010		
			Dry Circuits			Wet circuits												Weighted med		
			Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max		Min	Max
Group 1 – Putrescible Waste	Food		65.8	54.1	76.0	68.0	62.3	71.8	66.2	39.7	80.4	68.2	61.3	75.0	88.1	88.1	88.1	68.3	39.7	89.4
	Others		0.3	0.0	0.9	0.3	0.0	0.6	0.0	0.0	0.1	0.1	0.0	0.4	0.0	0.0	0.0	0.2	0.0	2.8
	Fines	<20mm	11.4	8.7	15.3	11.1	8.8	12.2	22.5	8.1	56.8	9.7	5.5	13.5	6.9	6.9	6.9	13.4	5.4	56.8
			77.6	**70.3**	**84.7**	**79.4**	**73.9**	**82.8**	**88.7**	**82.7**	**96.5**	**78.0**	**75.1**	**83.4**	**95.1**	**95.1**	**95.1**	**81.9**	**67.2**	**96.5**
Group 2 – Paper/Cardboard	Paper		9.0	5.8	11.6	8.8	5.0	12.3	1.7	0.4	3.1	9.0	5.6	12.6	1.6	1.6	1.6	5.7	0.4	12.8
	Cardboard	Packaging	1.3	0.1	2.3	1.1	0.3	3.3	0.8	0.2	1.3	1.6	0.7	2.9	2.6	2.6	2.6	1.0	0.0	3.3
		Non packaging	0.1	0.0	0.3	0.2	0.0	0.7	0.2	0.0	0.5	0.1	0.0	0.2	0.0	0.0	0.0	0.1	0.0	0.7
			10.5	**6.2**	**13.0**	**10.1**	**5.4**	**14.4**	**2.7**	**1.7**	**3.7**	**10.7**	**7.6**	**14.8**	**4.2**	**4.2**	**4.2**	**6.9**	**1.7**	**15.3**
Group 3 - Contaminants	Plastic	Film plastic bags	6.6	3.8	9.1	6.7	5.3	8.4	4.5	0.3	8.4	6.5	4.9	8.5	0.2	0.2	0.2	6.4	0.2	10.7
		Bottles	0.5	0.3	0.8	0.2	0.1	0.4	0.2	0.0	0.5	0.3	0.1	0.6	0.1	0.1	0.1	0.4	0.0	1.2
		Other	0.9	0.6	1.3	1.4	1.0	2.3	1.4	0.8	2.2	1.4	0.9	2.1	0.2	0.2	0.2	1.3	0.2	3.1
			8.0	**5.0**	**10.4**	**8.3**	**6.4**	**9.8**	**6.1**	**1.3**	**10.3**	**8.2**	**6.3**	**10.0**	**0.6**	**0.6**	**0.6**	**8.1**	**0.6**	**13.3**
	Glass	Packaging	1.2	0.2	2.6	0.7	0.1	1.6	0.1	0.0	0.1	0.7	0.4	1.1	0.1	0.1	0.1	0.6	0.0	2.6
		Non packaging	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.3
			1.2	**0.2**	**2.7**	**0.7**	**0.1**	**1.6**	**0.1**	**0.0**	**0.1**	**0.8**	**0.4**	**1.1**	**0.1**	**0.1**	**0.1**	**0.7**	**0.0**	**2.7**
	Metals	Ferrous	0.5	0.1	0.9	0.4	0.1	0.7	0.0	0.0	0.0	0.5	0.2	0.7	0.1	0.1	0.1	0.4	0.0	1.5
		Non Ferrous	0.2	0.0	0.5	0.2	0.0	0.6	0.0	0.0	0.1	0.2	0.1	0.7	0.0	0.0	0.0	0.1	0.0	0.8
			0.7	**0.2**	**1.1**	**0.5**	**0.2**	**1.3**	**0.1**	**0.0**	**0.1**	**0.7**	**0.4**	**1.3**	**0.1**	**0.1**	**0.1**	**0.5**	**0.0**	**1.9**
	Composites		0.5	0.1	0.9	0.4	0.2	0.8	0.1	0.0	0.2	0.5	0.2	1.0	0.0	0.0	0.0	0.3	0.0	1.3
	Textiles		0.3	0.1	0.5	0.3	0.1	0.8	0.0	0.0	0.1	0.2	0.1	0.4	0.0	0.0	0.0	0.3	0.0	1.7
	Health care textiles		0.5	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.0	2.2	0.0	0.0	0.0	0.1	0.0	3.4
	Combustibles	Wood	0.1	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.5
		Other	0.1	0.0	0.2	0.1	0.1	0.1	1.0	0.1	3.7	0.1	0.0	0.3	0.0	0.0	0.0	0.4	0.0	3.7
	Incombustibles	Inerts	0.2	0.0	0.8	0.2	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.6	0.0	0.0	0.0	0.1	0.0	0.9
	Special Waste	Organic packages	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	4.1
		Bones > 25 cm	0.4	0.0	1.4	0.0	0.0	0.0	0.9	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	5.4
		Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
			2.0	**1.0**	**5.5**	**1.0**	**0.5**	**1.4**	**2.4**	**0.4**	**3.8**	**1.6**	**0.6**	**3.7**	**0.0**	**0.0**	**0.0**	**2.0**	**0.0**	**6.9**
		Total Contaminants	**12.0**	**8.5**	**18.2**	**10.5**	**8.6**	**11.9**	**8.6**	**1.8**	**14.2**	**11.3**	**9.0**	**13.6**	**0.8**	**0.8**	**0.8**	**11.2**	**0.8**	**20.7**
		Nº of samples	8			6			4			8			1					

Obs.: Values in percentage of weight

Table 13. Summary results for characterisation of SC-OFMSW carried out in 2011

Physical Characterization RO 2011			Municipalites												EGEU PRIVATE			TRATOLIXO PRIVATE			MARL - PRiVATE			2011		
			Amadora			Lisboa Dry Circuits			Lisboa Wet Circuits			Loures Linha de Secos*												Weighted med		
			Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max		Min	Max.
Group 1 – Putrescible Waste	Food		76.7	72.2	81.3	70.1	53.5	83.8	75.3	67.9	81.5	76.9	59.3	85.6	76.0	69.2	83.9	72.5	68.2	75.7	94.7	94.7	94.7	73.5	53.5	94.7
	Others		0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.6	0.5	0.0	2.0	0.1	0.0	0.3	0.4	0.0	1.1	0.0	0.0	0.0	0.1	0.0	2.0
	Fines	<20mm	9.8	6.9	12.7	8.1	5.2	12.8	8.9	4.4	16.0	4.4	0.0	13.7	9.6	3.2	14.4	8.3	6.5	10.6	4.1	4.1	4.1	8.5	0.0	16.0
			86.5	**84.9**	**88.2**	**78.2**	**62.1**	**89.0**	**84.4**	**77.4**	**87.2**	**81.9**	**71.4**	**85.8**	**85.7**	**81.1**	**88.8**	**81.2**	**79.9**	**82.2**	**98.7**	**98.7**	**98.7**	**82.1**	**62.1**	**98.7**
Group 2 – Paper/Cardboard	Paper		6.6	5.8	7.5	8.4	3.1	14.1	4.7	0.1	7.5	7.0	4.7	12.3	3.9	1.9	6.0	7.9	6.7	9.8	0.4	0.4	0.4	6.3	0.1	14.1
	Cardboard	Packaging	0.3	0.2	0.4	0.7	0.2	1.7	0.5	0.0	1.3	0.6	0.2	1.5	0.7	0.2	1.2	1.2	0.8	1.5	0.0	0.0	0.0	0.7	0.0	1.7
		Non packaging	0.1	0.0	0.2	0.1	0.0	1.0	0.7	0.0	4.9	0.1	0.0	0.1	0.2	0.0	0.6	0.1	0.0	0.1	0.0	0.0	0.0	0.2	0.0	4.9
			7.0	**6.4**	**7.7**	**9.2**	**3.5**	**15.9**	**6.0**	**3.9**	**8.8**	**7.7**	**4.9**	**13.8**	**4.8**	**2.7**	**6.8**	**9.1**	**8.1**	**11.0**	**0.4**	**0.4**	**0.4**	**7.2**	**0.4**	**15.9**
Group 3 - Contaminants	Plastic	Film plastic bags	5.5	3.4	7.6	8.2	4.7	14.0	6.2	4.1	8.5	5.8	4.0	6.9	6.1	5.7	6.4	5.1	3.0	6.8	0.2	0.2	0.2	6.9	0.2	14.0
		Bottles	0.1	0.0	0.2	0.4	0.0	1.0	0.1	0.0	0.2	0.3	0.0	0.5	0.2	0.1	0.3	0.4	0.1	0.6	0.1	0.1	0.1	0.3	0.0	1.0
		Other	0.3	0.3	0.3	1.0	0.5	2.2	0.7	0.2	1.8	0.8	0.3	2.0	1.2	0.4	2.1	0.9	0.8	1.0	0.0	0.0	0.0	0.9	0.0	2.2
			5.9	**3.8**	**8.1**	**9.6**	**5.3**	**16.2**	**7.1**	**5.3**	**9.5**	**6.9**	**5.0**	**8.4**	**7.5**	**6.9**	**8.2**	**6.4**	**4.0**	**8.3**	**0.3**	**0.3**	**0.3**	**8.2**	**0.3**	**16.2**
	Glass	Packaging	0.0	0.0	0.0	0.8	0.1	1.6	0.3	0.1	1.0	0.6	0.1	1.1	0.0	0.0	0.1	0.4	0.3	0.5	0.0	0.0	0.0	0.4	0.0	1.6
		Non packaging	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.1	0.1	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.4
			0.1	**0.0**	**0.1**	**0.8**	**0.2**	**1.6**	**0.3**	**0.1**	**1.0**	**0.6**	**0.1**	**1.5**	**0.0**	**0.0**	**0.1**	**0.5**	**0.4**	**0.5**	**0.0**	**0.0**	**0.0**	**0.5**	**0.0**	**1.6**
	Metals	Ferrous	0.1	0.1	0.1	0.5	0.1	0.9	0.1	0.0	0.3	0.3	0.1	0.7	0.1	0.0	0.2	0.5	0.2	1.0	0.0	0.0	0.0	0.3	0.0	1.0
		Non Ferrous	0.0	0.0	0.0	0.2	0.0	0.5	0.1	0.0	0.2	0.2	0.0	0.4	0.1	0.0	0.1	0.3	0.1	0.7	0.0	0.0	0.0	0.1	0.0	0.7
			0.1	**0.1**	**0.1**	**0.6**	**0.2**	**1.4**	**0.2**	**0.1**	**0.3**	**0.5**	**0.1**	**0.9**	**0.2**	**0.1**	**0.2**	**0.8**	**0.3**	**1.2**	**0.0**	**0.0**	**0.0**	**0.4**	**0.0**	**1.4**
	Composites		0.3	0.2	0.4	0.6	0.2	1.8	0.2	0.0	0.4	0.5	0.2	0.9	0.1	0.1	0.2	0.4	0.3	0.6	0.5	0.5	0.5	0.4	0.0	1.8
	Textiles		0.0	0.0	0.0	0.3	0.0	1.0	0.1	0.0	0.4	0.6	0.0	2.6	0.0	0.0	0.1	0.6	0.2	1.4	0.0	0.0	0.0	0.2	0.0	2.6
	Health care textiles		0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.1	0.8	0.0	2.4	0.0	0.0	0.0	0.1	0.0	0.4	0.0	0.0	0.0	0.1	0.0	2.4
	Combustibles	Wood	0.0	0.0	0.0	0.1	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.4
		Other	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	0.1	0.1	0.0	0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2
	Incombustibles	Inerts	0.0	0.0	0.0	0.3	0.0	1.0	0.1	0.0	0.4	0.1	0.0	0.5	0.0	0.0	0.0	0.4	0.1	1.0	0.0	0.0	0.0	0.1	0.0	1.0
	Special Waste	Organic packages	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Bones > 25 cm	0.0	0.0	0.0	0.2	0.0	1.3	1.5	0.0	4.6	0.0	0.0	0.0	1.6	0.0	4.9	0.3	0.0	1.0	0.0	0.0	0.0	0.8	0.0	4.9
		Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
			0.3	**0.3**	**0.4**	**1.6**	**0.4**	**3.3**	**2.0**	**0.2**	**5.1**	**2.4**	**1.3**	**4.8**	**1.9**	**0.4**	**5.3**	**2.0**	**1.9**	**2.1**	**0.6**	**0.6**	**0.6**	**1.7**	**0.2**	**5.3**
		Total contaminants	**6.4**	**4.1**	**8.7**	**12.6**	**7.5**	**22.0**	**9.6**	**6.8**	**13.8**	**10.4**	**7.3**	**14.9**	**9.6**	**7.5**	**13.8**	**9.7**	**6.8**	**12.0**	**0.9**	**0.9**	**0.9**	**10.7**	**0.9**	**22.0**
		Nº samples	2			18			7			9			4			3			1					

Obs.: Values in percentage of weight

* Circuit R2 includes domestic fraction

Table 14. Results of preliminary physico-chemical characterisation of waste samples

		UK					Finland	Italy		Portugal		
		Luton [a]	**Hackney** [a]	**Ludlow** [a]	**Eastleigh**	**Eastleigh**	**Forssa**	**Treviso**	**Treviso**	**Lisbon raw waste**	**Lisbon to digester**	**Lisbon to digester**
		(Lab 2)	(Lab 2)	(Lab 2)	(Lab 2)	(Lab 1)	(Lab 1)	(Lab 1)	(Lab 3)	(Lab 3)	(Lab 1)	(Lab 3)
Fundamental characteristics for anaerobic digestion												
pH		5.12 ± 0.01	5.18 ± 0.01	4.71 ± 0.01	5.02 ± 0.01	5.70	5.34	6.16			5.93	
TS	% WW [b]	23.70 ± 0.06	25.74 ± 0.18	23.74 ± 0.08	25.89 ± 0.01	28.62 ± 0.07	27.02 ± 0.12	27.47 ± 0.03	24.43 ±4.57	33.80	6.31 ± 0.005	6.33
VS	% WW	21.84 ± 0.10	23.47 ± 0.31	21.71 ± 0.09	24.00 ± 0.03	26.83 ± 0.16	24.91 ± 0.05	23.60 ± 0.09	20.16 ± 3.75	27.60	4.93 ± 0.05	5.01
VS	%TS	91.28 ± 0.20	91.17 ± 0.91	91.44 ± 0.39	92.70 ± 0.12	94.18 ± 0.42	92.26 ± 0.26	86.60 ± 0.40	83.32 ± 5.87	81.7	78.19 ± 0.86	79.1
TOC	%TS	51.2 ± 1.2	51.3 ± 0.2	48.3 ± 1.0	48.76 ± 0.87							
TKN		3.12 ± 0.01	3.13 ± 0.03	3.42 ± 0.04	2.91 ± 0.05	2.74 ± 0.05	2.39 ± 0.04	2.55 ± 0.03	2.84 ± 0.76	1.5	6.93 ± 0.07	4.30
TKN	$g\ kg^{-1}$ WW	7.39 ± 0.02	8.06 ± 0.08	8.12 ± 0.09	7.53 ± 0.13	7.84 ± 0.16	6.45 ± 0.1	7.02 ± 0.1	7.19 ± 2.06	5.1	4.37 ± 0.05	2.72
CV	$kJ\ g^{-1}$ TS	21.43 ± 0.12	21.64 ± 0.11	20.66 ± 0.18	20.97 ± 0.02	21.32 ± 0.08	21.39 ± 0.11	20.50 ± 0.01			25.23 ± 0.26	
Biochemical composition												
Lipids	$g\ kg^{-1}$ VS	148 ± 4	157 ± 2	151 ± 1	149 ± 1	152 ± 2	156 ± 0.5	202 ± 0.5			314 ± 0.4	
Crude protein	$g\ kg^{-1}$ VS	213 ± 1	213 ± 2	235 ± 3	197 ± 4	183 ± 4	162 ± 0.4	186 ± 3			554 ± 6	
Nutrients												
TKN (N)	$g\ kg^{-1}$ TS	31.2 ± 0.1	31.3 ± 0.3	34.2 ± 0.4	29.1 ± 0.5	27.4 ± 0.5	23.9 ± 0.4	25.5 ± 0.3	28.44 ± 7.62	15	63.9 ± 0.7	43.0
TP (P)	$g\ kg^{-1}$ TS	4.87 ± 0.08	6.41 ± 0.12	5.41 ± 0.32	2.82 ± 0.13	2.94 ± 0.01	2.73 ± 0.05	3.47 ± 0.06	3.26 ± 1.54	5.0	8.92 ± 0.12	4.0
TK (K)	$g\ kg^{-1}$ TS	12.3 ± 0.1	12.9 ± 0.6	14.3 ± 0.8	8.59 ± 0.27	11.2 ± 0.2	10.0 ± 0.2	10.0 ± 0.1			29.2 ± 0.4	
Elemental analysis												
N	%TS	3.12 ± 0.01	3.13 ± 0.03	3.42 ± 0.04	2.91 ± 0.05	2.80 ± 0.02	2.46 ± 0.03	2.58 ± 0.05			5.72 ± 0	
C	%TS	51.2 ± 1.2	51.3 ± 0.2	48.3 ± 1.0	48.8 ± 0.9	50.6 ± 0.2	49.4 ± 0.04	47.2 ± 0.01			54.8 ± 0.1	
H	%TS	6.56 ± 0.04	6.67 ± 0.13	5.53 ± 0.63	6.37 ± 0.19							
S	%TS	0.21 ± 0.00	0.23 ± 0.03	0.15 ± 0.01								
O	%TS	30.7 ± 1.2	29.8 ± 0.4	34.3 ± 2.5	34.7 ± 0.9							

[a] Samples analysed as part of the Defra funded project WR1208 (Banks et al., 2011) [b] WW = wet weight

5.2 Physico-chemical characterisation

The results of physico-chemical characterisation of the selected SC-OFMSW samples are given in Table 14**.** The comparison of the results was made between partners MTT, Verona, Valorsul and Greenfinch, as reported in D2.1.

Three samples were taken at the Valorsul anaerobic digestion plant, corresponding to raw waste arriving at the plant, the digester feed, and the reject stream after a pre-treatment process involving manual sorting, shredding, sieving and hydropulping as described by Vaz et al. (2008)

The results showed a strong degree of similarity in the samples, especially from the viewpoint of key parameters in anaerobic digestion. Total and volatile solids contents were generally similar. The Valorsul raw waste had slightly lower moisture content, and both this sample and the one from Treviso had a lower TS/VS ratio indicating the present of more inert materials. TKN values were all similar and as expected were relatively high on a wet weight basis, suggesting the potential for ammonia toxicity with this feedstock. Concentrations of plant nutrients (N, P and K) suggested that the digestate from this feedstock has significant potential for fertiliser replacement. The elemental analysis was in good agreement and the measured calorific value confirmed this is an energy-rich substrate.

6 Conclusions

The data obtained on fuel consumption and collection tonnages will be carried forward for use elsewhere in the project.

The collections implemented by Lisbon “Wet circuits” and Amadora collect more waste per producer-day (average 43 kg producer^{-1} day^{-1}) than the Lisbon 'dry' circuits and Loures circuit R1 with average values of 5 kg producer^{-1} day^{-1} and 13 kg producer^{-1} day^{-1}, respectively. Loures circuit R2 includes household collections which contribute to the lower quantities collected (~9 kg producer^{-1} day^{-1}). These differences are related to the type of producer and to the urban density.

With regard to urban density it can be seen that Lisbon, when compared with Loures and Amadora, shows a higher discrepancy between circuits with respect to the number of establishments per km^2 because it includes a larger area with different topographical characteristics (historic neighbourhoods, downtown restaurants and also suburbs with a lower urban density). In terms of average values the Lisbon collection presents a ratio of about ~59 establishments per km^2 followed by Loures with ~ 55 and Amadora with ~25.

The results of the physical characterisation campaigns for the organic fraction of waste selectively collected in canteens, markets, restaurants and others large producers (SC-OFMSW)showed that organic material made up ~82%, paper and cardboard ~7% and contaminants ~11% on a wet weight basis. Plastic materials (plastic bags) were the main contaminants and when in a wet and dirty condition represented ~8% of the total weight collected.

Waste from households (SS-OFMSW) was separated and characterised and the results compared to the SC-OFMSW. The results indicated no significant differences between waste selectively collected from large producers and source segregated waste selectively collected from households, and confirmed that these two streams are likely to show the same behaviour when used as feedstock to an anaerobic digester.

Comparing the results with examples from Spain and the UK indicated that the use of biodegradable bags for collection has a double benefit, as it reduces the contaminant content and also contributes to the organic fraction; while in Valorsul the use of non-biodegradable plastic bags leads to contamination and represents a corresponding loss of organic material. Despite this, the putrescible content of the SC-OFMSW is within the range reported in the literature.

With respect to physico-chemical characterisation the results showed a strong degree of similarity in the samples, especially from the viewpoint of key parameters in anaerobic digestion. Concentrations of plant nutrients (N, P and K) suggested that the digestate from this feedstock has significant potential for fertiliser replacement. The elemental analysis was in good agreement and the measured calorific value confirmed this is an energy-rich substrate.

Comparison of results from different countries should be undertaken with care, since it involves different consumer habits, with differences in implementation of the collection schemes (communication campaigns, incentives and support materials) and also in the waste physical characterisation methodologies used.

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Appendix A - Analytical methods

Appendix A1 – Basic characteristics for anaerobic digestion

1. Basic characteristics for anaerobic digestion		***Method***
pH		DIN ISO 10390
TS (% fresh matter)		EN 14346
VS (% fresh matter)		DIN CEN TS 14775
COD (g kg-1 fresh matter)		Analogue DIN 38414-S9
2. Nutrients value as fertiliser substitute (g kg^{-1} TS)		***Method***
TKN (N)		EN 3342
TP (P)		DIN EN ISO 11885
TK (K)		DIN EN ISO 11885
3. Essential trace elements (mg kg^{-1} TS)		***Method***
Microwave digestion with acids under pressure		***Necessary for TP, TK, group 3 and 4***
Cobalt (Co)		DIN EN ISO 11885
Iron (Fe)		DIN EN ISO 11885
Manganese (Mn)		DIN EN ISO 11885
Molybdenum (Mo)		DIN EN 17294
Selenium (Se)		DIN EN 17294
Tungsten (W)		DIN EN 17294
4. Potentially toxic elements (mg kg^{-1} TS)		***Method***
Cadmium (Cd)		DIN EN 17294
Chromium (Cr)		DIN EN ISO 11885
Copper (Cu)		DIN EN ISO 11885
Mercury (Hg)		DIN EN ISO 16772
Nickel (Ni)		DIN EN ISO 11885
Lead (Pb)		DIN EN 17294
Zinc (Zn)		DIN EN ISO 11885
5. Biochemical composition (g kg^{-1} VS)		***Method***
Carbohydrates	Sugar and Starch	VDLUFA-METHODS
Lipids		VDLUFA-METHODS
Crude proteins		VDLUFA-METHODS
Hemi-cellulose		VDLUFA-METHODS
Cellulose		VDLUFA-METHODS
Lignin		VDLUFA-METHODS
6. Elemental analysis (%TS)		***Method***
N		DIN 51722-1
C		DIN 51732
H		DIN 51732
S		DIN 51724-3
O		DIN 51732
7. Calorific Value (kJ g^{-1} TS)		***Method***
Hu		DIN 51900-3

- **Determination of pH**

ISO 10390 - Soil quality -- Determination of pH
ISO 10390:2005 specifies an instrumental method for the routine determination of pH using a glass electrode in a 1:5 (volume fraction) suspension of soil in water (pH in H_2O), in 1 mol/l potassium chloride solution (pH in KCl) or in 0,01 mol/l calcium chloride solution (pH in $CaCl_2$).

- **Determination of dry and volatile matter**

EN 14346 - Characterization of waste - Calculation of dry matter by determination of dry residue or water content
This European Standard specifies methods for the calculation of the dry matter of samples for which the results of performed analysis are to be calculated to the dry matter basis. Depending on the nature of the sample, the calculation is based on a determination of the dry residue (Method A) or a determination of the water content (Method B). It applies to samples containing more than 1 % (m/m) of dry residue or more than 1 % (m/m) of water.
DIN CEN / TS 14 775 - Solid biofuels - Determination of ash content
This standard specifies a method for determination of the ash content in all solid biofuels. The ash content is determined by calculation from the mass of the residue that remains after heating the sample in air at a temperature of (550 ± 10) °C under strictly regulated conditions in terms of time, the sample mass and the technical data of the device. Automatic devices may be used for this purpose. Here Leco TGA 701 D4C was used.
The sample is well mixed and the moisture is brought to equilibrium with the laboratory atmosphere to obtain a representative analysis sample.
The weight of the analysis sample is determined automatically. The sample is transferred into a dish and the dish is inserted in the furnace. The furnace temperature is evenly raised up to 550 °C ± 10 °C until there is no more decrease of weight. The difference in weight shows the loss on ignition. The residue in per cent of the original sample means the ash content.

- **Determination of Chemical Oxygen Demand (COD)**

DIN 38414 (S9): German standard methods for the examination of water, waste water and sludge; sludge and sediments (group S); determination of the chemical oxygen demand (COD) (S 9)
In environmental chemistry, the chemical oxygen demand (COD) test is commonly used to measure the amount of organic compounds in water indirectly.
The COD of a material is related to the mass of the initial weight oxygen, which is equivalent to the mass of potassium dichromate, which reacts with the oxidisable substances contained in the material. 1 mol K2Cr2O7 corresponds to 1.5 mol O2.
It is expressed in milligrams per litre (mg/l), which indicates the mass of oxygen consumed per litre of solution.
The basis for the COD test is that nearly all organic compounds can be fully oxidised to carbon dioxide with a strong oxidizing agent under acidic conditions. The amount of oxygen required oxidizing an organic compound to carbon dioxide, ammonia, and water.
For all organic matter to be completely oxidised, an excess amount of potassium dichromate (or any oxidizing agent) must be present. Once oxidation is complete, the amount of excess potassium dichromate must be measured to ensure that the amount of Cr3+ can be determined with accuracy. To do so, the excess potassium dichromate is titrated with ferrous ammonium sulphate (FAS) until the entire excess oxidizing agent has been reduced to Cr3+. Typically, the oxidation-reduction indicator Ferroin is added during this titration step as well. Once all the excess dichromate has been reduced, the Ferroin indicator changes from blue-green to reddish-brown. The amount of ferrous ammonium sulphate added is equivalent to the amount of excess potassium dichromate added to the original sample. Any metals are previously converted into metal ions by sulphuric acid. Chloride ions are bound by mercury ions in an insoluble form to prevent interference in the determination.

Appendix A2 – Nutrients value as fertiliser substitute

- **Determination of kjeldahl nitrogen**

DIN EN 13342: Characterization of sludges. Determination of Kjeldahl nitrogen

This method describes a procedure for the determination of "Kjeldahl Nitrogen" in sludge and sludge products. The digestion is catalysed by selenium or copper, the temperature being raised by a high concentration of sodium sulphate. Although wet samples are normally taken for analysis, it is recognised practice to report results on a dry mass basis (g/kg). Consequently, it is also necessary to determine the dry residue of the homogenised sample used for analysis (see EN 12880).

- **Determination of total phosphorous and potassium**

EN 13657 - Aqua regia digestion of waste

This standard specifies methods of digestion with aqua regia. Solutions produced by the methods are suitable for analysis e.g. by atomic absorption spectrometry (FLAAS, HGAAS, CVAAS, GFAAS), inductively coupled plasma emission spectrometry (ICP-OES) and inductive coupled plasma mass spectrometry (ICP-MS). The method is applicable to the digestion of waste for example for the following elements: Al, Sb, As, B, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Mo, Ni, P, K, Se, Ag, S, Na, Sr, Sn, Te, Ti, Tl, V, Zn.

The digestion was microwave assisted.

ISO 17294-2:2003 - Water quality -- Application of inductively coupled plasma mass spectrometry (ICP-MS) -- Part 2: Determination of 62 elements

ISO 17294-2:2003 specifies a method for the determination of the elements aluminium, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, caesium, calcium, cerium, chromium, cobalt, copper, dysprosium, erbium, europium, gadolinium, gallium, germanium, gold, hafnium, holmium, indium, iridium, lanthanum, lead, lithium, lutetium, magnesium, manganese, molybdenum, neodymium, nickel, palladium, phosphorus, platinum, potassium, praseodymium, rubidium, rhenium, rhodium, ruthenium, samarium, scandium, selenium, silver, sodium, strontium, terbium, tellurium, thorium, thallium, thulium, tin, tungsten, uranium, vanadium, yttrium, ytterbium, zinc, and zirconium in water (for example drinking water, surface water, groundwater, wastewater and eluates).

Taking into account the specific and additionally occurring interferences, these elements can also be determined in digests of water, sludges and sediments.

The working range depends on the matrix and the interferences encountered. In drinking water and relatively unpolluted waters, the limit of application is between 0,1 micrograms per litre and 1,0 micrograms per litre for most elements.

The detection limits of most elements are affected by blank contamination and depend predominantly on the laboratory air-handling facilities available.

The lower limit of application is higher in cases where the determination is likely to suffer from interferences or in case of memory effects.

Appendix A3 – Essential trace elements & potentially toxic elements

- **Determination of cobalt, iron, manganese, molybdenum, selenium, tungsten, cadmium, chromium, copper, mercury, nickel, lead and zinc**

EN 13657 - Aqua regia digestion of waste

This standard specifies methods of digestion with *aqua regia*. Solutions produced by the methods are suitable for analysis e.g. by atomic absorption spectrometry (FLAAS, HGAAS, CVAAS, GFAAS), inductively coupled plasma emission spectrometry (ICP-OES) and inductive coupled plasma mass spectrometry (ICP-MS). The method is applicable to the digestion of waste for example for the following elements: Al, Sb, As, B, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Mo, Ni, P, K, Se, Ag, S, Na, Sr, Sn, Te, Ti, Tl, V, Zn.

The digestion was microwave assisted.

ISO 17294-2:2003 - Water quality -- Application of inductively coupled plasma mass spectrometry (ICP-MS) -- Part 2: Determination of 62 elements

ISO 17294-2:2003 specifies a method for the determination of the elements aluminium, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, cesium, calcium, cerium, chromium, cobalt, copper, dysprosium, erbium, europium, gadolinium, gallium, germanium, gold, hafnium, holmium, indium, iridium, lanthanum, lead, lithium, lutetium, magnesium, manganese, molybdenum, neodymium, nickel, palladium, phosphorus, platinum, potassium, praseodymium, rubidium, rhenium, rhodium, ruthenium, samarium, scandium, selenium, silver, sodium, strontium, terbium, tellurium, thorium, thallium, thulium, tin, tungsten, uranium, vanadium, yttrium, ytterbium, zinc, and zirconium in water (for example drinking water, surface water, groundwater, wastewater and eluates).

Taking into account the specific and additionally occurring interferences, these elements can also be determined in digests of water, sludge and sediments.

The working range depends on the matrix and the interferences encountered. In drinking water and relatively unpolluted waters, the limit of application is between 0,1 micrograms per liter and 1,0 micrograms per liter for most elements.

The detection limits of most elements are affected by blank contamination and depend predominantly on the laboratory air-handling facilities available.

The lower limit of application is higher in cases where the determination is likely to suffer from interferences or in case of memory effects.

ISO 1483:2007 - Water quality - Determination of mercury - Method using atomic absorption spectrometry

This European Standard specifies two methods for the determination of mercury. For the method described in Clause 4, tin (II) chloride is used as the reducing agent. For the method given in Clause 5, sodium borohydride serves as the reducing agent. The choice of method depends on the equipment available and the matrix (see Clause 3). Both methods are suitable for the determination of mercury in water, for example in drinking, ground, surface and waste waters, in a concentration range from 0,1 µg/l to 10 µg/l. Higher concentrations can be determined if the water sample is diluted. Lower concentrations in the range of 0,001 µg/l to 5 µg/l can be determined if special mercury analysers with an optimised instrument are used or if atomic fluorescence spectrometry is applied (see EN 13506 or ISO 17852).

Appendix A4 – Biochemical composition

- **Determination of carbohydrates (sugar, starch), lipids, crude proteins**

VDLUFA method book volume III

Cell components include: crude proteins, ash, fat, shares of the Group NfE: the non-structural carbohydrates, sugar and starch, and a residual "organic residue".

Structural substances include mainly structural carbohydrates and associated substances, the group is made up of fibre fractions and a portion of the fraction of NfE Weender feed analysis.

The sum of the structural substances is the fraction neutral detergent fibre (NDF, neutral detergent fibre).

Acid-detergent fiber (ADF, acid detergent fiber) represents a part of the NDF, it is NDF without hemicelluloses.

Finally, acid-detergent lignin (ADL lignin, acid detergent) by definition, includes mainly the lignin and is a part of the ADF, it is ADF without the cellulose.

ADF: The samples are heated in sulfuric acid solution of Cetyltrimethylammonium-Bromid. Insoluble matter is filtered. It is referred to ADF. (Cellulose + lignin)

NDF: The soluble fraction of cells is extracted by boiling with a neutral solution (sodium lauryl sulphate). The sum of the structural substances is separated by filtration. It consists of cellulose, hemicellulose and lignin.

Lignin: The remaining residue from ADF determination is treated for 3 hours with 72% sulfuric acid at room temperature, filtered off and washed with water, dried and weighed. After ashing of the organic substance the residue is weighed again. The loss on ignition corresponds to the lignin.
Crude proteins: This is the sum of all compounds containing nitrogen. Mostly Kjeldahl nitrogen is measured in a first step. Then the result is multiplied by a factor which represents the reciprocal value of the typical N-content of crude protein. This is typically 6.25 (vegetable protein) or 6.38 (animal protein) – going out from an average N content of crude protein of 16% (plant) and 15.7 (animal).

Appendix A5 – Elemental Analysis

- **Determination of carbon, hydrogen and nitrogen**

DIN 51732
Principle: Combustion of the sample in an oxygen flow followed by H_2O and CO_2 measurement using IR detection, NOx with a thermal conductivity detector
Device: automat Leco TRU SPEC CHN
Measurement: The grinded sample is weighed directly into a tin capsule and it is closed. The combustion takes place at 950 ° C followed by measurement of the combustion gases. The results based on weight are given in %(w/w).

- **Determination of sulphur (total sulphur)**

DIN 51724, Part 3
Principle: Combustion of the sample in an oxygen flow followed by SO_2 measurement using IR detection
Device: automat SC 144 DR (Leco)
Measurement: The grinded test sample is thermally decomposed or oxidised in a ceramic pot (with the aid of V_2O_5) at high temperature (> 1300 ° C) in an oxygen flow, and the resulting SO_2 is analysed as total sulphur. The result is given in %(w/w).

Appendix A6 – Calorific value

- **Determination of gross and net calorific value**

prEN 16023 Characterization of waste - Determination of calorific value
This European Standard specifies a method for the determination of the gross calorific value of waste at constant volume and at the reference temperature 25 °C in a bomb calorimeter calibrated by combustion of certified benzoic acid. The result obtained is the gross calorific value of the sample at constant volume with both the water of the combustion products and the moisture of the waste as liquid water. In practice, wastes are burned at constant (atmospheric) pressure and the water is either not condensed but is removed as vapour with the flue gases. Under these conditions, the operative heat of combustion to be used is the net calorific value of the fuel at constant pressure. In this European Standard the net calorific value at constant volume is described as it requires less additional determinations. This method is applicable to all kinds of wastes.

Appendix B – Statistical background

Appendix B1 - Aleatory random sampling
The following parameters can be used for the description of the sample:
The average of the measured values is:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

The standard deviation of the sample: The standard deviation of a set of measurements $x_1, x_2, \ldots, x_n$ is the average of the squares of the deviations of the measurements about their mean.

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Coefficient of variation of sample: is a relative measure of variability in which the standard deviation is expressed as a percentage of the mean.

$$var\ coeff\ (x_i) = \frac{s}{\bar{x}}$$

The confidence interval can be obtained from the following formula:

$$CI = \bar{x} \pm \frac{t_{\alpha;n-1}.\, var\ coeff(x_i)}{\sqrt{n}}$$

where $t_{\alpha;n-1}$ is the confidence coefficient (z-value) and can be obtained from table of t-distribution associated with the confidence level desired.

Appendix B2 - Stratified random sampling

If a stratified random sampling procedure has been used the results for each stratum have to be disclosed separately. For the calculation of the overall result the results of the single strata have to be weighted and put in the right relation, according to its portion in the parent population. The total result is the weighted mean of the single stratum results.

$$\hat{\bar{X}} = \bar{x} = \frac{1}{N}\sum_{h=1}^{L} x_h \frac{N_h}{N} = \frac{1}{N}\sum_{h=1}^{L} \bar{x}_h N_h = \sum_{h=1}^{L} \bar{x}_h \left(\frac{N_h}{N}\right)$$

where $h = 1, 2, \ldots, L$ (number of strata)
n_h- number of sampling units in stratum h
N_h - number of survey units in stratum h
N – size of the overall population

The standard deviation s for the estimator $\hat{\bar{X}}$ of the total average can be calculated according to the following formula:

$$s_{\hat{\bar{X}}} = \sqrt{\sum_{h=1}^{L}\left(\frac{N_h}{N}\right)^2 \frac{s_h^2}{n_h}\left(1 - \frac{n_h}{N_h}\right)}$$

ou

$$s_{\hat{\bar{X}}} = \sqrt{\sum_{h=1}^{L}\left(\frac{N_h}{N}\right)^2 \frac{s_h^2}{n_h}} \qquad \left(for\ \frac{n_h}{N_h} < 0.05\right)$$

Additional references:

European Commission, "Methodology for the Analysis of Solid Waste", March 2004
ISO/IEC Guide 99:2007 - International vocabulary of metrology -- Basic and general concepts and associated terms (VIM)

Additional appendices: full data sets for characterisation campaigns, available in electronic spreadsheet format