D 2.2 Waste Profiling

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Date: March 2014

Dissemination level: PU

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 308363).

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1 Summary

The objective of the investigation undertaken by Fraunhofer Institute for Building Physics (IBP) was to profile municipal solid waste (MSW) and waste management systems in the European Union (EU 27) and associated countries. Data was collected for the following issues:

- regulation of waste management systems and waste legislation
- waste management systems (collection, treatment and disposal)
- composition of MSW
- variation of the biodegradable content of MSW
- energy potential of biogenic waste (calorific value, methane generation potential)
- cellulose content of MSW, particularly of the biogenic content of MSW
- inhibitors for microorganisms occurring in MSW
- prices for disposal of MSW, so-called "gate fees".

The geographical scope for this review was the 27 member states of the EU (EU 27) and associated countries. Literature research was chosen as the methodology to employ. Interviews were used to supplement literature information on MSW. The main feature of European waste legislation is the so called Waste Hierarchy (in order of decreasing priority): prevent, reuse, recycle, recover and dispose. Waste management systems of EU member states are based on the performance of these options in line with the overall goal of sustainability. The degree of implementation of waste legislation differs among EU member states. Gaps are located mainly in Eastern and South-Eastern Europe. This is reflected in the shares of treatment options for MSW. High landfill rates indicate minimal implementation of EU waste legislation. Composition of MSW is variable and influenced by a variety of parameters, such as demography, affluence and season. Detailed data on the composition of all individual MSW streams for each country of the EU 27 and the associated countries is rare.

MSW consists of a number of waste streams: household-collected waste, recycling collections, bulky waste, litter and street sweepings, commercial waste and waste collected at recycling centres. This report details the composition of these component waste streams for UK´s MSW. The composition of household-collected waste (residual waste) and overall MSW are approximately similar. Therefore composition of residual waste can be roughly estimated based on the composition of MSW. This is not as easy as may be expected, as neither the composition of MSW orf residual waste is known for some countries in the East of Europe as a result of the lack of reliable data. Approximately 30 to 40 % of EU´s total MSW consists of separately collected biodegradable kitchen and garden waste. Not all EU member states have implemented separate collection systems for biodegradable waste fractions, like kitchen, garden waste, paper and cardboard waste. It can be assumed that countries without separate collection systems have higher amounts of biodegradable waste materials in the category household and similar waste (mixed waste or residual waste). Parameters like low heating value (LHV) and moisture closely depend on the composition of the MSW. On average European MSW has a LHV of about 9 MJ/kg and a moisture content of about 30 to 40 % ww (wet weight). Comparing different biodegradable wastes, paper and cardboard have the highest content of cellulose and cellulose like substances of approximately 90 %. As inhibitors for microorganisms heavy metals were identified, especially copper and copper alloys.

Prices for disposal vary according to the technology used, existing restrictions – e.g. on pre-treatment conditions or exhaust air treatment - and revenues for generated energy or products. Between the member states exists a large variation in the costs for treatment and disposal technologies. No general trend for the level of disposal costs among European countries could be established. This report provides an overview of waste management practices and information on MSW across Europe. Results of this investigation show, that there are future needs for recycling and treatment of MSW. Waste2Go could be an appropriate approach to provide missing waste treatment capacities and tap the full recycling potential of MSW, particularly for the biogenic fraction.

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2 Methodology

In the following section the methodological approach of literature research and data collection are outlined. The geographical frame of data collection is identified and defined.

2.1 Literature research

The literature analysed included reports published mainly by the European Commission (EC) and data from Eurostat statistics (Eurostat) (see Table 2). Reasons for the use of Eurostat data were amongst others:

- Data quality: consistency, actuality and high level of availability,
- Comparability: the approach of Eurostat statistics is equally carried out across the EU member states and candidate states for accession.

The advantages of reports by the EC may be summarized as follows:

- Comparability of waste management performance and legal implementation through coverage of most member states and partly associated countries in reports launched by the EC.
- The studies deal with a broad range of waste related topics.
- Improved credibility of the studies due to the Commission's role of monitoring waste management performance of the member states.
- Sufficient data availability for all EU 27 member states, partly for associated countries of the EU.

Scientific articles were complementary evaluated for detailed information about individual waste fractions, especially for the chemical and physical characteristics of MSW. No reports on those issues launched by the EC were identified. Detailed analyses of MSW or its individual elements were normally carried out on local scale. This resulted in difficulties determining country-specific characteristics of MSW. For the overview of waste legislation relevant legal texts were sighted and summarised. An overview of the evaluated literature is given in Table 2.

Collected information and data from literature were supplemented by expert knowledge obtained through interviews. In this regard talks with projects partners were conducted, too. In particular Mr. Helstrip was questioned about the waste management system and treatment of waste in the UK [1]. Mr. Fischer and Mr. Rapf of the Institute for Sanitary Engineering, Water Quality and Solid Waste Management of the University of Stuttgart, Germany were asked about the composition of MSW and chemical and physical characteristics of MSW [2, 3]. Concerning treatment of biodegradable waste, staff of the composting plant Kirchheim unter Teck, Germany were consulted [4].

The geographical scope for data collection as part of this review, was the 27 member states of the European Union (EU 27) and associated countries (see Table 2), although Croatia is part of the EU since 1st July 2013. The investigative scope has not been expanded, because latest collected data on MSW was from 2012. At this time Croatia has not been part of the EU and therefore it was taken into account as associated country in this report. A complete list of all countries and their abbreviations in alphabetical order is shown in Table 1.

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Table 1: *EU 27 member states and associated countries [5, 6, 7]*

Country	*Abbreviation*	*Status*
Albania	*AL*	*Associated country, potential candidate country for the EU*
Austria	*AT*	*EU-27 member state*
Belgium	*BE*	*EU-27 member state*
Bosnia Herzegovina	*BA*	*Associated country, potential candidate country for the EU*
Bulgaria	*BG*	*EU-27 member state*
Croatia	*HR*	*Associated country, acceding candidate country for the EU*
Cyprus	*CY*	*EU-27 member state*
Czech Republic	*CZ*	*EU-27 member state*
Denmark	*DK*	*EU-27 member state*
Estonia	*EE*	*EU-27 member state*
Finland	*FI*	*EU-27 member state*
France	*FR*	*EU-27 member state*
Germany	*DE*	*EU-27 member state*
Greece	*EL*	*EU-27 member state*
Hungary	*HU*	*EU-27 member state*
Iceland	*IS*	*Associated country, official candidate country for the EU, part of EFTA*
Ireland	*IE*	*EU-27 member state*
Italy	*IT*	*EU-27 member state*
Kosovo	*XK*	*Associated country, potential candidate country for the EU*
Latvia	*LV*	*EU-27 member state*
Liechtenstein	*LI*	*Associated country, part of EFTA*
Lithuania	*LT*	*EU-27 member state*
Luxembourg	*LU*	*EU-27 member state*
Malta	*MT*	*EU-27 member state*
Montenegro	*ME*	*Associated country, official candidate country for the EU*

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Netherlands	*NL*	*EU-27 member state*
Norway	*NO*	*Associated country, part of EFTA*
Poland	*PL*	*EU-27 member state*
Portugal	*PT*	*EU-27 member state*
Romania	*RO*	*EU-27 member state*
Serbia	*RS*	*Associated country, official candidate country for the EU*
Slovakia	*SK*	*EU-27 member state*
Slovenia	*SI*	*EU-27 member state*
Spain	*ES*	*EU-27 member state*
Sweden	*SE*	*EU-27 member state*
Switzerland	*CH*	*Associated country, part of EFTA*
The former Yugoslav Republic of Macedonia	*MK*	*Associated country, official candidate country for the EU*
Turkey	*TR*	*Associated country, official candidate country for the EU*
United Kingdom	*UK*	*EU-27 member state*

2.2 Collection of data

Data was recorded in a tabular format using Microsoft Excel® and organised to the issues:

- MSW composition
  - chemical wastes, health care and biological wastes, metallic wastes, non-metallic wastes (paper and cardboard, glass, rubber, plastic, wood, textile and waste containing polychlorinated biphenyls (PCB)), discarded equipment, animal and vegetal waste, mixed waste, common sludges, mineral and solidified wastes
- MSW analysis
  - moisture, calorific value, amount of ash and inerts, pH value, cellulose content, chemical composition and content of inhibitors for microorganisms of MSW
- waste treatment
  - amount of MSW treated with composting and digestions, recycled, incinerated or disposed onto landfills
- waste management systems
  - implementation of a nationwide pay-as-you-throw system (PAYT), collection coverage, rate of biodegradable waste landfilled, existence of ban or restrictions for the disposal of MSW onto landfills, separate collection systems
- costs and gate fees
  - costs for collection, sorting, treatment and disposal of MSW as well as some waste fractions.

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Mainly actual and specific data for the individual countries and waste fractions was collected, the oldest data used was taken from 1994 and the most recent data is from 2013. Therefore the tabular evaluation offered the ability to handle the large amount of data and provided the opportunity to compare different data sources. The tables have been made available online for all project participants and they were asked for feedback and contribution.

The information collection for the Eurostat data commenced in December 2012 and was terminated in April 2013. On 16th May 2013 the Eurostat data about MSW had been partially updated. Only data for the total amount of MSW is now available for the year 2011. In this investigation the composition of MSW is required for the evaluation; therefore the Eurostat data from 2010 was used. In section 3.2 data of 2011 is used for the treatment of MSW across Europe so far as it was available. The data collection and processing of Eurostat are explained briefly in Annex A. Table 2 shows the individual research issues and connected resources.

Around 3,525 pages of literature were analysed and 5 interviews were conducted. The following number of resources were evaluated:

- 13 books,
- 4 internet documents,
- 12 scientific articles,
- 33 legal texts,
- 21 reports.

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Table 2: Evaluated literature

Section	Literature							
	Title	Author	Year	Year of data Collection	Client	Type of Resource	Number of pages	Reference
Waste legislation	Regulation (EC) No 2150/2002	European Parliament and Council	2002	N/A	N/A	Legal text	36	[8]
	Directive 2008/98/EC	European Parliament and Council	2008	N/A	N/A	Legal text	28	[9]
	Directive 2000/76/EC	European Parliament and Council	2000	N/A	N/A	Legal text	21	[10]
	Council Directive 1999/31/EC	European Council	1999	N/A	N/A	Legal text	19	[11]
	Regulation (EC) No 1013/2006	European Parliament and Council	2006	N/A	N/A	Legal text	98	[12]
	Regulation (EU) No 135/2012	European Commission	2012	N/A	N/A	Legal text	3	[13]
	Regulation (EU) No 664/2011	European Commission	2011	N/A	N/A	Legal text	3	[14]
	Regulation (EC) No 308/2009	European Commission	2009	N/A	N/A	Legal text	4	[15]
	Corrigendum to Regulation (EC) No 1013/2006	European Parliament and Council	2008	N/A	N/A	Legal text	1	[16]
	Regulation (EC) No 1379/2007	European Commission	2007	N/A	N/A	Legal text	14	[17]
	Corrigendum to Commission Regulation (EC) No 1379/2007	European Commission	2008	N/A	N/A	Legal text	5	[18]
	Regulation (EC) No 669/2008	European Commission	2008	N/A	N/A	Legal text	9	[19]
	Regulation (EC) No 1418/2007	European Commission	2007	N/A	N/A	Legal text	42	[20]
	Regulation (EC) No 740/2008	European Commission	2008	N/A	N/A	Legal text	9	[21]
	Regulation (EC) No 967/2009	European Commission	2009	N/A	N/A	Legal text	5	[22]
	Regulation (EU) No 837/2010	European Commission	2010	N/A	N/A	Legal text	5	[23]
	Directive 91/689/EEC	European Council	1991	N/A	N/A	Legal text	8	[24]
	Regulation (EC) No 166/2006	European Parliament and Council	2006	N/A	N/A	Legal text	17	[25]
	Directive 94/31/EC	European Council	1994	N/A	N/A	Legal text	1	[26]

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	Decision 2000/532/EC	European Commission	2000	N/A	N/A	Legal text	22	[27]
	Decision 2000/738/EC	European Commission	2000	N/A	N/A	Legal text	3	[28]
	Regulation (EC) No 1137/2008	European Parliament and Council	2008	N/A	N/A	Legal text	54	[29]
	Green Paper on the management of bio-waste in the European	European Commission	2008	N/A	N/A	Report	18	[30]
	Regulation (EC) No 574/2004	European Commission	2004	N/A	N/A	Legal text	33	[31]
	Regulation (EC) No 783/2005	European Commission	2005	N/A	N/A	Legal text	4	[32]
	Regulation (EC) No 221/2009	European Parliament and Council	2009	N/A	N/A	Legal text	3	[33]
	Regulation (EU) No 849/2010	European Parliament and Council	2010	N/A	N/A	Legal text	40	[34]
	Directive 94/62/EC	European Parliament and Council	1994	N/A	N/A	Legal text	23	[35]
	Directive 2006/66/EC	European Parliament and Council	2006	N/A	N/A	Legal text	14	[36]
	Directive 2000/53/EC	European Parliament and Council	2000	N/A	N/A	Legal text	9	[37]
	Implementing EU waste legislation for green growth	Monier, V. et al.	2011	2008	EC	Report	200	[38]
	Screening of waste management performance of EU Member States	BiPro GmbH	2011	N/A	EC	Report	49	[39]
Waste management systems	Eurostat	European Commission	2011	2011	N/A	Internet Document	N/A	[40]
	Screening of waste management performance of EU Member States	BiPro GmbH	2011	N/A	EC	Report	49	[39]
	Costs for municipal waste management in the EU	Hogg, D.	2002	2003	EC	Report	79	[41]
	Waste management options and climate change	Smith, A. et al.	2001	1999	EC	Book	224	[42]
	Success stories on composting and separate collection	European Commission	2000	N/A	EC	Book	70	[43]
	Implementing EU waste legislation for green growth	Monier, V. et al.	2011	2008	EC	Report	200	[38]
	Screening of waste management performance of EU Member States	BiPro GmbH	2011	N/A	EC	Report	49	[39]
	Waste management and treatment of MSW in the UK	Helstrip, M.	2013	N/A	N/A	Communication	N/A	[1]

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	Treatment of kitchen waste	Kirchheim u.T. GmbH	2013	N/A	N/A	Communication	N/A	[4]
	Managing municipal solid waste – a review of achievements in 32 European countries	European Environment Agency (EEA)	2013	2013	N/A	Book	40	[44]
Composition of MSW	Eurostat	European Commission	2011	2011	N/A	Internet Document	N/A	[40]
	Waste management options and climate change	Smith, A. et al.	2001	1999	EC	Book	224	[42]
	Regulation (EC) No 2150/2002	European Parliament and Council	2002	N/A	N/A	Legal Text	36	[8]
	Eurostat: statistics explained	European Commission	2014	N/A	N/A	Internet Document	N/A	[7]
	Einführung in die Abfallwirtschaft	Kranert, M. and Cord-Landwehr, K.	2010	N/A	N/A	Book	665	[45]
	Municipal solid waste	Fischer, K.	2013	N/A	N/A	Communication	N/A	[2]
	Assessing the composition of municipal solid waste in Wales	Burnley, S. J. et al.	2007	2001-	N/A	Journal Article	20	[46]
	A review of municipal solid waste composition in the United Kingdom	Burnley, S. J.	2007	N/A	N/A	Journal Article	12	[47]
	Implementing EU waste legislation for green growth	Monier, V. et al.	2011	2008	EC	Report	200	[38]
Variation of the biodegradable content of MSW	Eurostat	European Commission	2011	2011	N/A	Internet Document	N/A	[40]
	Directive 1999/31/EC of 26	European Council	1999	N/A	N/A	Legal text	19	[11]
	Costs for municipal waste management in the EU	Hogg, D.	2002	2003	EC	Report	79	[41]
	Regulation (EC) No 2150/2002	European Parliament and Council	2002	N/A	N/A	Legal text	36	[8]
	Biodegradable municipal waste management in Europe	Crowe, M. et al.	2002	N/A	N/A	Report	123	[48]
	Overview of the use of landfill taxes in Europe	Fischer, C. et al.	2012	N/A	N/A	Report	96	[49]
	Waste management options and climate change	Smith, A. et al.	2001	1999	EC	Book	224	[42]

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Physical and chemical characteristics of MSW	Waste management options and climate change	Smith, A. et al.	2001	1999	EC	Book	224	[42]
	Definition of waste recovery and disposal operations	Sander, K. et al.	2004	N/A	EC	Report	370	[50]
	Revisiting the elemental composition and the calorific value of the organic fraction of municipal solid wastes	Komilis, D. et al.	2012	N/A	N/A	Journal Article	10	[51]
	Thermal methods of municipal waste treatment	C-Tech Innovation Ltd.	2003	1994	N/A	Report	47	[52]
	Estimation of municipal solid waste heating value in Greece in the frame of formulating appropriate scenarios on waste treatment	Antonopoulos, I.-S. et al.	2010	2008		Report	8	[53]
	Municipal solid waste composition determination supporting the integrated solid waste management system in the island of Crete	Gidarakos, E. et al.	2006	2004	N/A	Journal Article	12	[54]
	Methodology for allocating municipal solid waste to biogenic and non-biogenic energy	U.S Department of Energy	2007	N/A	N/A	Report	18	[55]
	Alternative strategies for energy recovery from municipal solid waste	Consonni, S. et al.	2005	N/A	N/A	Journal Article	13	[56]
	A thermochemical concept based equation to estimate waste combustion enthalpy from elemental composition	Meraz, L. et al.	2003	N/A	N/A	Journal Article	9	[57]
	Influence of green waste, biowaste and paper–cardboard initial ratios on organic matter transformations during composting	Francou, C. et al.	2008	N/A	N/A	Journal Article	9	[58]
	Why energy from waste incineration is an essential component of environmentally responsible waste management	Porteous, A.	2005	N/A	N/A	Journal Article	9	[59]
	Bio-ethanol fromlignocellu-lose: Status, perspectives and challenges in Malaysia	Goh, Chun Sheng; Tan et al.	2010	N/A	N/A	Journal Article	8	[60]
	Directive 1999/31/EC	European Council	1999	N/A	N/A	Legal Text	19	[11]

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	Costs for municipal waste management in the EU	Hogg, D.	2002	2003	EC	Report	79	[41]
	Managing municipal solid waste – a review of achievements in 32 European countries	European Environment Agency (EEA)	2013	2013	N/A	Book	40	[44]
	Biodegradable municipal waste management in Europe	Crowe, M. et al.	2002	N/A	N/A	Report	123	[48]
	Overview of the use of landfill taxes in Europe	Fischer, C. et al.	2012	N/A	N/A	Report	96	[49]
	Proceedings of 14th Annual North American Waste to Energy Conference, NAWTEC	N/A	2006	N/A	N/A	Book	187	[61]
	Einführung in die Abfallwirtschaft	Kranert, M. and Cord-Landwehr, K.	2010	N/A	N/A	Book	665	[45]
	Allgemeine Mikrobiologie	Fuchs, Georg et al.	2007	N/A	N/A	Journal Article	678	[54]
	The inhibition of microorganisms by heavy metals	Sadler, W. R. and Trudinger, P. A.	1967	N/A	N/A	Journal Article	11	[62]
	Heavy metal content of combustible municipal solid waste in Denmark	Riber, C. et al.	2005	1999-	N/A	Journal Article	7	[63]
	Chemical and physical parameters of municipal solid waste	Rapf, M.	2013	N/A	N/A	Communication	N/A	[3]
	Implementing EU waste legislation for green growth	Monier, V. et al.	2011	2008	EC	Report	200	[38]
Prices for disposal	Screening of waste management performance of EU Member States	BiPro GmbH	2011	N/A	EC	Report	49	[39]
	Costs for municipal waste management in the EU	Hogg, D.	2002	2003	EC	Report	79	[41]
	Waste management options and climate change	Smith, A. et al.	2001	1999	EC	Book	224	[42]
	Managing municipal solid waste - a review of achievements in 32 European countries	European Environment Agency (EEA)	2013	2013	N/A	Book	40	[44]
	Success stories on composting and separate collection	European Commission	2000	N/A	EC	Book	70	[43]

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3 Results

This chapter represents the results of the literature analysis. Relevant European waste legislation was reviewed and briefly summarised in order to provide the context for this study. Waste management practices throughout Europe were summarised, followed by a review of the classifications of the various components of MSW. This was then used to identify trends in the composition of municipal solid wastes across Europe. In order to determine the amount of the most suitable feedstock which would be available to the Waste2Go process, the biodegradable content of MSW and its chemical and physical characteristics were then reviewed. In order to provide economic information on the processing of waste streams, prices for disposal of MSW in Europe were summarised.

3.1 Waste legislation

Five Directives and Regulations on European waste legislation were identified as being of relevance to this study, their content is detailed below.

The basis for the European waste management industry is the Waste Framework Directive (WFD) (Directive 2008/98/EC) [9]. The main feature of the WFD is the European Waste Hierarchy. This concept consists of five legally binding steps (in order of preference): prevention (avoid and reduce), reuse and preparation for reuse, recycling, recovery and safe disposal. Waste management strategies should be based on the performance of these options in line with the overall goal of sustainability. In general the directive establishes a legal framework for the treatment of waste to protect the environment and human health from the harmful effects of waste generation and treatment. The directive also includes a 50 % recycling target by weight for waste materials such as paper, plastic, glass and metal from households and waste streams similar to waste from households to be achieved by 2020 [9].

Statutory framework on operating conditions and technical requirements for the waste treatment operations incineration and landfilling is defined in the Directives 2000/76/EC [10] and 1999/31/EC [11] and amending acts. Directive 2000/76/EC [10] sets operating conditions on delivery and reception of waste for incineration and the subsequent combustion process. The report also details air emission limit values for the exhaust gases from incineration plants. Directive 1999/31/EC [11] aims to ensure high standards for the final disposal of waste. The directive encourages waste prevention through composting and biogasification of biodegradable wastes as well as recycling. For that reason the Directive includes targets for the diversion of biodegradable wastes from landfills, requiring the promotion of waste sorting, material recycling and energy recovery.

Regulation (EC) No 1013/2006 [12] specifies the procedures for controlling waste shipments and restrictions within the European Union and from or to third countries. Implementation of Community policy on waste generation, recovery and disposal is monitored by the European Union through statistical data. Regulation (EC) No 2150/2002 [8] provides a framework for the continuous and comparable production of statistics by member states and the Commission.

Above mentioned Directives and Regulations are summarised in Table 3. Based on the deadline for implementation into member states and entry into force all of the directives detailed should already be implemented; however there are gaps in implementation which are described below.

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Table 3: Summary of Directives and Regulations on European waste legislation [8, 9, 10, 11, 12]

Abbreviation	Title	Legislator	Entry into force	Deadline for transposition into member states
Directive 2008/98/EC	Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Waste Framework Directive)	European Parliament	12.12.2008	12.12.2010
Directive 2000/76/EC	Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste	European Parliament	28.12.2000	28.12.2002
Directive 1999/31/EC	Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste	European Council	16.07.1999	-
Regulation (EC) No 1013/2006	Regulation (EC) No 1013/2006 of the European parliament and of the Council of 14 June 2006 on shipments of waste	European Parliament	14.07.2006	12.07.2007
Regulation (EC) No 2150/2002	Regulation (EC) No 2150/2002 of the European Parliament and of the Council of 25 November 2002 on waste statistics	European Commission	29.12.2002	-

Beside the aforementioned regulations the management of specific waste streams is detailed in further directives, which were felt to be less relevant for this investigation, e.g. the handling of packaging waste, the disposal of spent batteries and the reusing, recycling and recovering of motor vehicles [35, 36, 37].

European waste legislation is not fully implemented and enforced in all member states. There are gaps primarily in Eastern and Southern Europe (e.g. LT, EL, IT, RO, HU, EE, MT, SK, PL, CY and others). Member states were obliged through the WFD to establish waste prevention programs on national level by 12th December 2013. Some countries in Eastern and Southern Europe do not have a waste prevention program and were expected to be unable to meet the deadline (BG, CY, CZ, EL, HU, IT, LT, LV, RO, SI and others). The WFD also provides the establishment of waste management plans (WMP) which shall contain forecasts regarding future municipal waste generation and referring treatment capacities. These are basic conditions for an environmentally sound waste management infrastructure in the future. Therefore some European countries are expected to have to deal with under capacities in future (BG, CY, CZ, EE, EL, HU, PL, RO, SE, SI, SK and others). The fulfilment of the targets of the Landfill Directive related to biodegradable MSW going to landfills is another quality characteristic for implementation of waste legislation. The 2006 target of a reduction to 75 % of biodegradable MSW going to landfills was not fulfilled by some countries (EL, LV, LT, IE, PL, CZ, MT, CY) in 2010. Therefore it is the author's opinion that these countries will struggle to achieve the more stringent targets for subsequent years [38, 39].

Another key indicator for the implementation of waste legislation is the number of infringement procedures concerning non-conformity and incorrect application of national transposition measures regarding the WFD and Landfill Directive. The highest number of infringement procedures was recorded in Greece, Ireland and Italy [39].

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In conclusion, EU waste legislation and the concept of the WFD are predominantly well established in Northern and Western Europe. Member states in Eastern and South-Eastern Europe have gaps in implementation, such as consideration of the waste hierarchy.

3.2 Waste management systems

Management of MSW within a country includes the

- collection / transport,
- treatment and
- final disposal of waste materials.

Starting from waste collection to final disposal, waste management systems differ within and between individual European countries. Two main systems exist for waste collection: kerbside collection and centralised 'drop-off' systems. Mixed household waste and waste similar to household waste (commercial and industrial wastes) are generally collected through kerbside systems. There are often kerbside systems for recyclable materials separately collected from mixed municipal waste such as biodegradable waste, paper and cardboard, plastics, glass and metal, the latter often mixed or mingled. In addition to kerbside collection, recyclables are sometimes collected through centralised systems, like recycling centres and drop-off centres [41, 42].

There are various possibilities for the treatment of collected waste materials including:

- material recycling,
- composting or digestion of biodegradable waste,
- incineration with or without energy recovery and
- mechanical-biological treatment.
- Ultimate disposal is the deposit onto or into landfills.

The first step for recycling operations of separate collected or mixed waste is sorting the collected waste. Usual methods of recycling operations are recovery of materials, e.g. aluminium out of cans, or reintegration of biogenic material to the economic cycle, e.g. composting of biodegradable waste [42, 43, 44].

3.2.1 Waste management systems across Europe

According to a study on behalf of the European Commission [39] key elements essential for good waste management were identified as:

- high status and development of recycling of MSW,
- existence of restrictions or bans and of typical charges for landfilling MSW,
- complete collection coverage,
- sufficient treatment capacity,
- fulfilment of the targets related to biodegradable waste going to landfills,
- use of Pay-as-you-throw systems,
- planning of future capacities,
- compliance with technical requirements,
- decoupling waste production from growing consumption and
- implementation of waste prevention in environmental policies.

Regarding to above mentioned key elements for good waste management performance, countries in Central and Northern Europe perform above average (AT, BE, DK, DE, FI, FR, LU, NL, SE, UK), but have problems in decoupling waste production from growing consumption (see Figure 1). It should further be noted that not all of these countries have to date implemented waste prevention as part of their environmental policies. Average performing member states are mainly located in Southern and Central to Eastern Europe (ES, HU, IE, PT, SI) (see Figure 1). These countries show

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deficits in collection coverage and in the planning of future treatment capacity, also waste prevention in these countries is often not taken into account on the political agenda. The largest implementation gaps can be found in member states in Southern and Eastern Europe (BG, CY, CZ, EE, EL, IT, LT, LV, MT, PL, RO) (see Figure 1). Deficits can be found in all key elements for good waste management systems. Below average performance is also reflected in the high dependence on landfilling with alternative treatment options for MSW rarely in place. In the majority of these states, large amounts of biodegradable wastes are landfilled; there are no restrictions or bans on waste disposal [39, 44]. For some issues detailed information is given below.

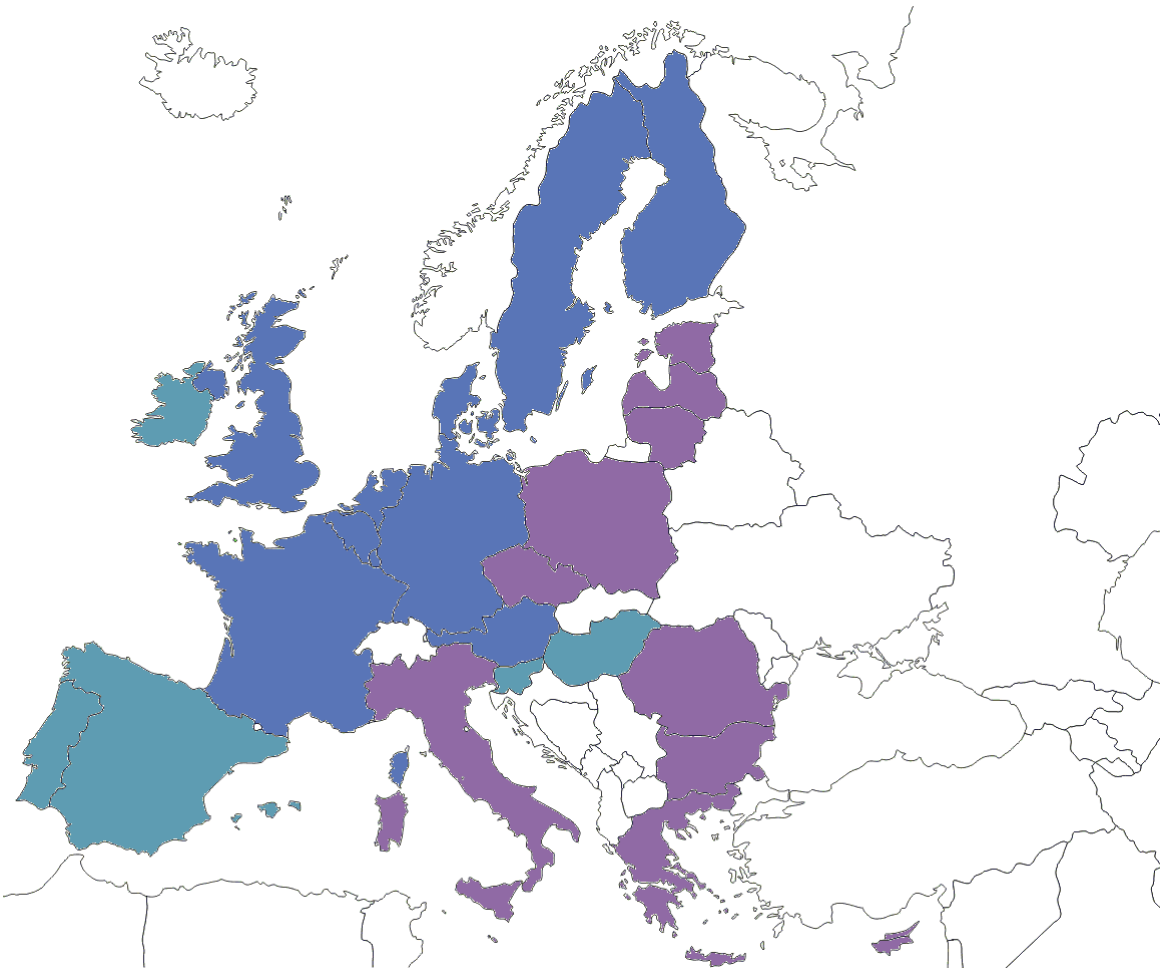

Figure 1: Waste management performance across Europe [39]

Some countries in Eastern Europe have deficits in the collection of waste as not the entire population have access to sufficient waste collection services; mainly rural and remote areas are not provided with such services. Wastes not covered by the collection system are disposed of without environmental controls and are dumped or burned illegally. All member states not reaching 100 % collection coverage were located in Eastern Europe (BG, LT, SI, HU, LV, PL, EE, RO). Here as well, the regional variation of collection systems and coverage within one country has to be taken into account. In almost all countries which reach 100 % collection coverage it is possible that separate collection systems for recyclable materials, for example for biodegradable waste, do not cover the whole territory [39].

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Wastes are finally disposed of, into landfill sites. The technical specification of landfill sites among the member states was found to be diverse. This concerns mostly the monitoring and treatment of leachate and landfill gas as well as aftercare and remediation. Moreover, not all types of wastes are permitted for disposal into landfill. The existence of bans and restrictions for landfilling varies across member states, as well as the type of restrictions and regulations relating to the pre-treatment. Countries located in South-Eastern Europe show the highest landfill rates and the highest amounts of biodegradable waste going to landfill. The majority of member states have introduced bans or restrictions for the disposal of municipal solid waste, especially the biodegradable waste components into landfill sites [39].

The existence of bans and restrictions for landfilling MSW has been shown to lead to a greater recycling rate and the implementation of other treatment methods. Landfill taxes can play an important role in encouraging a shift up of the waste hierarchy. There are a few countries in the East of Europe which have either not implemented any waste incineration technique or employ only waste incineration without energy recovery, which has reduced efficiency. Only a small number of European countries use mechanical biological treatment for residual waste as a pre-treatment before landfilling [39, 40, 44].

3.2.2 Waste treatment

Figure 2 provides an overview of the amount per capita, of MSW treated with the techniques material recycling, composting and digestion, incineration with and without energy recovery as well as landfilling across Europe in 2011. The countries are sorted in ascending order, taking into account the amount of MSW going to landfills. Some countries did not report the whole amount of generated MSW undergoing any treatment technique. The reasons identified for the incomplete reporting are insufficient data availability, errors in the collection of data and collection coverage lower than 100 %. If the latter is not reached, countries have to estimate the total amount of MSW. Therefore a partial quantity of MSW is reported with no treatment. Uncertainties also exist in the shares of MSW incinerated with and without energy recovery. There are no clear classification criteria in Eurostat data reporting which allows a clear distinction between incineration with energy recovery and incineration without energy recovery. Taking the geographical distribution into account, countries with more advanced waste treatment strategies are located in North-Western and Central Europe. Countries in the Eastern parts of Europe tend to have less advanced waste treatment strategies [40].

Figure 3 shows the regional recycling rates for MSW in 2008/2009 [44]. It can be seen that countries mainly located in northern and central Europe show high material recycling rates. Some countries in Eastern and South-Eastern Europe (i.a. BG, CZ, LV, LI, RO, TR and SK) have low recycling rates and are anticipated to miss the 50 % recycling target for 2020. It should be noted that recycling rates vary regionally within countries by more than 15 % between the 'best' and 'worst' regions. For a few European countries data on regional level is available and displayed graphically below in Figure 4 [44]. In this case the recycling rates include composting and digestion of biodegradable MSW. These differences may be influenced by regional and local policies and differences in reporting, respectively. For example waste sent to sorting plants can be reported as 100 % material recycling although parts of the sorted waste are incinerated or landfilled [44].

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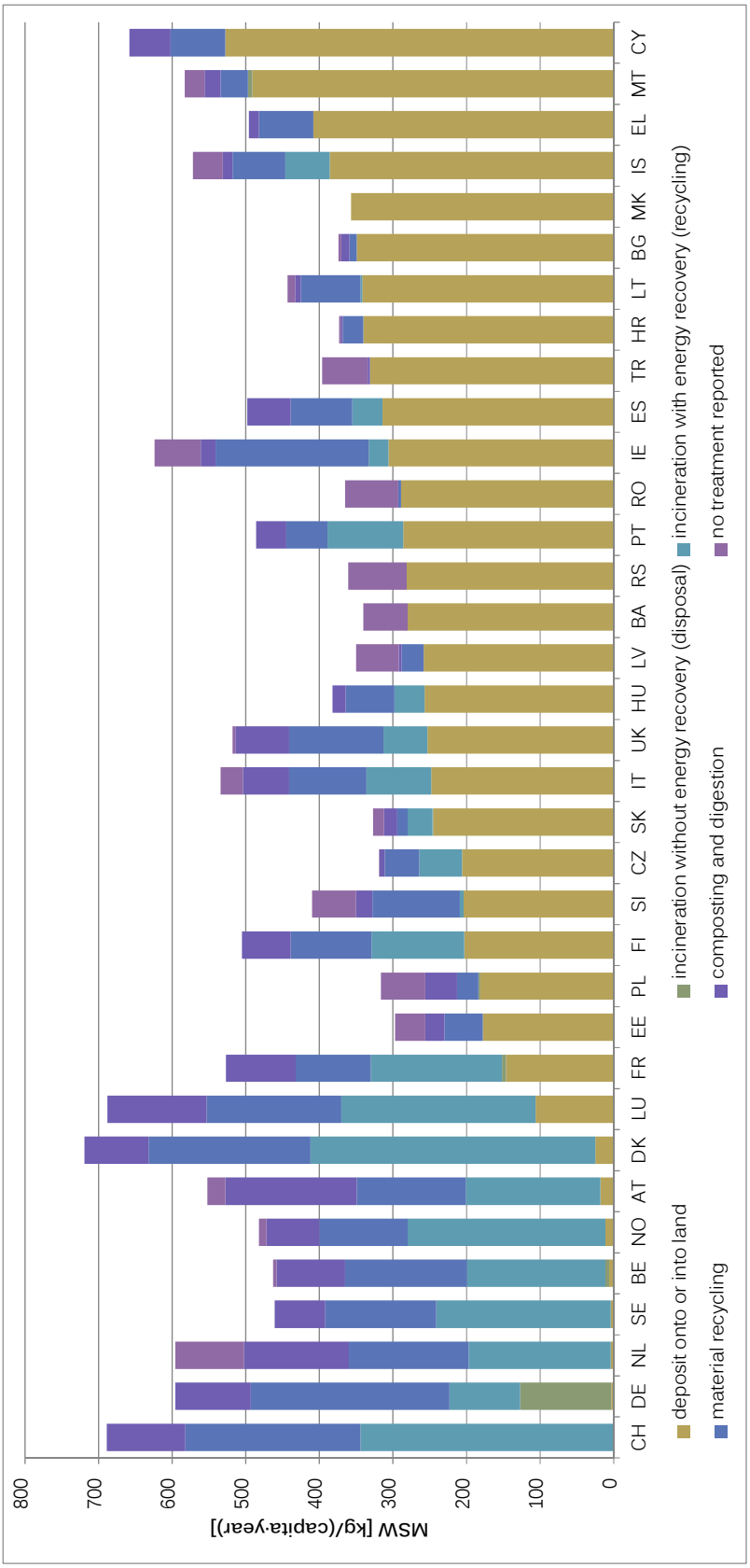

Figure 2: Treatment of MSW across Europe kg per capita in 2011 [40]

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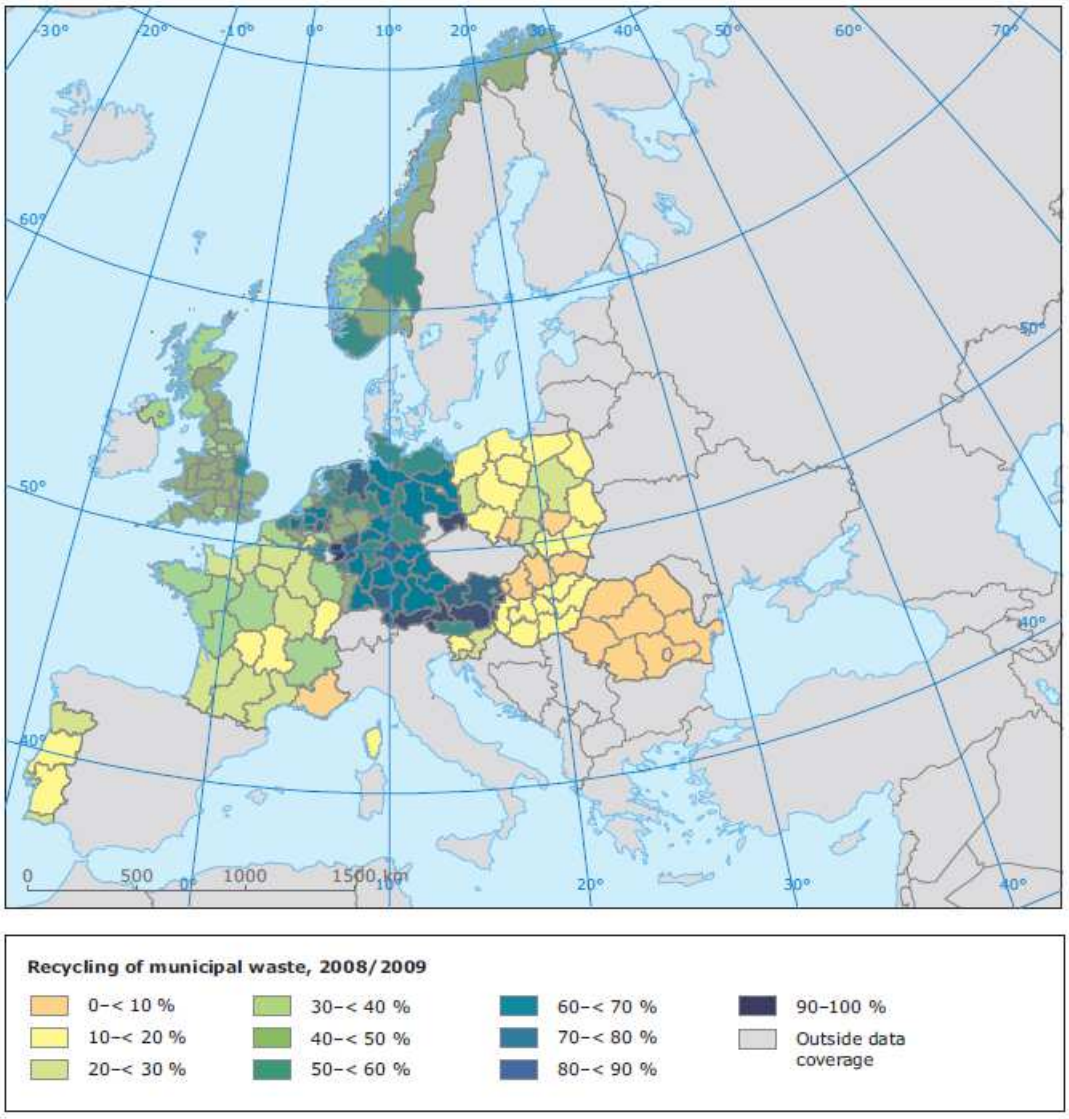

Note: Recycling includes material recycling and composting/digestion. Recycling rates are calculated as a percentage of municipal solid waste generated. 2008 data were used for Belgium, Germany, France, Hungary, Romania and Slovenia. 2009 data were used for the rest of the countries.

Figure 3: Regional recycling rates for MSW 2008/2009 [44]

Countries which displayed high recycling rates were found to have introduced separate collection systems for recyclable materials. This was particularly true for biodegradable waste; with the separate collection of biowaste favouring composting and digestion technologies. Thus, some countries in South-Eastern Europe have low biological treatment rates as they do not segregate out the biodegradable fraction [40]. In comparison with material recycling performance and recycling rates of biodegradable waste, the latter are increasing more modestly [44]. Reasons for low recycling rates of biodegradable waste were found to be the absence of a pan-European obligation to recycle biowaste (only the amount of biodegradable waste sent to landfills is limited) and the low amount of biodegradable waste in the MSW of some countries, e.g. LI, SI and NO [40]. This matter is discussed later on under Section 3.3. The share of composting and digestion of biodegradable waste on the total amount of MSW treated in 2010 is shown in Figure 4. In this case no data was available for BA and MK [40].

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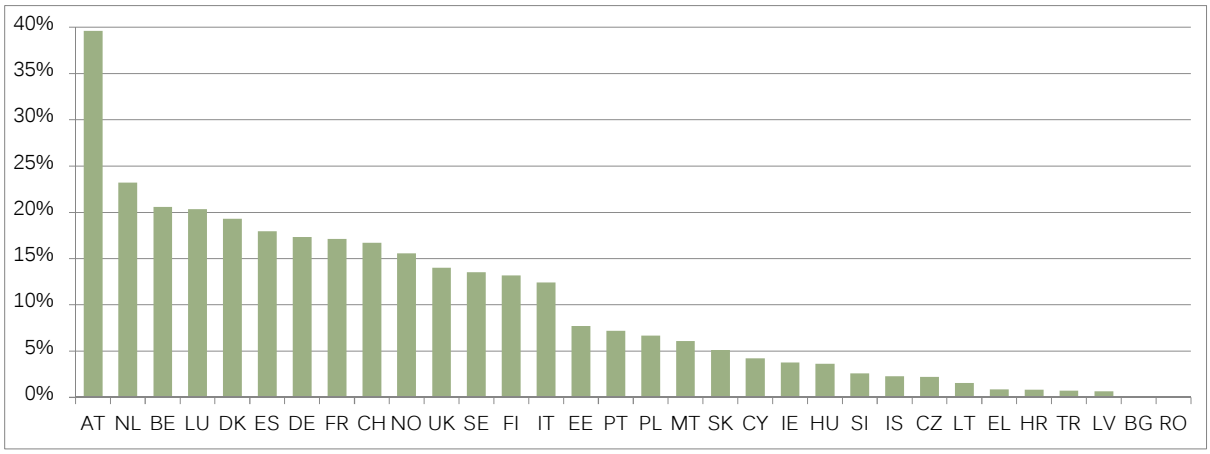

Figure 4: Share of composting and digestion on the total treatment of MSW across Europe (2010) [40]

Separate collection of biodegradable MSW and therefore high shares of composting and digestion are more common in North, West and Central Europe. Countries in Eastern and the South-East of Europe tend to favour other waste treatment options. An additional reason for this is the non-existence of a common EU quality standard for generated compost or digestate. The development of such an EU quality standard is on the European Commission's agenda and is scheduled to be finalised in 2014 [44].

According to the EEA report 'Managing municipal solid waste' there is clear correlation between the amount of MSW recycled and the cost of landfilling. High costs for landfilling of MSW induce a switch to other disposal options such as recycling. More details about costs for waste treatment operations are given in Section 3.6 [44].

Although sufficient treatment capacity and infrastructure for the MSW generated exists in the majority of member states, there was a lack of capacity identified in a few countries in Eastern Europe including Bulgaria, Poland and the Czech Republic. It was felt by the authors that, the concept of Waste2Go could be a possible solution to meet future demands in these countries for recycling and the treatment of municipal solid waste.

3.3 Composition of MSW

MSW consists of different types of solid waste generated by households and commercial establishments. Due to the guidelines set by Regulation (EC) No 2150/2002 on waste statistics [8] uncertainties exist about the comparability of national data. The main reason for this uncertainty is the use of varying definitions of MSW among the European countries. There is no clear and precise definition of the term 'municipal solid waste'; it is used in various ways reflecting diverse waste management streams and practices. Dissimilarities between various countries reporting and treatment of MSW result to some extent from differences in the generation and disposal of similar waste streams. Data on the generation of MSW is influenced for example by the proportion of commercial or bulky waste which sometimes falls under the definition of MSW. Eurostat defines municipal waste for the purpose of national annual reporting as follows:

> "Municipal waste consists of waste collected by or on behalf of municipal authorities and disposed of through waste management systems. Municipal waste consists mainly of waste generated by households, although it also includes similar waste from sources such as shops, offices and public institutions." [7].

This definition specifies the characteristic feature for MSW as the way it is collected by or on behalf of municipal authorities. Another definition of MSW can be found in the Landfill Directive (Council Directive 1999/31/EC) [11]; here it is defined as:

> "Waste from households, as well as other waste which, because of its nature or composition, is similar to waste from households".

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In this context the characteristic feature of MSW is its composition.

The following list represents a classification of wastes reflecting Regulation (EC) No 2150/2002 [8] on waste statistics which are mainly used in this investigation:

- chemical wastes
- health care and biological wastes
- metallic wastes
- non-metallic wastes: glass, paper and cardboard, plastics, wood, textiles and waste containing PCB
- discarded equipment
- animal and vegetal wastes: animal and mixed food waste, vegetal wastes
- mixed wastes: household and similar wastes, sorting residues, mixed and undifferentiated materials
- common sludges
- mineral and solidified wastes.

Unfortunately some waste types are listed as one category in Eurostat, e.g. health care and biological wastes. In this case no additional information was found about the composition of these waste categories. In the course of this investigation the term household and similar wastes is used in the place of residual waste and includes all kind of mixed waste collected by or on behalf of municipal authorities. Residual waste is only one part of the total MSW; there are other waste streams which contribute to it. The data available on the composition of MSW is analysed below.

To find out the detailed composition of MSW for one country, compositional analysis must be carried out. These measurements have to include all components of the waste stream and cover all seasons of the year; therefore they are time-consuming, expensive and elaborate. For a detailed analysis of MSW composition the following waste streams should be quantified:

- household-collected waste
- recycling collections
- bulky waste
- litter and street sweepings
- commercial waste
- waste collected at recycling centres.

The composition of the entire waste stream must be known to make qualitative assessments about the potential for recycling and biodegradability. The analysis of the composition of MSW mainly tends to be based on bulk samples of household waste from collection vehicles. Thus, only the composition of the household collected waste mixed with waste of small businesses can be calculated [2, 45]. Within the literature research of this WP only one study which was based on UK MSW was identified [46]. The detail of this study is recorded below.

From 2001 to 2003 a practical survey to assess the composition of the entire MSW stream was undertaken in Wales. The results can be considered to be representative for the composition of MSW in the investigated areas of the UK, because all of the above mentioned parts of the MSW stream were sampled and analysed. In addition to this geographical, waste management and socio-demographic factors were taken into account for the selection of sampling areas. Sampling was carried out over a full year to remove the effects of any seasonal variation. The waste from each household was individually sorted by hand. Kerbside recyclables collection was included in the evaluation of household-collected waste. One insight gained from the investigation was the existence of wide variation in the quantity of household-collected waste within and between the local authority areas. There was a large degree of variation in the share of several fractions on the total amount of MSW. When taking a 90 % confidence interval into account, variations can be ± 80 % for some fractions. In the following diagrams the composition of the individual MSW streams and overall composition of MSW are shown (Figure 6 to Figure 10) [46].

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Data from [46] was summarised according to the classification of wastes detailed above. No data could be associated to the categories chemical wastes, health care and biological wastes or common sludges. Therefore these categories were not shown in Figure 5 to Figure 10. The category potentially hazardous waste was also introduced, because it was not possible to assign this kind of waste to any of the other already identified categories. The category non-metallic recyclables was split into paper and cardboard, wood, textiles (including shoes) as well as glass and plastics since waste containing biodegradable material is of priority for the Waste2Go process.

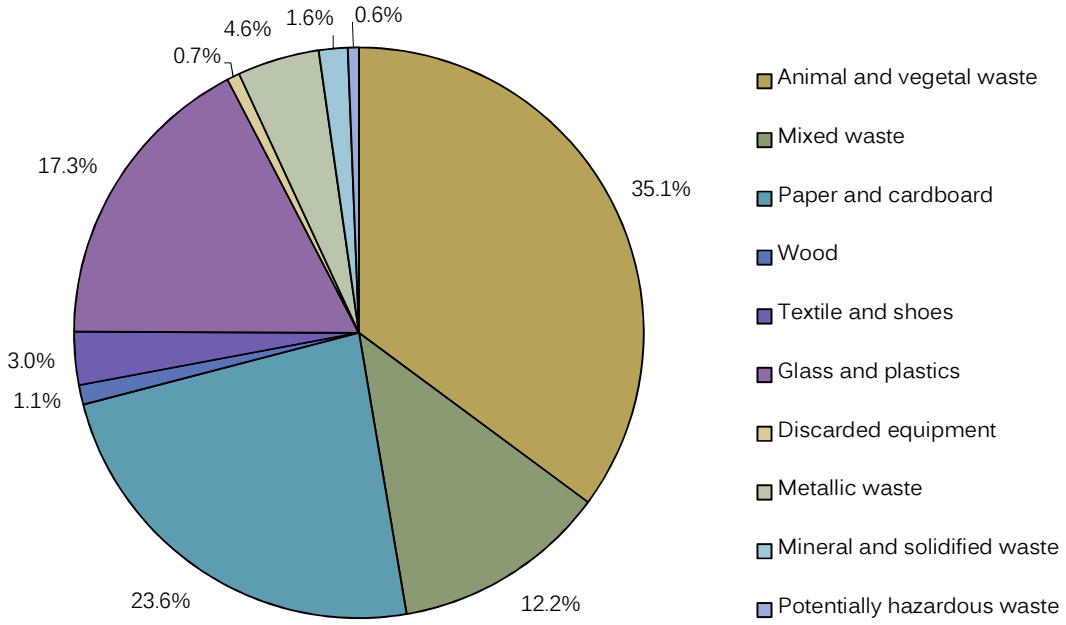

Figure 5: Composition of household-collected waste in the UK (2001) [46]

The highest proportions of household-collected waste in the UK were animal and vegetal waste, mixed waste as well as paper and cardboard waste. The category animal and vegetal waste consists of kitchen waste, garden waste and other organic waste. If one compares the composition of household-collected waste (see Figure 5) to the overall composition of MSW (see Figure 6), which consists of the waste streams household-collected waste, commercial waste, bulky waste as well as litter and street sweepings, only slight differences appear. Household-collected waste contains, compared with the overall MSW, up to 4.6 % more of the fractions animal and vegetal waste as well as up to 4 % more glass and plastics. The overall MSW has in contrast to household-collected waste a ca. 3.6 % higher share of construction and demolition waste and a ca. 5 % higher share of mixed waste.

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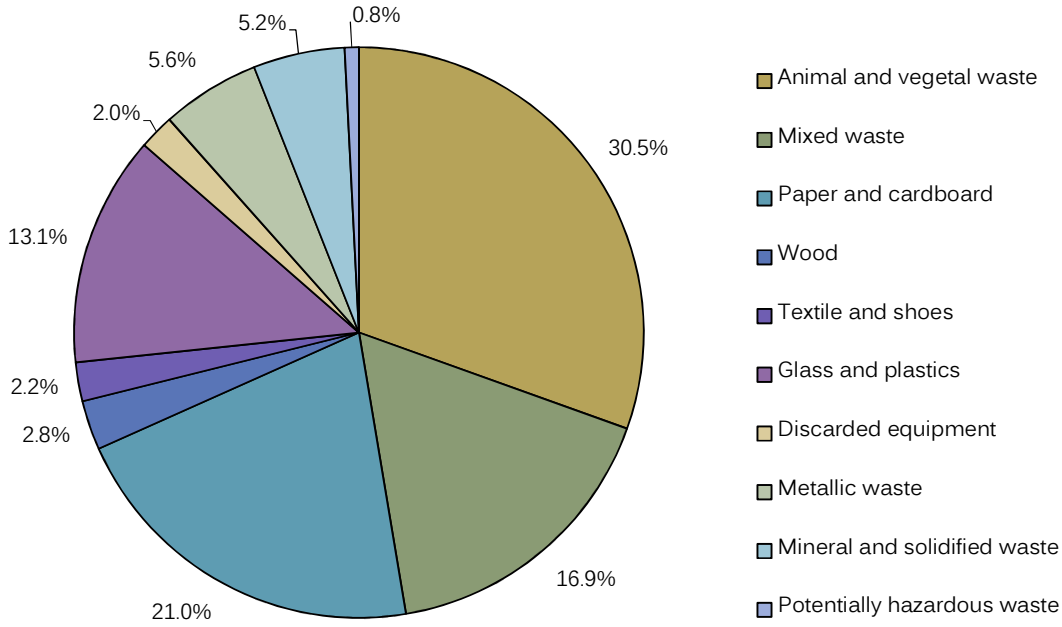

Figure 6: Overall composition of MSW in the UK (2001) [46]

Non-metallic recyclables (paper and cardboard, wood, textile and shoes, glass, plastics) as well as animal and vegetal waste still constitute the lion's share of MSW. There is a decrease in the share of animal and vegetal waste and further waste fractions for MSW when compared to household waste. When compared to household-collected waste, MSW has 4.6 % less animal and vegetal waste content. It should be noted that the survey investigates the composition of the individual waste streams only, like commercial waste. There is no information about the amount of each of the waste stream, only the total amount of MSW is known for the year 2001. The composition of those waste streams is shown in the diagrams addressing commercial waste (Figure 7), litter and street sweepings (Figure 8), bulky waste (Figure 9) and waste from recycling depots (Figure 10), The majority of these waste streams have significant shares of animal and vegetal waste. The category mixed waste has a composition similar to household-collected waste. For the overall composition of MSW the individual components of mixed bagged waste are included in the respective fractions of MSW; therefore the share of mixed waste on the overall composition of MSW is set to zero. The category waste has its largest share to the composition of waste from recycling depots (Figure 10). Commercial waste (Figure 7) has a high potential for recycling, it contains high amounts of non-metallic recyclables, e.g. paper and cardboard, glass and plastics as well as animal and vegetal waste.

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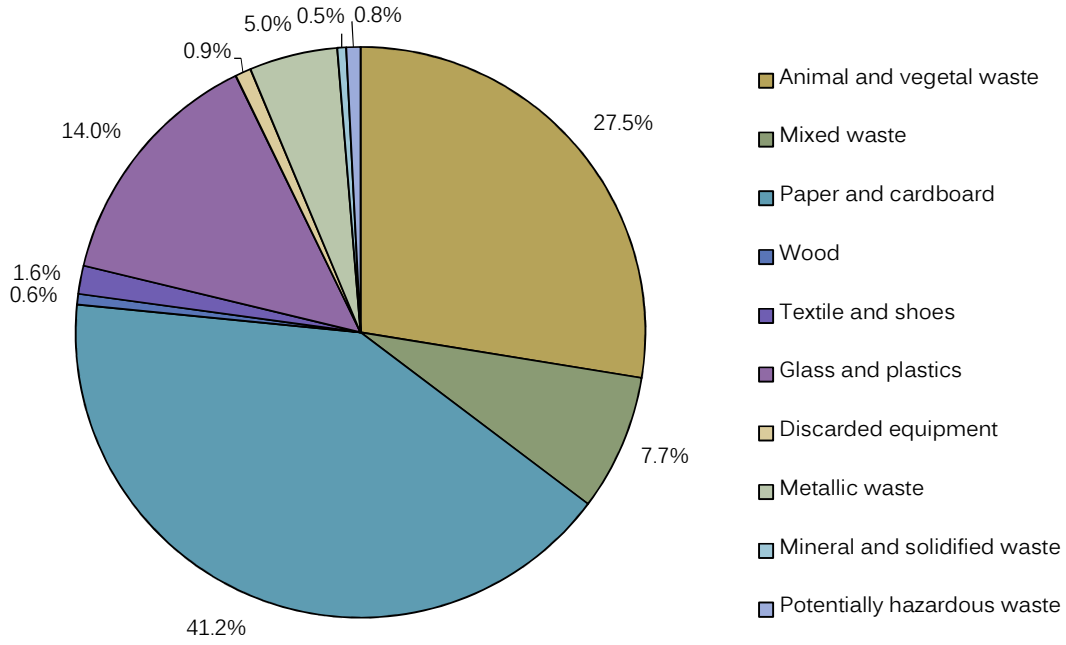

Figure 7: Composition of commercial waste in the UK (2001) [46]

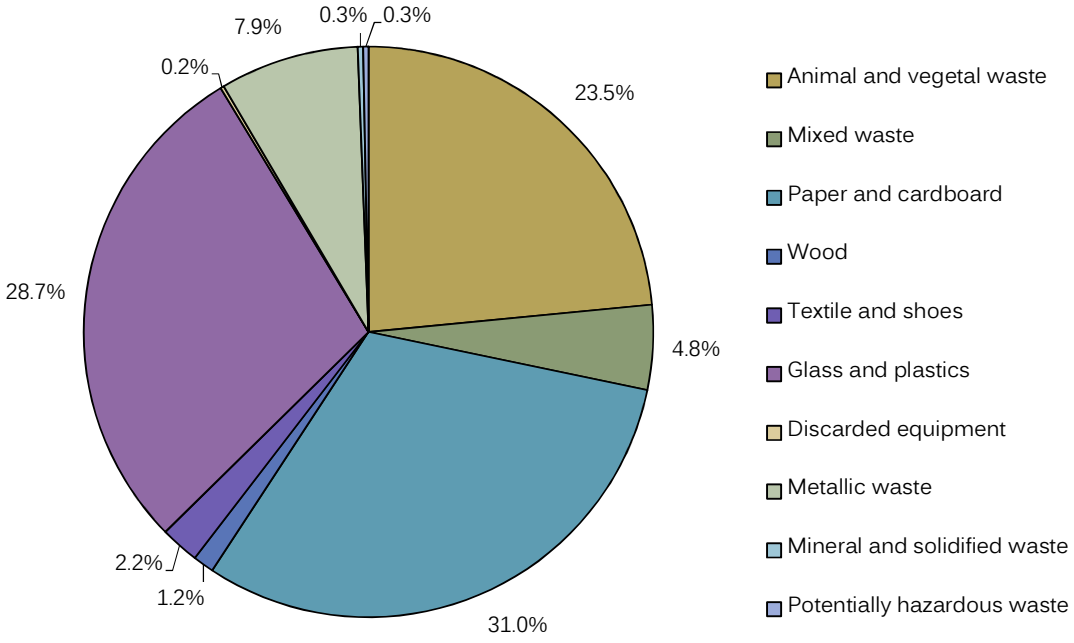

Figure 8: Composition of litter and street sweepings in the UK (2001) [46]

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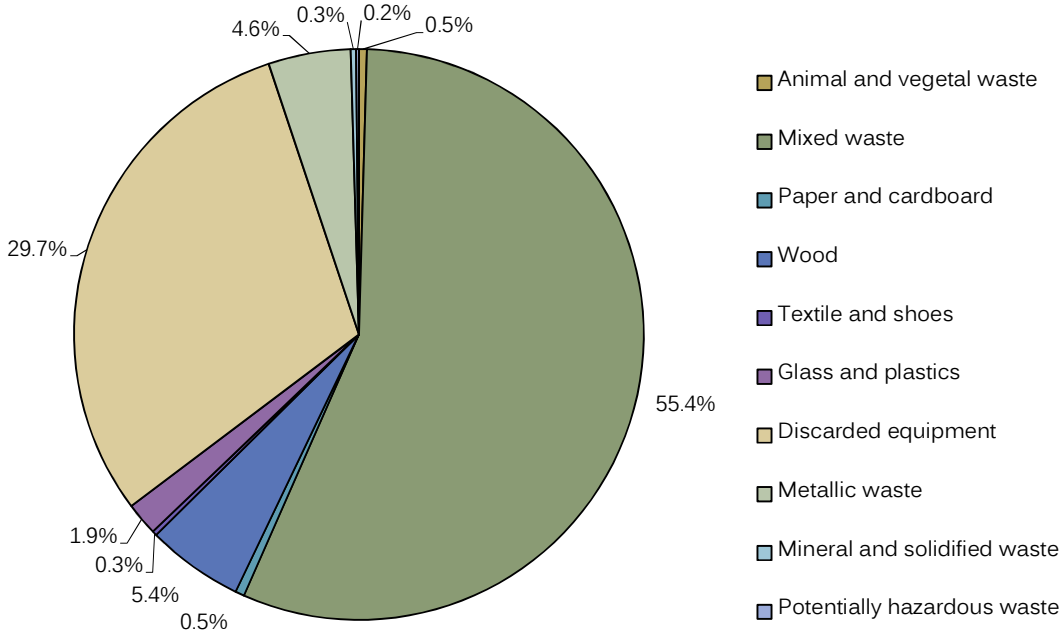

Figure 9: Composition of bulky waste in the UK (2001) [46]

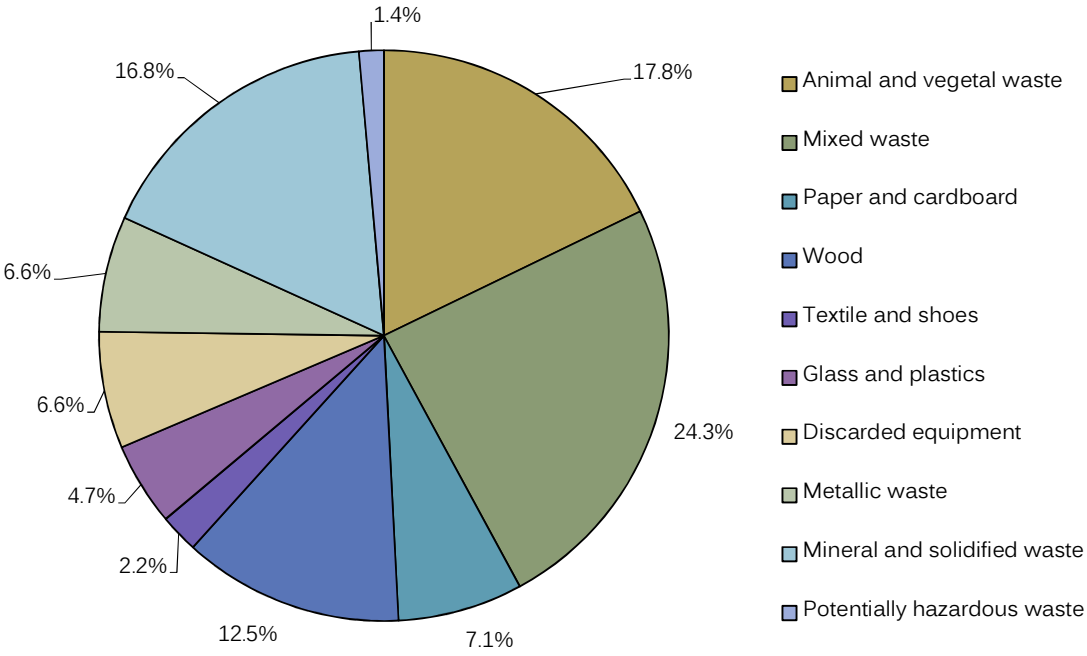

Figure 10: Composition of waste from recycling depots in the UK (2001) [46]

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In conclusion it can be seen that each waste stream contributing to the total MSW varies in composition. Therefore it is important to take each of them into account when investigating of the composition of MSW. However, the composition of MSW and household-collected waste (residual waste) is approximately comparable. If only data on the composition of one of these waste streams is available, the composition of the other stream can be estimated.

In [46] a maximum theoretical recycling and composting rate of 65 % was calculated for the United Kingdom. The biodegradable share of the overall MSW is about 62 %. Of this 62 % the compostable content is approximately 28 %, consisting of animal and vegetal waste (kitchen and garden waste).

Detailed investigations such as the one reviewed above, of MSW are rare. There also exist problems because of the non-systematic and inconsistent procedure of the different surveys. Therefore insufficient information is available to produce robust, comparable national averages [2]. As a result Eurostat data was used to derive an average composition of municipal solid waste and identify general trends across Europe.

Furthermore the composition of MSW is variable. Not all variables that influence the waste generation by households and the disposal patterns can be identified clearly, some known variables which influence the composition of MSW are:

- demography (age structure of the population)
- season
- geography (regional or local conditions)
- waste collection method
- provision and scope of recycling schemes
- legislation, like local policy on the collection of waste, e.g. compostable waste
- lifestyle impacts.

Where possible the authors have attempted to explain how the identified variables influence the generation and composition of MSW. People older than 65 years tend to produce a lower total amount of MSW and less packaging waste. The age group 17 to 44 creates more kitchen waste and people younger than 16 years generate high amounts of nappies and plastic bottles. There are also differences between the life and consumption level of rural and urban areas, with urban areas heavily influenced by the presence of commercial waste, such as waste paper and cardboard. The health and social work sector generates large amounts of nappies and incontinence pads. A large density of hotels and restaurants creates more food waste. In contrast to this home composting is a more common practice in less densely populated (suburban or rural) areas, which leads to a lower amount of collected biodegradable waste. Another example for the influence of local conditions is observed in areas with large tourist industries which are predominantly seasonal. They influence significantly the composition of waste, in particular packaging and food waste. Biowaste is an example of seasonal variation with the amount of garden waste being reduced in the winter months. Last but not least, in spring and summer months a higher percentage of plastic bottles were observed as a result of increased liquid consumption owing to elevated temperatures and in winter months a lower percentage of nappies are disposed [47].

In addition to these varying influence factors random week-to-week variations and systematic variations exist. This variability makes measuring and defining the composition of MSW complicated. Furthermore designations of waste fractions, methodological and systematic approach of waste analysis are not equally carried out in all investigations and countries. That is why as a result of the difficulties outlined above; it is not currently possible to definitively determine the detailed composition of waste for each country. This problem is even more prononunced in the associated countries for which there is a distinct lack of reliable data [40].

On the basis of Eurostat data tendencies for the composition of MSW across Europe were derived. Thereby only some important components of the composition of MSW were examined in detail and split into categories (see Table 4). No data was available for some associated countries of the EU, in this case IE, CH, LI, CZ, RS and BA.

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Table 4: Waste categories of MSW and waste fractions which potentially comprise biodegradable material [40]

Waste fraction	Subgroup	Does the waste fraction contain biodegradable material?
Household and similar waste (mixed waste)	None	Yes, potentially
Animal and vegetal waste	None	Yes, predominantly
Non-metallic recyclables	Paper and cardboard waste	Yes, predominantly
	Textile waste	Yes, potentially, if it contains natural fibre.
	Wood waste	Yes, potentially
	Glass, rubber, plastics and waste containing PCB	No
Metallic Waste	None	No
Discarded equipment	None	No
Mineral and solidified waste	None	No
Chemical and health care waste	None	Yes, potentially But for reasons of animal and public health some parts have to be collected and disposed separately.
Common sludges	None	Yes, potentially

In the following section a summary of data shown in Table 13 of Annex B (Composition of MSW) is given. The waste streams for countries in Central and Northern Europe tend to have shares of about 50 % household and similar waste. Countries in the South and East of Europe tend to have larger shares up to 90 %. Here the recording method for waste statistics is important. If waste is only collected or recorded as mixed household and similar waste in one country, the shares of the individual fractions are not known. The highest rate of individually recorded biowaste is found in countries in Central Europe. They tend to have shares of up to 20 %; in contrast to this the shares in the South and North of Europe vary from 0 to 15 %. Countries in Eastern Europe tend to have lower shares of biowaste with a maximum of 5 %. It is important to note here that this separately recorded biowaste is not the whole amount of biodegradable waste of MSW.

There are also shares of biowaste and biodegradable material located in the category household and similar waste, however owing to the quality of the data available it is not possible to draw reliable conclusions about the biogenic content of household and similar waste. The same applies to the share of non-biodegradable material which is located in the category biowaste and biodegradable waste. However the share of non-biodegradable material, which is erroneously disposed with biowaste, appears to be negligible compared with the total amount of biodegradable waste.

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Countries with high shares of household and similar waste and low shares of biowaste tend to have larger amounts of biodegradable material located in the category household and similar waste [40].

Looking at the share of non-metallic recyclables it can be seen how the individual countries take advantage of the potential for recycling of MSW. Countries in Central and Northern Europe tend to have shares up to 30 % of non-metallic recyclables. In comparison to this the shares in Southern Europe are on the whole much lower and vary widely from 0 % to 20 %. Countries in Eastern Europe tend to have shares with a maximum of 10 % [40].

In summary the composition and reporting on MSW is highly variable between and within countries and is influenced by a variety of parameters. Detailed data on the composition of all individual component waste streams which together make up MSW for individual countries are incredibly rare. The composition of household-collected mixed waste (residual waste) and overall MSW are approximately comparable based on the data sets that are available. Therefore the composition of residual waste can be approximated using the composition of MSW. Unfortunately this is not possible for the whole of Europe as the composition of MSW for some countries in Eastern Europe is not known due to a lack of reliable data.

3.4 Variation of the biodegradable content of MSW

For the determination of the biodegradable content of MSW, Eurostat data was chosen as a basis. Therefore it was necessary to establish those fractions of MSW which include biodegradable materials.
Table **4** in the previous section shows the waste fraction designations according to Eurostat statistics and a comment if it contains biodegradable material or not [40].

In the course of this evaluation Eurostat data on MSW was aggregated and the waste fractions: metallic waste, discarded equipment, waste containing PCB as well as mineral and solidified waste were combined to form the category "waste with low biodegradable potential". These waste categories were combined, as they are of lower interest to the objective of this investigation. In Figure 11 the aggregated data on the amount of waste fractions [t/a] for EU member states and associated countries are shown (for the amount of waste fractions [kg/(capita·year)] see Annex C Figure 16). Data was sorted according to the total amount of MSW per capita. For HR, IS, LI and RS no data was available.

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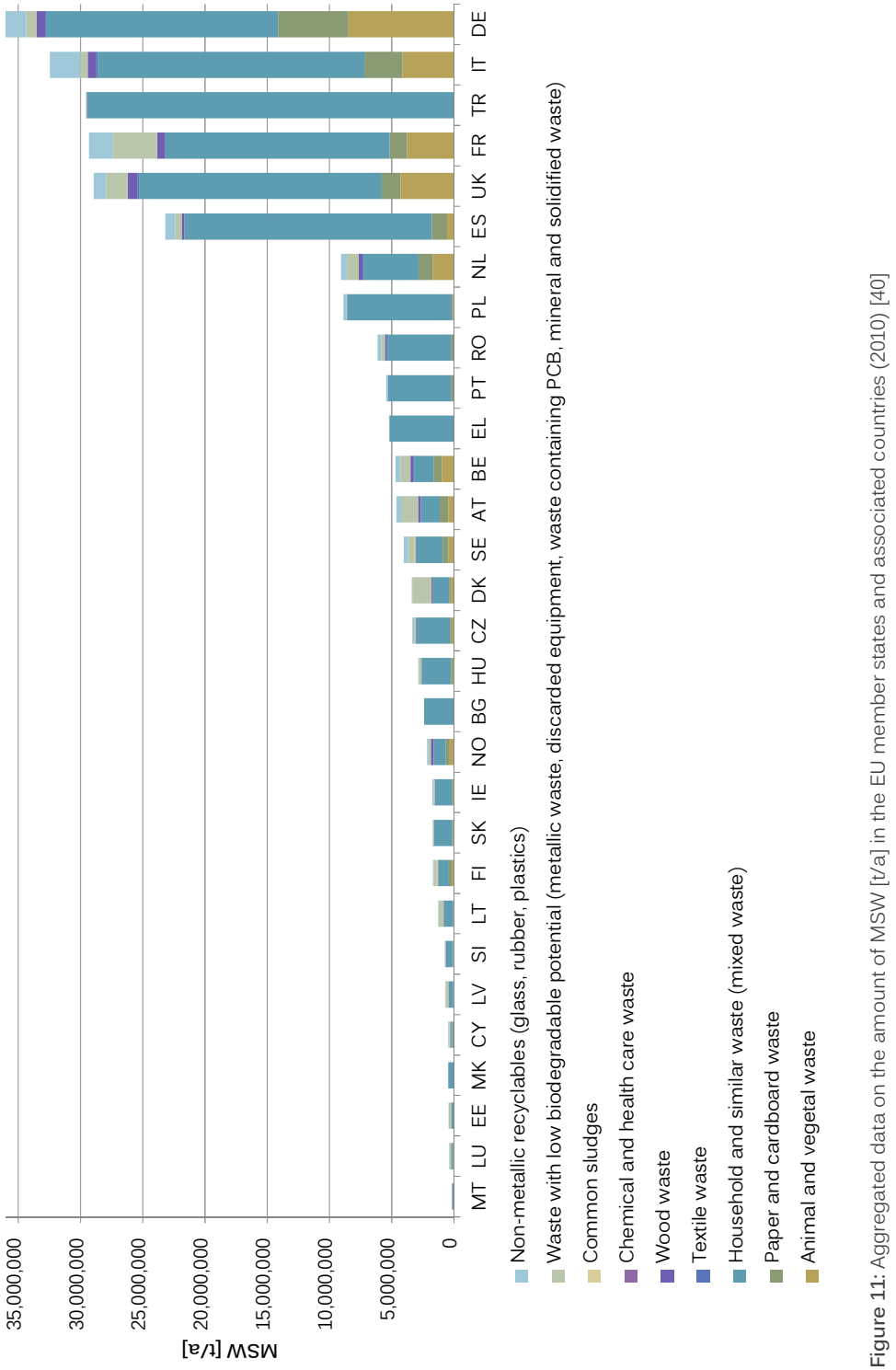

Figure 11: Aggregated data on the amount of MSW [t/a] in the EU member states and associated countries (2010) [40]

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According to Eurostat data [40] the amount of biodegradable material in MSW varies across Europe. Countries with high amounts of paper and cardboard as well as animal and vegetal waste are mainly located in Northern and Central Europe (see Figure 16). In contrast the amount of mixed household waste and thus the amount of potential biodegradable material is relatively high in countries in Eastern and Southern Europe. Therefore it is difficult to provide a clear statement about the amount of biodegradable waste in MSW. Further detailed investigations about the composition of mixed household waste across Europe are required.

There is no specific legal definition provided for biodegradable municipal solid waste. The Directive 1999/31/EC on the landfill of waste [11] defines biodegradable waste as follows:

> "Biodegradable waste means any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard [11]."

In this investigation the same definition was used to evaluate trends of the biodegradable content of MSW across Europe.

There are two fractions of MSW which contain predominantly biodegradable material. These are animal and vegetal waste and paper and cardboard waste. Most European countries have separate collection systems for these waste fractions. Therefore the amount of biodegradable material can be equated to the amount of the separately collected waste streams. Furthermore some fractions of MSW potentially contain biodegradable material. These include household and similar waste, textile waste, wood waste, chemical and health care waste and common sludges. For these waste streams the share of biodegradable material is variable and as a result difficult to quantify.

Mixed municipal solid waste contains a number of mixed waste streams including household waste, bulky waste and street cleaning residues. The content of biodegradable material may vary according to a variety of reasons described in detail in Section 3.3. It is difficult to make a statement on the proportion of biodegradable material of the following substances as some parts may not be biodegradable due to their size, elemental composition or the presence of hazardous substances. Wood waste contains wooden packaging, sawdust, shavings, bark, cork, cuttings and particle board. Textile waste includes worn clothing, leather, textile packaging and composite materials e.g. impregnated textiles as a result it can be concluded that textile waste, contains mainly biodegradable natural fibre as well as some non-biodegradable synthetic fibres. The waste fraction health care and biological waste includes infectious and non-infectious health care wastes. This waste stream contains potentially biodegradable material, but infectious health care waste has to be collected, treated and disposed of separately in order to reduce the risk to animal and public health. Common sludges include sludges from the treatment of public sewage waste water, cesspit contents, unpolluted dredging spoils as well as liquor and digestate from the anaerobic treatment of MSW. Here it should be recalled that the definition of MSW varies across the member states. Therefore different countries include different elements in their definition of MSW. Sewage sludge is one element that many countries do not categorise as MSW [41]. The remaining waste fractions are judged to have low to non-biodegradable potential. These include non-metallic recyclables like glass, rubber and plastics as well as metallic waste, discarded equipment, waste containing PCB and mineral and solidified waste, however there are established recycling routes for many of these materials which could provide an income stream if they can be proactively removed from mixed waste streams.

A study by the European Environment Agency estimates that 30 to 40 % of the total MSW in Europe consists of biodegradable kitchen and garden waste [44]. The study also evaluates the potential of kitchen and garden waste in the MSW for some European countries. Table 5 shows that some countries have a low occurance of kitchen and garden waste in MSW. The proportion of kitchen and garden waste can vary greatly between countries, in part because of variations in the way MSW is defined. It is also influenced by a number of factors such as differences in waste management systems, regional or local conditions as well as social and cultural differences.

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 308363).

Table 5: Percentage of kitchen and garden waste in the total amount of MSW across some European countries [44]

Percentage of kitchen and garden waste in total MSW	Countries
< 20 %	Lithuania, Norway, Slovenia
20 % - 30 %	Bulgaria, Denmark, Ireland, Hungary, Latvia, Switzerland
30 % - 40 %	Germany, France, Italy, Sweden, United Kingdom
40 % - 50 %	Austria, Belgium, Czech Republic, Estonia, Finland, Luxembourg, Netherlands, Poland, Romania, Spain
50 % - 60 %	Greece, Portugal, Slovakia
60 % - 80 %	Malta

Table 6 gives an overview of the existence of separate collection systems for waste fractions with biodegradable content in European countries. In most European countries collection systems were (partly) implemented for the separate collection of waste fractions with biodegradable content. For some countries of Eastern Europe no information was available. The waste fractions textiles and wood are not collected separately in a few countries. As was detailed in section 3.2 it should be considered that not all countries reach 100 % collection coverage although the separate collection system is implemented on a nationwide basis [48, 49].

Based on the information contained in Table 6 it can be assumed that countries, which have not or have only partially implemented separate collection systems for certain waste fractions, contain higher amounts of these waste fractions in the category household and similar waste (mixed waste). In this case it should be noted that even in countries with separate collection systems a significant quantity of waste containing biodegradable material will be collected as mixed waste. Therefore national management options are required to deal with this [48, 49].

In conclusion, the Waste2Go process could be a major contributor to maximising the recovery of materials contained within MSW. For sorted waste, relatively defined streams could be supplied to the process to convert the biogenic material. For mixed waste streams, the waste could be segregated post heat treatment with, streams with low biogenic content such as metals and plastics being diverted to existing recycling processes to maximise their value, the significant remaining biogenic fraction could then be processed using the Waste2Go process rather than going to landfill, anaerobic/aerobic digestion or incineration.

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Table 6: Existence of a separate collection system for waste fractions with biodegradable content in European countries [48, 49]

Country	Separate Collection	Fractions of MSW with biodegradable content collected separately				
		Paper and cardboard	Food waste	Garden waste	Textiles	Wood
AT	✓	✓	✓	✓	✓	✓
BE (Flanders)	✓	✓	✓	✓	✓	✓
BG	N/A	N/A	N/A	N/A	N/A	N/A
CZ	N/A	N/A	N/A	N/A	N/A	N/A
DK	✓	✓	✓	✓	×	×
EE	(✓)	(✓)	(✓)	(✓)	N/A	N/A
FI	✓	✓	✓	✓	✓	✓
FR	✓	✓	✓	✓	✓	✓
DE	✓	✓	✓	✓	✓	✓
EL	✓	✓	×	✓	×	×
IS	N/A	N/A	N/A	N/A	N/A	N/A
IE	✓	✓	✓	✓	✓	×
IT	✓	✓	✓	✓	✓	×
LI	✓	✓	✓	✓	N/A	N/A
LT	✓	✓	✓	✓	N/A	N/A
LU	N/A	N/A	N/A	N/A	N/A	N/A
NL	✓	✓	✓	✓	✓	×
NO	✓	✓	✓	✓	✓	✓
PL	✓	✓	✓	✓	N/A	N/A
PT	✓	✓	✓	✓	✓	✓
RO	(✓)	N/A	N/A	(✓)	N/A	N/A
RS	N/A	N/A	N/A	N/A	N/A	N/A
SK	✓	✓	✓	✓	N/A	N/A
SI	✓	✓	✓	✓	N/A	N/A
ES	✓	✓	✓	✓	×	×
SE	✓	✓	✓	✓	×	×
CH	✓	✓	✓	✓	N/A	N/A
TR	(✓)	(✓)	(✓)	(✓)	N/A	N/A
UK	✓	✓	✓	✓	✓	×

Key

✓ a separate collection for the waste fraction is implemented on a nationwide basis

(✓) a separate collection for the waste fraction is partially implemented or is planned to be implemented according to the National Waste Management Plan

× no separate collection system implemented

N/A no information available

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3.5 Physical and chemical characteristics of MSW

Based on the literature that it was possible to review as part of this study, mainly scientific articles (see section 2.2); the physical and chemical characteristics of MSW were evaluated. Despite a thorough review of the available literature the authors were not able to obtain data for all countries of interest or for all the waste fractions previously identified. As a result it is difficult to extrapolate a robust set of values for the physical and chemical characteristics (e.g. energy potential or moisture content) of MSW. It was possible to determine the lower heating value (LHV) of household waste and ranges for several fractions for some European countries using the available data sets. In case of determining the cellulose content of MSW, only data on biodegradable waste fractions were found. In addition some inhibitors for microorganisms were identified.

The parameters LHV and moisture closely depend on the composition of MSW. On average European MSW has a LHV of about 9 MJ/kg and moisture content in the region of 30 to 40 % ww. Comparing different biodegradable wastes, paper and cardboard have the highest content of cellulose and cellulose like substances with approximately 90 % dw (dry weight). The cellulose content of green waste of about 74 % dw and biowaste has a relatively low 13 % dw. As inhibitors for microorganisms, heavy metals were identified, especially copper and copper alloys.

3.5.1 Energy potential

Table 7 shows the LHV of household waste and the share of waste of biogenic origin (e.g. paper and cardboard waste, garden waste) for the European countries for which data was available, arranged according to the value of LHV. Data on the LHV for unsorted MSW was not available. Values for LHV differ across Europe from 5.1 to 11.6 MJ/kg for household waste [61]. When the available data for European countries was complied and averaged the typical LHV for household waste was in the region of 9 MJ/Kg. Data on the biogenic share of household waste is contained in Table 7, e.g. in the form of organic waste or paper and cardboard waste. The average proportion of thebiogenic source of energy from household waste in Europe is around 60 %.

Plastics and rubber are waste fractions with a high average LHV. The LHV is highly dependent on the composition of the waste fractions. For instance plastic waste comprising polypropylene (PP) or high-density polypropylene (HDPE) has a higher heating value, approximately 49 MJ/kg [55], than plastic waste consisting of polyvinyl chloride (PVC) or polyethylene terephthalate (PET) with a LHV of around 20 MJ/kg [51, 52].

Besides kitchen and plastic waste, the fractions paper and cardboard, wood and textile waste possess high calorific potentials. The average LHV of these wastes is in the region of 12 to 14 MJ/kg (see Table 8).

The waste fractions with the lowest LHV are glass and metallic waste. In both cases the LHV has a negative value. This means that if these waste fractions were disposed in a municipal waste incineration, they would take more energy to burn than would be given out by their combustion. This contrasts with the chemical analysis of glass and metallic waste, which did display a small positive LHV, this is thought to be the result of food remnants or paper labels on cans. The LHV of glass and metallic waste is usually rounded to 0 MJ/kg [42].

The waste fractions kitchen waste and plastics show the highest range of variation, from the data compiled on LHV's. The identified values for the possible minimum and maximum LHV can vary by 32 MJ/kg [42, 53, 55]. The energy potential of waste material results inter alia from its chemical composition, i.e. the content of C, H, O, N and S. As well as the physical composition of MSW, the chemical composition can significantly vary among countries, regions and cities. The physical composition of MSW is usually dependent on the socio-economic conditions of a country, two major factors are demographic distribution and national waste legislation (see section 3.3) [51].

In practice the heating value of waste is determined with a calorimetric bomb [53]. There are also some mathematical models which allow the approximation of the energy content of MSW. The basis of the calculation to determine the

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energy content is the physical, elemental or proximate composition of waste. Most equations correlate the energy content of waste with its elemental composition (e.g. content of carbon, oxygen and hydrogen), usually found in literature [51]. The LHV of a sample of MSW from Greece (see Table 9) was calculated using such a mathematical model.

Table 7: Lower heating value (LHV) and share of biogenic energy of mixed household waste (residual waste) in Europe [45] out of [61]

Country	LVH	Biogenic energy share
	[MJ/kg]	[%]
CH	11.6	58
NO	11.0	64
IE	10.9	58
SE	10.7	75
UK	10.5	63
PT	10.4	50
FI	10.1	55
IT	10.0	59
AT	9.7	49
FR	9.5	59
DE	9.5	67
BE	9.4	53
NL	9.2	70
LU	8.7	58
ES	8.7	62
EL	8.6	62
DK	8.5	65
HU	7.8	45
BG	7.2	48
PL	7.2	54
RO	7.1	52
SK	6.6	51
TR	5.5	68
CZ	5.1	68

Table 8 shows the lower heating value (LHV) of some waste fractions of MSW. Based on the evaluated literature, average LHVs were determined. Table 8 also contains the minimum and maximum LHV with examples for waste materials which was taken from the available literature, this data demonstrates the wide range regarding the LHV of waste.

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Table 8: Lower heating value (LHV) of some waste fractions of MSW

Waste fraction	Subgroup	LHV (lower heating value) [MJ/kg]			Source
		Average	Min.	Max.	
Animal and vegetal waste	Garden waste	12.5	4.8[(1)]	19.6[(2)]	[42, 52, 53, 55, 56, 64]
	Kitchen waste	20.3	5.5[(3)]	38.3[(4)]	[52]
Household and similar waste (mixed waste)	Residual waste	12.0	4.0[(5)]	20.1[(6)]	[42 ,51, 52, 55, 64]
	Fines	6.4	0[(7)]	14.8[(8)]	[52]
Non-metallic recyclables	Paper and cardboard waste	14.8	4.0[(9)]	26.4[(10)]	[42, 51, 52, 53, 55, 56, 59, 64]
	Plastics	32.6	17.4[(11)]	49.4[(12)]	[42, 50, 51, 52, 53, 55]
	Rubber	31.1	25.9[(13)]	42.0[(14)]	[42, 55, 64]
	Glass	0	-0.1[(15)]	0.2[(16)]	[53, 55, 56, 59, 64]
	Wood	14.7	10.5[(17)]	20.0[(18)]	[38, 51]
	Textiles	14.7	10.5[(19)]	18.5[(20)]	[42, 52, 55]
	Leather	15.2	N/A	N/A	[53, 64]
Metallic Waste	No subgroup	0.1	-0.1[(21)]	1.4[(22)]	[38, 42, 52, 55, 56]
Chemical and health care waste	Spent solvents	10.0	N/A	N/A	[52]

Key

N/A no data available

Examples for LHV of different waste materials:

[(1)] grass, plants and shrubs; [(2)] wood, branches and dry garden waste; [(3)] food waste, vegetables and fruit; [(4)] raw and fried fats; [(5)] disposable nappies; [(6)] vacuum cleaner dirt and undefined combustibles; [(7)] unspecified non-combustibles; [(8)] unspecified combustibles; [(9)] kitchen, office and toilet paper; [(10)] liquid and waxed cartons; [(11)] PVC, PET and PU; [(12)] LDPE, HDPE, PS and PP; [(18)] logging residues, deciduous and coniferous wood

[(13)], [(14)], [(15)], [(16)], [(17)], [(19)], [(20)], [(21)], [(22)] not specified

The difficulty in determining physical and chemical characteristics of MSW is the variable composition of its waste fractions (see section 3.3). Therefore it is not possible to specify one value for MSW as a whole. Furthermore physical and chemical characteristics are seldom analysed for a whole country. It is difficult to create a representative sample, because of the variable composition of MSW (see section 3.3).

Figure 12 shows the composition of several samples of MSW. For these samples LHV, moisture, content of combustibles and inerts were analysed. These parameters are set out in Table 9. Comparing the LHV of household waste (
Table 7) and MSW (Table 9) shows that there are only slight differences. Therefore the LHV of household waste can be employed as a basis for the estimation of LHV of MSW.

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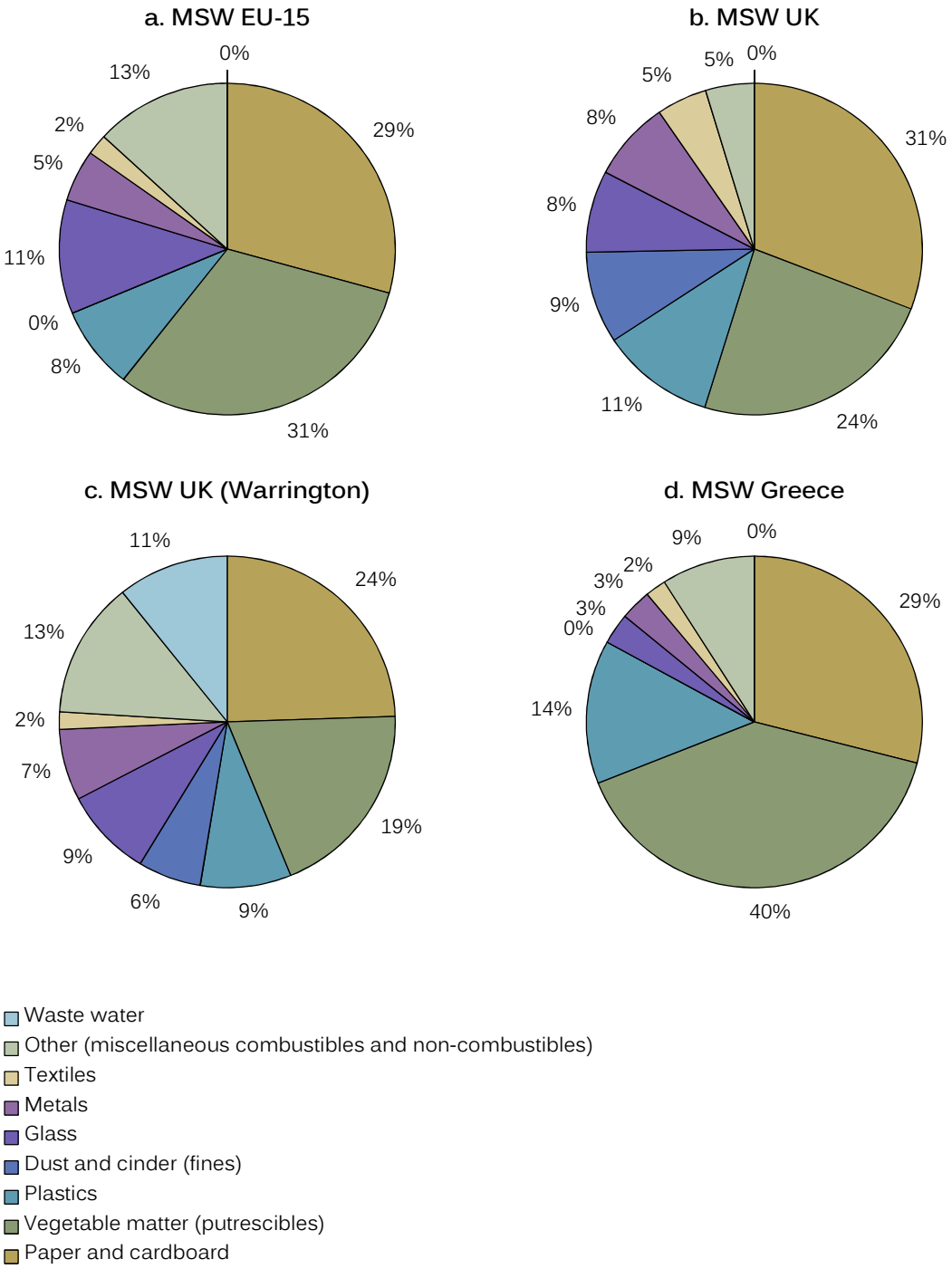

Figure 12: Typical composition of several samples of MSW [42, 52, 53, 59]

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Table 9: Parameters of different MSW samples

Parameter	Unit	MSW EU 15 [42]	MSW UK [59]	MSW UK (Warrington) [52]	MSW Greece [53]
LHV	MJ/kg	8.50	10.60	9.27	9.75*
Moisture	% ww	N/A	31.20	31.56	N/A
Combustibles	% ww	N/A	44.60	43.32	N/A
Inerts	% ww	N/A	24.20	25.12	N/A

* value was calculated on basis of MSW composition

Key

N/A no data available

% ww % wet weight

3.5.2 Moisture content

The moisture content of MSW depends on its composition just like the LHV of waste. Table 10 contains an overview of different waste fractions of MSW and their moisture content. If one compares the LHV and moisture content of waste (Table 8 and Table 10), the waste fractions with a high LHV, e.g. fried fats, have low moisture content. In [52] the moisture content of MSW has been calculated after certain waste fractions have been recycled. If a high percentage of glass and metals is recycled, the relative moisture content of MSW increases as glass and metals are 'dry' waste streams.

As in the case of LHV it is not possible to specify one definitive value for the moisture content of MSW. It closely depends on its composition and therefore various factors, e.g. the existing waste management systems employed (see sections 3.2 and 3.3). Based on the evaluated studies a range of 30 to 40 % ww should be used for guidance as to the moisture content of MSW across Europe [38, 52, 55].

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Table 10: Moisture content of some waste fractions of MSW

Waste fraction	Subgroup	Moisture [% ww]			Source
		Average	Min.	Max.	
Animal and vegetal waste	Garden waste	42	0[1]	75[2]	[51, 52, 53, 57]
	Kitchen waste	52	0[3]	96[4]	[51, 52, 53, 57]
Household and similar waste (mixed waste)	Residual waste	14	3[5]	37[6]	[38, 52, 53, 57]
	Fines	30	N/A	N/A	[56]
Non-metallic recyclables	Paper and cardboard waste	8	0[7]	25[8]	[51, 52, 56, 57]
	Plastics	3	0[9]	15[10]	[42, 51, 52, 53, 56, 57]
	Rubber	1[11]	N/A	N/A	[52, 57]
	Glass	2	2[12]	3[13]	[53, 56, 57]
	Wood	17	8[14]	22[15]	[53, 56, 57]
	Textiles	11	0[16]	25[17]	[53, 57]
	Leather	9	7[18]	10[18]	[57]
Mineral and solidified waste	Ash, rock and dirt	8	N/A	N/A	[57]

Key

N/A no data available

% ww % wet weight

Examples for moisture of different waste materials:

[1] dry grass, dirt, ripe leaves and rotten timber; [2] grass, evergreen shrubs and mixed greens; [3] food waste and fried fats; [4] fruits, vegetables, uncooked meat and cooked pasta; [5] household and vacuum cleaner dirt; [7] glossy paper and waxed cartons; [8] corrugated paper and newsprint; [9] plastic film, e.g. PU and PVC; [10] mixed plastics, e.g. PE and PP; [11] tires; [14] demolition softwood and hardwood waste; [15] wood and bark; [18] leather shoes; [19] leather

[6], [12], [13], [16], [17] not specified

3.5.3 Cellulose Content

The cellulose content of different biodegradable wastes is summarised in Table 11. The authors were unable to locate any studies which assessed the cellulosic content of European MSW as a whole or even data on the cellulosic content of European MSW component fractions. The most applicable data that was obtained was an analysis of Malaysian MSW. According to [60] the organic fraction of MSW contains 17.7 % dw (dry weight) lignin, 47.4 % dw α-cellulose and 6.9 % dw hemicellulose.

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Table 11: Cellulose content of different biodegradable wastes [58]

Waste fraction	Moisture content [% ww]	Cellulose content [% dw TOM]		
		Lignin	Hemicellulose	Cellulose like substances
Green waste	50	29.5	12.9	32
Biowaste	90	1.6	4.3	7.3
Paper and cardboard waste	5	11.4	11	68.4
Mixture for composting (1)	70	14.1	10.8	57.2
Mixture for composting (2)	68	18	8	43.5
Mixture for composting (3)	61	18	12.9	52.5
Mixture for composting (4)	65	19.4	11.1	52.1
Mixture for composting (5)	67	20.1	10.9	40.2
Mixture for composting (6)	64	26.3	18.9	26.6

Key

% ww % wet weight

% dw % dry weight

% TOM % total organic matter

Composition of mixtures for composting

(1) 19 % ww green waste, 58 % ww biowaste, 58 % ww paper and cardboard

(2) 58 % ww green waste, 33 % ww biowaste, 9 % ww paper and cardboard

(3) 37 % ww green waste, 37 % ww biowaste, 26 % ww paper and cardboard

(4) 48 % ww green waste, 35 % ww biowaste, 17 % ww paper and cardboard

(5) 35 % ww green waste, 55 % ww biowaste, 10 % ww paper and cardboard

(6) 67 % ww green waste, 33 % ww biowaste, 0 % ww paper and cardboard

3.5.4 Inhibitors for microorganisms

Inhibitors for microorganisms contained in waste are cited as [54]: heavy metals (e.g. copper, mercury), preservatives (e.g. potassium sorbate, benzoic acid) and high concentrations of salt or penicillin.

Data on the content of heavy metals in different types of wastes are summarised in Table 12. Concentrated copper and copper alloys have a pronounced inhibitory effect on microorganisms [62]. Therefore metal and electronic wastes are the waste fractions with the highest potential content of inhibitors.

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Table 12: Heavy metal content of several types of waste [45, 63]

Country	Type of waste	Heavy metal content [g/t dm]							
		As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
DK	MSW	N/A	7.6	95	N/A	1.2	47	520	520
DK	MSW	3.7	5.7	22	218	1.8	18	930	610
DK	MSW	13.6	6.89	41.8	614	0.6	25.7	373	1020
AT	Mixed household waste	N/A	6.3	N/A	360	1.8	N/A	420	660
AT	MSW	N/A	8	N/A	360	1.3	N/A	600	830
AT	MSW	N/A	11.5	N/A	640	N/A	N/A	430	1300
CH	Mixed household waste	207	11	310	820	4.2	100	530	1300
CH	MSW	4.1	11	360	780	2.9	110	700	1600
DE	MSW	1.4	12	33	678	1.4	29	481	1007
DE	Biowaste	N/A	0.1-1	5-130	8-81	0.01-0.8	6-59	10-183	50-470
DE	Green waste	N/A	0.07-0.65	14.3-24.6	15.5-68.8	0.05-0.18	11.3-17	13.8-30.3	63.5-100

Key

dm dry matter

N/A no data available

3.6 Prices for disposal

Prices for the disposal of waste vary according to the technology used, existing restrictions e.g. on pre-treatment conditions or exhaust air treatment, and any revenues or subsidies for generated energy or products. Between the member states there is a large variance in the costs for treatment and disposal technologies. According to the European Commission no comprehensive analysis has been undertaken to give an overview of the costs of different waste management options at local and national levels for all EU member states. Tendencies within the European Union have been determined on the basis of collected data.

Countries in Eastern Europe on average have lower operating costs for treatment and disposal of waste due to a lower level of technology. Higher demands regarding the recovery of resources and minimisation of emissions into the environment cause higher costs on treatment and disposal [39, 41].

For the costs of collection systems it is not possible to provide more detailed analysis, as the costs for sorting are often included in the costs for collection of the different waste streams. The collection of recyclables e.g. packaging material and plastics tend to have higher operating costs than the collection of other waste streams. Sorting costs for manual processing plants vary depending on the type of waste; there are generally lower costs for paper and cardboard, with higher costs for dry recyclables like plastics, packaging, glass and cans. Composting costs are mainly depending on the technology used ranging from low-tech (open air composting in windrows, with no odour treatment) with ca. 30 €/t [39] compared to high-tech (high specification plants with aeration and odour treatment) with ca. 90 €/t [41]. Costs for digestion vary in a similar manner [39, 41, 42].

Costs for incineration vary mainly depending on the type of technology used, existing flue gas cleaning systems and the treatment of bottom ash. Costs can range from 30 €/t up to 200 €/t [41, 42, 43]. It is difficult to determine an average, because costs for the treatment of flue gas and bottom ash are often not included and revenues are partially included.

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The highest variation of costs for landfilling exist due to operation costs of landfill sites including aftercare and existing restrictions or bans for pre-treatment and sorting of waste streams [39, 41, 42, 43]. In addition to operating costs some countries raised a tax on landfilling (AT, BE, BG, CZ, DK, EE, ES, FI, FR, IE, IT, LV, NL, PL, PT, SE, SI, UK) [39].

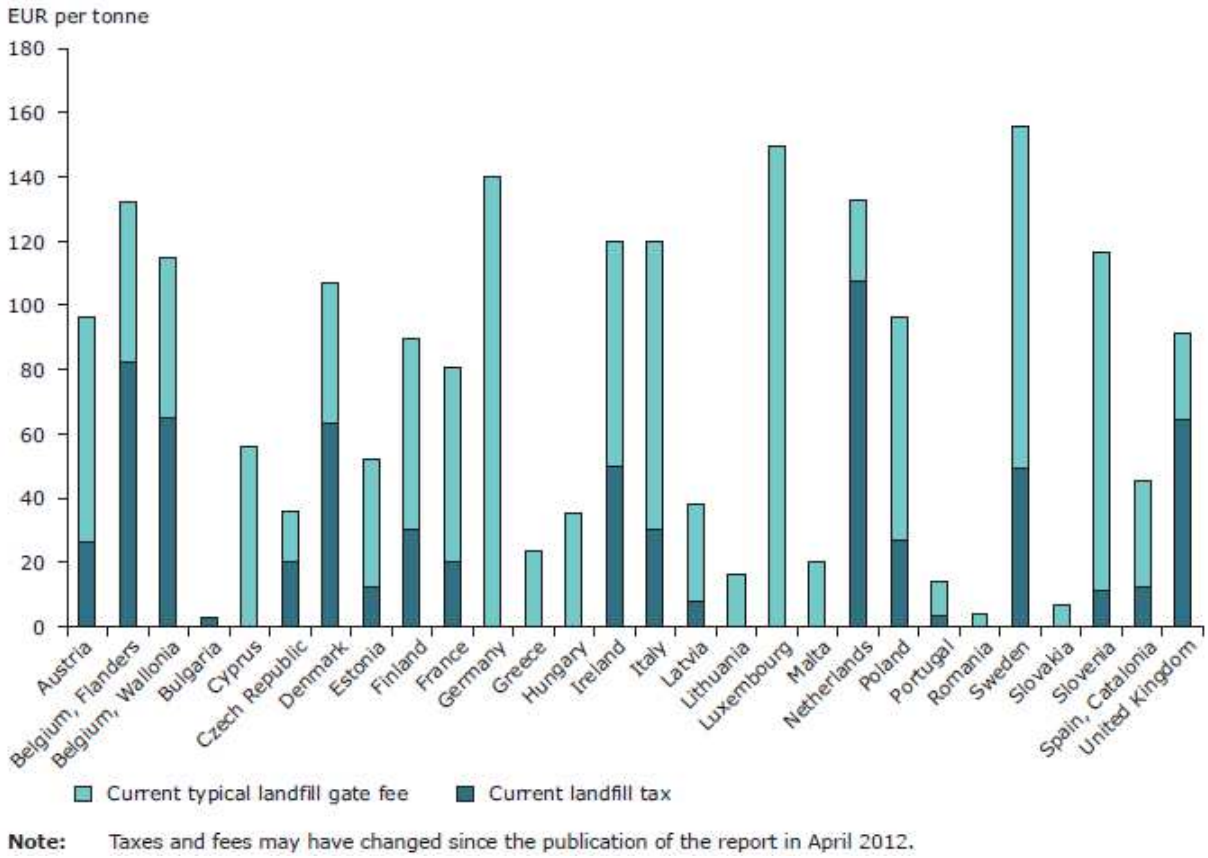

Figure 13: Typical charge (gate fee and landfill tax) for legal landfilling of non-hazardous municipal waste in EU member states and regions [44]

So far prices for disposal can only be estimated. Owing to the factors discussed above there is a tendency to higher costs due to:

- higher level of technology
- the existence of restrictions or bans for final disposal into landfills
- a high level of aftercare and remediation of landfills
- the existence of flue gas treatment systems of incineration plants
- Increased recycling rates, respectively for sorting of co-mingled waste fractions and separate collection of waste streams.

In conclusion, the cost of waste treatment and disposal varies greatly across and within European countries. Landfill costs are largely dependant on local policies regarding the implementation of gate fees and restrictions on waste deposits. As with the earlier sections of this report definitive data is not freely available making it difficult to evaluate the true cost of MSW disposal across Europe. The typical charges that could be determined from the available literature are shown in Figure 13 for the legal landfill of MSW in EU member states and regions.

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4 Summary and Discussion

Desktop research, supplemented by interviews of waste industry representatives, was selected as a viable methodological approach, to identify European waste management systems and compile data on MSW composition. It became apparent very early in the study that 'MSW' is a term with multiple definitions as a result there is a great deal of variation in what is included and excluded as MSW between various studies impacting on the comparability of the various data sets. There is also an overall lack in definitive studies which include the level and quality of information required to give a detailed overview of the European waste industry.

It was decided that questionnaires would not be a viable source of information for this study. Several difficulties arise from data acquisition through questionnaires:

- There must be sufficient responses to obtain comparable data.
- Due to business rivalry operators of waste management facilities tend to treat data as strictly confidential.
- Data can only be validated if comparable data is available from various sources.
- The barrier of language

As described under section 3.2 some countries in Eastern Europe have waste management systems which do not cover the whole country. In this case it is not easy to determine average values for one country. For these reasons and the existing uncertainties concerning data on MSW (e.g. definition of MSW), it was considered to be the right approach to use statistical data.

In order to analyse waste management systems and gather detailed information on MSW (e.g. generation, composition, physical and chemical parameters) of an individual country an in-depth survey is required. To evaluate the detailed composition of residual waste (household waste) of one country a sorting analyses of waste is required. Such analyses are connected with high effort and costs. The last nationwide survey throughout Germany took place in 1983 to 1985 [2]. In course of this investigation such detailed data acquisition was not possible. Thus, standardised data from public statistics seemed to be an appropriate solution to derive tendencies about MSWs composition and waste management practices. Although Eurostat data is partly estimated and extrapolated, it is compiled in a uniform manner and checked for inconsistencies by statistical offices. Eurostat data on household waste is usually determined indirectly, using waste collectors or waste treatment operators as data sources. As the data from Eurostat is checked and validated as far as possible, it was concluded, that this data was plausible and broadly comparable. Due to different units and reference years, a direct comparison of Eurostat data and literature data was not possible.

As described under section 3.3, caution is advised when comparing data on MSW across different countries. There is no clear and precise definition of the term 'municipal solid waste'; it is used in various ways reflecting diverse waste management practices (see section 3.3). In general MSW cannot be compared between different countries, due to the kind of waste collected by different municipalities. Data and information on MSW must therefore be expected to be incomparable by nature [65].

To evaluate the collected data easily, it was recorded in tabular format (see section 2.1.) and aggregated in a useful manner. The data on the generation of MSW was summarised, with waste fractions containing biodegradable material, taking the main focus of the investigation – assessing the biodegradable potential of MSW. The geographical frame of data collection was the EU-27 and associated countries, although HR is part of the EU since 1st July 2013 (see section 2.1). The investigative scope has not been expanded to EU-28 as a rough calculation identifies that the total population of EU-28 is only about 0.8 % higher compared to total population of EU-27 [66]. Therefore it was considered to be accurate to collect data on EU-27 and include HR as associated country in the investigative scope.

Regarding data on chemical and physical parameters of MSW it was necessary to extend the research and analyse scientific journals. Detailed country specific information on MSW is rare. MSW concerning parameters, e.g. LHV and moisture content, vary not only from country to country, but also within one country. Additionally these parameters

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closely depend on the composition of the MSW investigated. As described under section 3.3, the composition of MSW can be influenced by a huge number of variables therefore it is not possible to determine definitive values. Therefore ranges for LHV and moisture of several waste fractions are listed under section 3.5. In case of LHV values for individual materials, e.g. PET or rubber, are generally known and easier to determine, due to a less variable composition [3]. Although average values for LHV, the biogenic energy share and heavy metal content of MSW and cellulose content of different biodegradable wastes are presented in this report, it should be noted that they can be subject to fluctuations.

With regard to the prices for disposal of waste, there were difficulties concerning data collection. It was not always easy to determine if the available data are concerning costs or gate fees. While "gate fee" describes a fee for public service activities which must be paid by the producer of waste for treatment and disposal, "costs" or "prices" cover the resulting costs of waste treatment and disposal. Besides it was not always clear if revenues are included or not. Collected data on the prices for disposal are comparable to a limited extent only. Therefore factors influencing the level of costs were derived at this point (see section 3.6).

Within the screening of evaluated literature in the frame of this investigation the following data gaps were identified:

- lack of general information on waste management systems and data on MSW mainly for associated countries of the EU (e.g. TK, MK, RS, ME)
- insufficient data on MSW for EU member states primarily located in South-East and Eastern Europe
- limited data on detailed composition of household waste (residual waste) of individual countries available
- detailed and comparable data on prices for disposal
- little data and information on content of inhibitors for microorganisms in MSW available
- ranges of LHV and moisture of MSW for individual countries.

Mainly for countries of South-East and Eastern Europe there was limited data on detailed composition of MSW in Eurostat and little public information on waste management systems available. In order to supplement the information available the authors suggest that research in greater depth, e.g. through questionnaires and interviews, to gather more information.

More information can also possibly be found in literature, concerning the detailed composition of household waste (residual waste). Due to the limited time frame of this investigation the literature analysed was limited to reports published by the EC and Eurostat data (see section 2.1.). Additional data was obtained from leading scientific journals, e.g. Waste Management. This approach is deemed sufficient to give an overview of different waste management practices and waste characteristics of MSW of different countries. To gain detailed information for all countries a more thorough literature review would be required. .

A cross-check of Eurostat data and data obtained from the literature was not possible. There was very limited literature information for some European countries and often Eurostat data is used in investigations. It is also difficult to compare data on waste from different surveys, due to (different) underlying research method(s), reference year and units. It was considered that Eurostat data is a reliable data source, because data are collected through national statistical institutes with a common used methodology.

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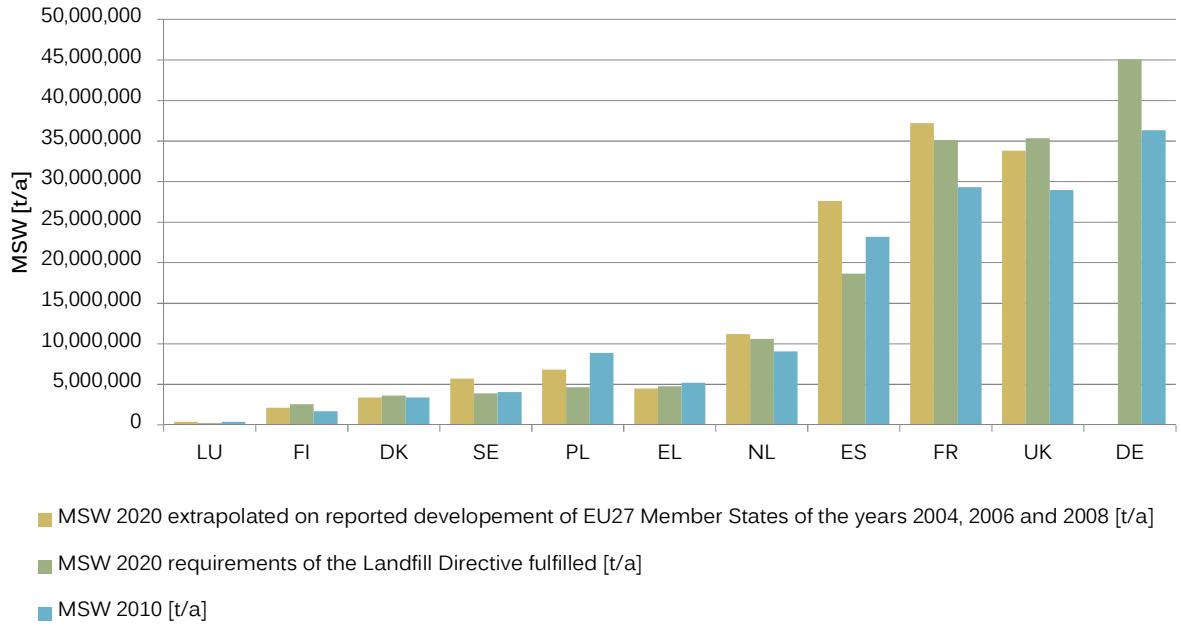
5 Outlook

The results of this investigation show, that there are future requirements for recycling and treatment of MSW. A lack of sufficient treatment capacity already exists, mainly in countries of Eastern Europe (see section 3.2). In future, despite waste avoidance being required by EU-legislation, growing quantities of waste are expected to be generated [38, 42].

Waste generation in the EU has been growing since records began, with a strong correlation between waste generation per capita and Gross Domestic Product (GDP). In Northern and Central Europe no decoupling of waste generation from increasing consumption has taken place. Countries in Southern Europe are anticipated to continue to increase their levels of waste generation until their economic activity has converged with that of Northern European countries. Therefore higher amounts of waste were expected in future [42]. Waste2Go could be an appropriate approach to provide missing waste treatment capacities and tap the full recycling potential of MSW.

Having a closer look on the forecast of generation of MSW (Figure 14), waste generation is anticipated to increase compared to data on 2010 in almost all countries shown in Figure 14. In some countries the amount of MSW decreases in 2020 compared to Eurostat data of 2010. Both forecast calculations for 2020 were taken from studies launched by the EC. It is not possible to draw conclusions why the amount of MSW decreases on comparison to 2010, because references to data sources for extrapolation are not given in these studies.

The amount of MSW calculated has been apportioned equally between all countries, if the requirements of the Landfill Directive were fulfilled [42]. Data from [38] had been extrapolated on data basis of 2004, 2006 and 2008. Origin of data basis is not mentioned in the report.



No data available for DE, generation of MSW extrapolated on reported development

Figure 14: Generation of MSW in 2020 compared with data of 2010 [38, 40, 42]

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In the future change of consumption and packaging patterns will vary the composition of waste in Europe. For example the amount of organic waste has decreased during the last decade due to an increase of packaging material [64]. Future development of waste treatment and disposal facilities should therefore be adapted to changes in the composition of waste.

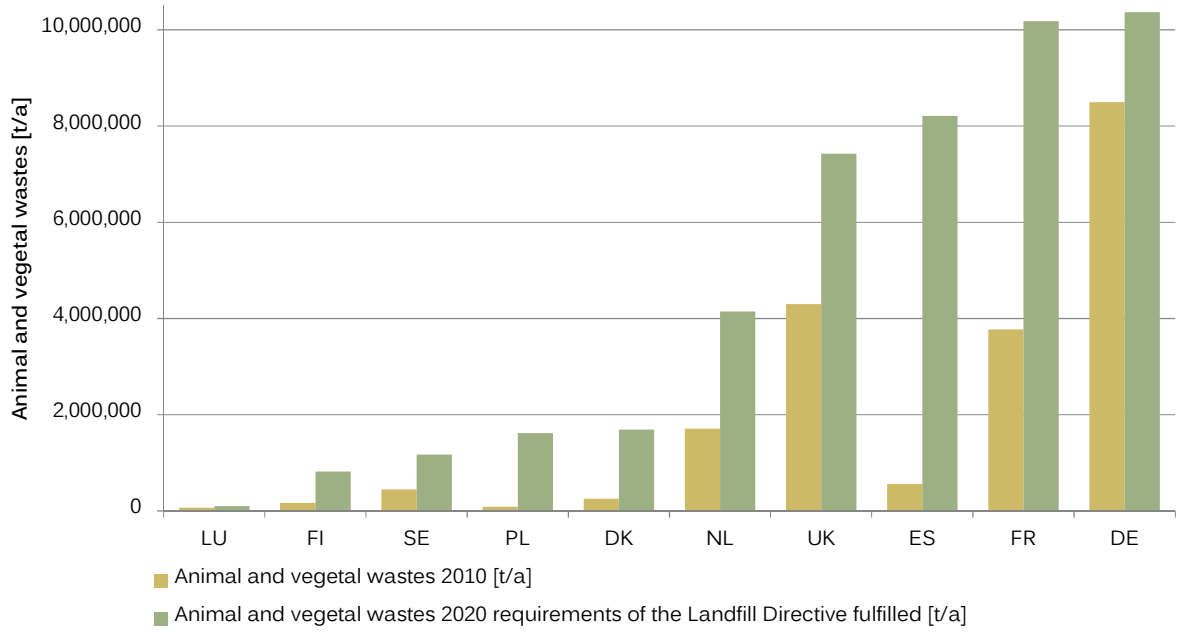

Figure 15: Generation of animal and vegetal wastes 2020 compared with data of 2010 [40, 42]

The amount of animal and vegetal wastes is anticipated to increase until 2020 according to the projection taken from [42] (see Figure 15). Data basis for calculation of data of 2020 is not mentioned in the report. Data of 2010 was taken from Eurostat [40]. Therefore it can only be assumed why the amount in 2020 increases strongly in some countries. The high relative growth of animal and vegetal wastes in ES and PL results probably from development and expansion of a separate collection system.

All in all it became clear in the process of this task that there is a need for research on detailed data on MSW especially regarding the composition of residual waste. Existing data gaps concerning data on MSW mainly for associated countries of the EU should be closed. This report only provides an overview over waste management practices and information on MSW across Europe. If there is a need for detailed information of one country further research is required.

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Annex A

Data collection and processing of Eurostat

Data are collected annual through national statistical institutes or other competent authorities like ministries of the environment. A questionnaire is completed by these institutions. According to Article 3 of the Waste Statistics Regulation (Regulation (EC) No 2150/2002) [8] member states can use four different methods to collect data on waste generation; these include surveys, administrative or other sources, statistical estimation procedures and combinations of the foregoing methods. Although household surveys offer a reliable way to determine the amount of waste generated in households in detail, they are seldom conducted for the evaluation of waste generation. For the determination of the generation of household waste data from waste collectors or waste treatment operators are usually used. Therefore data is partly estimated and extrapolated. Data from administrative or other sources are useful for filling up gaps but not for supplying the core data set. Deficits on data quality result from slight differences in waste classification, besides information required on waste generation is available only for a small proportion of producers of waste. Data collected through statistical estimation procedures can be generated by applying waste factors on waste-related activities [67].

Another method to collect data on waste generation is the estimation via causal models based on visible parameters or an indirect determination through data on waste treatment or waste collection. Examples of waste related data sets, which could be used for statistical estimation procedures, are EU production statistics, waste treatment reports or welfare indicators. Waste treatment reports are the most important data source, but there are problems associated with the use of them. First, there is a practical problem. Waste treatment operators do usually not know from whom they receive the waste and a lot of waste types are non-specific, this means the waste material cannot be assigned to one specific waste fraction. The second problem is theoretical or ideological. The Regulation on Waste Statistics seeks to ensure that data is collected on the two cornerstones of the waste cycle: waste generation and the waste treatment. If one uses the waste treatment as information source, only one aspect will be covered. Therefore the results of the estimation procedure will be entirely consistent, because only limited additional information is available. An independent calculation of the amounts of waste generated and treated will point out differences which reflect real differences (e.g. storage or time lags) and the quality of the estimation method. Thus, the quality of estimations is restricted. A good example for the estimation of waste generation is the calculation of waste generation from the agricultural sector via economic indicators. In this case there is a stable and strong causal relation between waste generation and production [67].

Data can also be calculated through a combination of the foregoing methods. The following problems can arise by combining different methods:

- data sets can be counted double,
- a lack of clarity can arise in the determination of methods and
- differences can occur in level of detail and quantity.

It is also important that data collection on waste treatment differs from data collection on waste generation. First the number of waste treatment operators is much lower than the number of waste generators. Secondly administrative data on waste treatment facilities is better available due to a stricter supervisor regime. But data requirements on waste treatment refer to treatment facilities and not to local units. This means that specific technical information is required which is below the level at which it is usually recorded in business registers. It is impossible to draw an inference from a sample, because most treatment factories are unique with regard to the waste types treated, their capacities and the technology applied [67]. Finally, collected data is processed by statistical offices in accordance with fixed rules like data editing, e.g. identification and correction of errors and inconsistencies, and imputation, e.g. handling of gaps [67].
For drawing up a harmonised waste statistic national quality reports are required. Reporting of data collection and quality is an important step for setting up a quality report on EU level, because every member state is free to choose their methods for data collection. The contents of the quality report and evaluation criteria for waste statistics are laid down in Regulation (EC) No 1445/2005 [67, 68].

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Annex B

Composition of MSW

Table 13: Amount of the individual fractions of MSW in 2010 [40]

Country	MSW total	Household and similar waste (mixed waste)	Animal and vegetal waste	Non-metallic recyclables (1)	Metallic waste	Discarded equipment (2)	Mineral and solidified waste	Chemical and health care waste	Common sludges
EU27	219,570,000	145,710,000	26,070,000	32,860,000	3,180,000	3,600,000	7,680,000	240,000	230,000
AT	4,622,626	1,519,578	464,120	1,277,963	117,400	88,985	1,146,025	8,115	440
BE	4,678,683	1,563,657	964,447	1,342,451	87,728	100,377	593,994	25,987	0
BG	2,396,337	2,396,337	0	0	0	0	0	0	0
CY	461,227	96,533	40,741	246,373	17,088	13,144	46,397	951	0
CZ	3,334,240	2,704,811	172,197	331,249	82,672	1,591	36,708	3,804	1,208
DE	36,311,611	18,638,974	8,494,631	8,353,734	272,139	524,839	0	27,294	0
DK	3,390,029	1,332,053	253,318	222,058	172,936	25,860	1,317,767	63,412	2,617
EE	430,499	178,761	8,116	37,132	167,702	14,488	23,156	377	767
EL	5,222,800	5,178,309	0	0	0	44,491	0	0	0
ES	23,198,185	19,883,975	558,430	2,221,314	56,415	102,295	373,386	2,370	0
FI	1,680,763	862,089	168,474	322,413	9,778	187,700	0	0	130,309
FR	29,306,586	18,042,903	3,771,278	3,924,707	636,131	228,374	2,688,758	14,435	0
HR	0	0	0	0	0	0	0	0	0
HU	2,864,896	2,367,376	103,086	184,905	177,536	27,940	3,949	104	0
IE	1,730,028	1,381,217	123,626	124,114	10,762	81,449	7,505	1,355	0
IS	0	0	0	0	0	0	0	0	0
IT	32,478,921	21,423,512	4,154,330	6,293,352	317,822	269,374	5,185	15,346	0
LI	0	0	0	0	0	0	0	0	0
LT	1,261,402	758,993	4,459	99,151	351,481	32,078	15,229	10	0
LU	385,467	118,697	67,700	46,808	8,421	1,439	141,369	300	733
LV	694,013	393,390	5,745	56,884	0	24,318	201,907	8,221	3,533
MK	451,382	451,382	0	0	0	0	0	0	0
MT	138,099	118,550	3,454	9,401	1,016	5,399	0	279	0
NL	9,071,995	4,435,946	1,707,527	1,975,431	64,349	351,388	519,934	17,420	0

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NO	2,228,608	983,460	334,350	650,305	68,040	125,277	3,005	9,996	0
PL	8,889,685	8,381,246	84,761	399,762	12,474	11,442	0	0	0
PT	5,463,650	5,086,473	15	376,469	1	684	0	7	0
RO	6,127,153	5,226,457	27,618	583,835	33,803	23,237	232,203	0	0
RS	0	0	0	0	0	0	0	0	0
SE	4,038,272	2,159,965	446,940	831,161	172,897	324,335	0	17,948	85,026
SI	727,708	516,545	52,384	92,690	7,615	19,853	32,103	860	5,658
SK	1,719,012	1,458,095	95,567	115,419	10,007	7,254	28,514	442	3,714
TR	29,587,465	29,454,911	556	70,137	5,299	5	20,130	43	36,384
UK	28,948,507	19,493,413	4,298,545	3,389,983	388,539	1,087,485	262,726	27,816	0

(1)Paper and cardboard, glass, rubber, plastics, textiles and wood

(2)Including waste containing PCB

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Annex C

Amount of the individual waste fractions of MSW across Europe

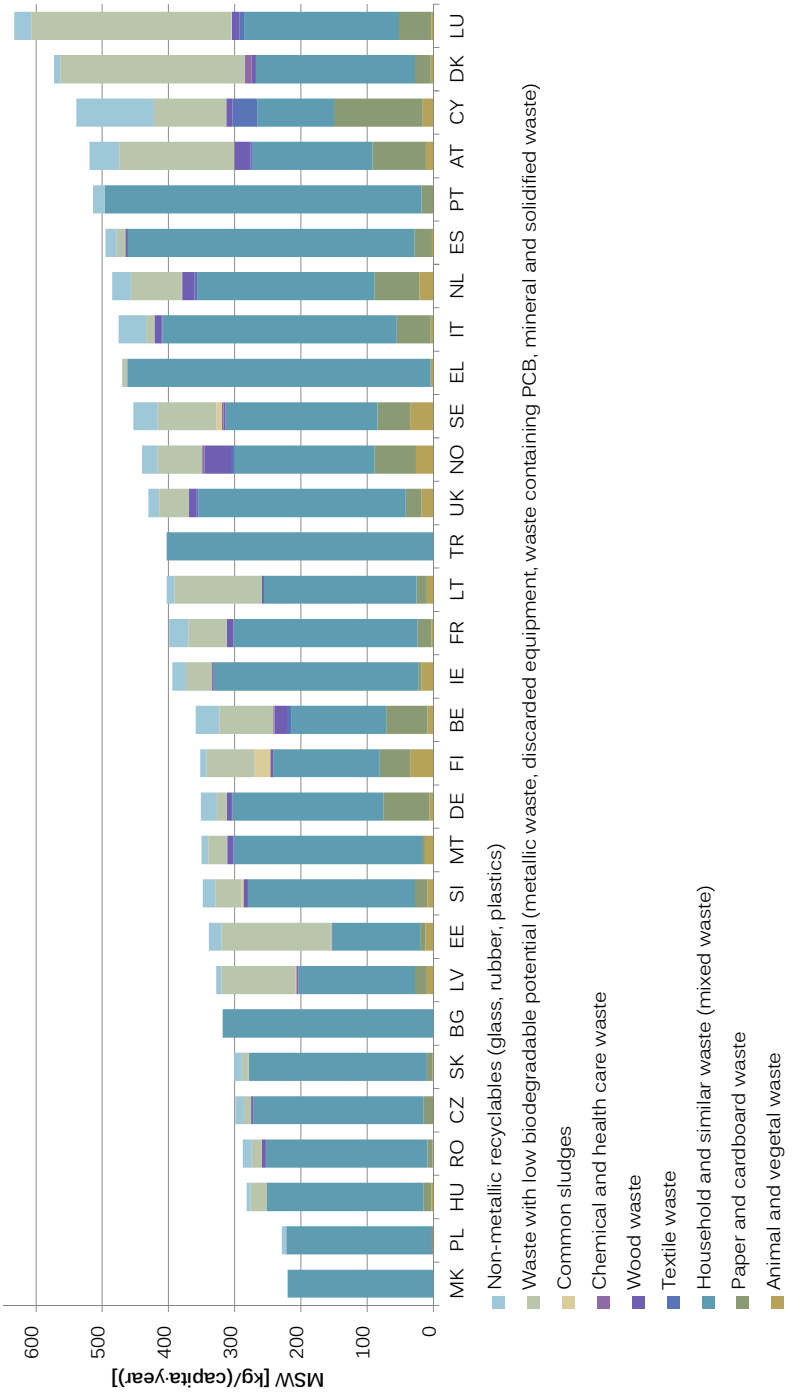

Figure 16: Aggregated data on the amount of MSW [kg/capita·a] in the EU member states and associated countries (2010) [40]

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This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 308363).

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This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 308363).