INNOVATIVE PLASMA BASED TRANSFORMATION
OF FOOD WASTE INTO HIGH VALUE GRAPHITIC
CARBON AND RENEWABLE HYDROGEN

Report about Food Waste Statistics In Europe

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Abstract:

Food waste could be an important source of alternative fuel. Nowadays, increasing population, advanced technologies and limited fossil fuels force authorities to use food waste as an alternative energy and material source. In addition, using food waste as an energy or material source decreases greenhouse gas emissions and demand on landfill. The aim of this report is to provide statistics and information about food waste generation in European Union (EU-28) for an evaluation of the regional and political waste management strategies from across Europe.

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1 SUMMARY

The objective of this investigation undertaken by Fraunhofer Institute for Building Physics (IBP) and Geonardo Environmental Technologies (GEO) within the EU project PlasCarb co-funded by the European Commission within the Seventh Framework Programme was to profile and evaluate regional and political food waste statistics and food waste management strategies and systems. A general overview is given for the conditions in the European Union (EU-28) and a more in-depth investigation was conducted on the five participating countries in PlasCarb (FR, HU, DE, NO and UK). Data was collected for the following issues:

- Food waste management systems (including collection, treatment or disposal).
- Various food waste disposal ways (landfill, anaerobic digestion, composting, incineration).
- Statistics of food waste generation in Europe (manufacturing, household, others).
- Price difference between different food waste management systems.

The geographical scope for this review is the European Union (EU-28). There is a lack of data for Cyprus, Luxemburg, Malta on food waste generation in the manufacturing sector. In addition to that, for Croatia the data of total food waste generation is not yet published (status October 2014). Literature research was chosen as the methodology to employ, in order to create a reliable data set in the given time frame.

The main feature of European waste legislation [1] is the so called Waste Hierarchy (in order of decreasing priority); prevent, reuse, recycle, recover and dispose. Waste management systems of EU-28 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 report details the composition of these component waste streams for EU-28 and explains differences between food waste, organic waste and biodegradable waste. As another result it is to mention that there is no common definition of food waste; e.g. the UKs Waste and Resources Action Programme (WRAP) defines it as all food and drink discarded throughout the entire food chain and has divided it into three types of waste: unavoidable waste, possibly avoidable waste and avoidable waste [2].

In addition, it is important to consider price difference between several food waste management systems. Policy and decision makers are not only interested in best solutions for the environment, they also take economic aspects into consideration. Especially for emerging nations waste management strategies depend on the price of the treatment, which is the reason for high usage rate of landfill.

Results of this investigation show that there are future needs for advanced food waste treatment approaches. The PlasCarb project could be an appropriate approach to provide an advanced technological alternative for the use of food waste fraction.

2 INTRODUCTION

This report undertaken by Fraunhofer Institute for Building Physics (IBP) and Geonardo Environmental Technologies (GEO) is prepared for the PlasCarb project which is supported by European Union 7th Framework Programme. PlasCarb contains 10 Work Packages (WP). This report is made within WP9 (Sustainability) and contains regional and political food waste statistics and food waste management strategies and systems in the European Union (EU-28). This data is expected to be useful for the whole project and especially for WP2 (Biogas Generation). These aspects are in relation to effects of regions within Europe, politics, economy and technology on food waste management. The Report is carried out by literature research combined with internal discussions (with project partners) to reach reliable conclusion for research outcome.

The goal of WP2 is to generate representative biogas from anaerobic digestion (AD) process with a feedstock rate of 1,800 tons mixed food waste, noting seasonal CH_4:CO_2 variations and impurity level versus seasonal input variations over a 12 month period. In this WP food waste will be obtained by GAP Waste Management Ltd. (GAP) and supplied to the AD unit from different sources and locations:

- Industrial food processing operations
- Catering operating
- Domestic food waste collections undertaken on behalf of municipalities covering different socio – economic areas

In the following paragraphs statistics concerning food waste generation and management strategies in general for the European Union (EU-28) and detailed for FR, HU, DE, NO and UK from different sectors will be explained. Food waste is produced from various sources. The main sectors that produce food waste are households, manufacturing, retail and wholesale. Therefore food waste generation, disposal options, price difference between several food waste management systems and causes of food waste generation will be investigated.

3 METHODOLOGY

Literature research was chosen for the entire study to analyse reports and directives published by the European Commission (EC) for the general overview on EU-28 level as well as country specific literature (regulations, technical and scientific reports) for the five national reports.

3.1 Investigation on EU-28 level

Regarding the general EU overview, literature sources include Eurostat statistics and reports from and commissioned by the EC and EU-28 as presented in Table 1. The most recent data from Eurostat about waste generation in EU-28 is from 2006 until 2011.

Table 1: List of literature and sources for the general report on EU-28 level

Title of the literature	Source of the literature	Date	Reference
Counting the cost of food waste: EU-28 food waste prevention, 10th report of session.	European Union Committee, London.	2014	[2]
Draft report on the commission green paper on the management of bio waste in the European Union.	European Parliament Committee on the environment, public health and food safety.	2010	[5]
Directive 1999/31/EC.	European Parliament and European Council.	1999	[3]
Directive 2008/98/EC.	European Parliament and European Council.	2008	[1]
Inventory of existing studies applying life cycle thinking to bio waste management.	JRC scientific and technical report.	2008	[6]
Preparatory study on food waste across EU-27.	European Commission.	2010	[7]
Supporting environmentally sound decisions for bio waste management, A practical guide to life cycle thinking (LCT) and life cycle assessment (LCA).	JRC scientific and technical report.	2011	[4]
Development of a Modelling Tool on Waste Generation and Management.	Eunomia Research & Consulting.	2014	[8]
Cost for Municipal waste Management in the EU.	Eunomia Research & Consulting.	2001	[10]

The reason for the use of the Eurostat data is:

- Data quality
- Consistency
- Actuality
- Availability
- Comparability

The advantages of reports by the European Commission are named as follows:

- Reliable data source
- Sufficient data availability

The disadvantage of using just European Commission reports is the missing comparison between different data sources. Scientific articles were complementary evaluated for detailed information on food waste. For the overview of waste legislation relevant legal texts were sighted and summarized. The geographical scope for data collection as part of this review is the European Union (EU-28).

Food waste/loss/damage/spillage/spoilage results within the whole food value chain, e.g.

- Agricultural production
- Post-harvest handling and storage
- Manufacturing
- Retail/wholesale
- Consumers
- By several reasons, among others:
- Crop not fully harvested
- Pests/infestation
- Process losses
- Date expiry [2].

Food waste can be defined as avoidable (e.g. left overs on a plate), partly avoidable (depends on the personal habits of the consumer, e.g. skin of an apple) and not avoidable fractions (e.g. bones).

In order to have clear(er) opinion on waste types it is important to define the differences between food waste, organic waste, biodegradable waste and bio waste.

- Food waste: Food waste or food loss is food that is discarded or cannot be used.
- Organic waste: Organic waste is anything that comes from plants or animals that is biodegradable.
- Biodegradable waste: Biodegradable waste is defined as ”any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard” [3].

- Bio-waste: biodegradable garden and park waste, biodegradable food and kitchen waste from households, restaurants, caterers and retail premises and biodegradable comparable waste from food processing plants" [1], [4].

Biodegradable waste is a broader term than bio waste, as it does not only focus on waste from households and other streams that are supposed to produce similar waste, but also on other industrial streams. Indeed, as mentioned in the Green Paper [5] "it does not include forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste such as natural textiles, paper or processed wood".

It is important to identify waste disposal methods in order to find feasible solutions between theoretical best options and practical best options and also review usage percentage of each method in EU-28. For example, landfill requires less advanced technology and supervision. But on the other hand it is not environmentally the best option. Available waste disposal methods are named and shortly explained as follows:

- Landfill: This method releases greenhouse gas (GHG) emissions, e.g. CO_2 and methane. Methane can be collected and combusted for energy production [6].
- Anaerobic digestion (AD): This process aims at the production of methane for electricity, heat production or the production of synfuels. It is especially suitable for wet organic matter such as kitchen waste [6].
- Composting: It can be divided into two major methods, namely open and closed methods. Open methods release the greenhouse gas methane in large amounts into open air, while closed vessel methods make it possible to collect the methane for combustion [6].
- Incineration: Depending on the type and efficiency, incineration of bio waste can generate electricity and/or heat which will thereby avoid energy production from other resources [6].
- Gasification: This process aims at the production of energy and synfuels. Also it is based on heat treatment and is most commonly utilized to produce CO that can be turned into synfuels [6].
- Recycling: According to the Waste Framework Directive it means any recovery operation of waste into products, materials or substances and is thus most often applied to waste streams which are not entirely from organic origin [1]. In regards to organic- or food waste recycling means frequently the application as animal fodder.

The most commonly used treatment (as mass percentage) option for bio waste in Europe is still landfill, although the landfill directive suggests the diversion of waste from landfill. This is the case in many newer member states like Poland, Slovenia, Estonia, Cyprus and Hungary, but also in the "older" ones like United Kingdom, Ireland, Spain and Greece. Table 2 gives more details of the treatment options within different countries in Europe [6].

Also as noted from Table 2 for some countries like Luxembourg, The Netherlands, Belgium and Austria, biological treatment is the main treatment option. Within the different biological treatment options for biodegradable waste composting is the most commonly used option [6].

Table 2: Different bio waste treatment options in EU in 2008 [6].

Country	**Landfill [%]**[****]	**Incineration [%]**	**Biological treatment [%]**[*****]
Austria[**]	18	26	56
Belgium[**]	16	40	44
Cyprus[***]	100	0	0
Denmark[**]	2	70	28

Table 2: Different bio waste treatment options in EU in 2008 [6], continued

Estonia***	100	0	0
Finland**	70	23	7
France**	37	48	15
Germany**	25	50	25
Greece**	89	10	1
Hungary***	91~	9	0
Ireland*	96	0	4
Italy**	69	22	9
Luxembourg**	7	52	41
Netherlands**	12	44	44
Poland***	97	0	3
Portugal*	61~	24	15
Slovenia***	98	0	2
Spain**	81	8	11
Sweden*	36~	43	21
UK**	96	0	4

Situation in 2004, management of food and green waste

** **Bio waste landfilled (extrapolated from bio waste produced in 1995)**

*** **Data on new member states, 2002**

**** **Landfill including landfill after MBT**

***** **Biological treatment includes composting and anaerobic digestion**

~ **Number has slightly been adapted to retrieve 100% total**

3.2 Investigation on national level

National reports were conducted for the five countries France, Hungary, Germany, Norway and the United Kingdom. Out of those, all countries are EU Member States with the exception of Norway; thus the national reports will not always comply entirely with the above mentioned definitions of waste types. However, the national reports attempt to align as much as possible to the methodology in section 3.1 in order to achieve comparable results on all investigation levels applied in this report.

The chosen methodology is literature- and desktop research, opening the opportunity to scrutinize national databases as well as technical, scientific and regulative documents. The aim of this methodology is to represent those national results on food waste generation and treatment which are most widely validated in the relevant national resources and from relevant national experts.

It can thus be the case that figures at national level do not entirely correspond to the respective figures from the investigation on EU level. National level data might be more up-to-date and more detailed compared to those reported by the relevant resources (e.g. EUROSTAT, BIOIS) on EU level.

4 RESULTS

4.1 Food Waste statistics on EU level

4.1.1 Food Waste Generation

Table 3: Total food waste generation [t] in EU-27 in 2006 [7].

	Manufacturing	Households	Other sectors	Total
EU27	34 755 711	37 701 761	16 820 000	89 277 472
Austria	570 544	784 570	502 000	1 858 000
Belgium	2 311 847	934 760	945 000	4 192 000
Bulgaria	358 687	288 315	27 000	674 000
Cyprus	186 917	47 819	21 000	256 000
Czech Republic	361 813	254 124	113 000	729 000
Denmark	101 646	494 914	45 000	642 000
Estonia	237 257	82 236	36 000	355 000
Finland	590 442	214 796	208 000	1 013 000
France	626 000	6 322 944	2 129 000	9 078 000
Germany	1 848 881	7 676 471	862 000	10 387 000
Greece	73 081	412 758	2 000	488 000
Hungary	1 157 419	394 952	306 000	1 858 000
Ireland	465 945	292 326	293 000	1 051 000
Italy	5 662 838	2 706 793	408 000	8 778 000
Latvia	125 635	78 983	11 000	216 000
Lithuania	222 205	111 160	248 000	581 000
Luxembourg	2 665	62 538	31 000	97 000
Malta	271	22 115	3 000	25 000
Netherlands	6 412 330	1 837 599	1 206 000	9 456 000
Poland	6 566 060	2 049 844	356 000	8 972 000
Portugal	632 395	385 063	374 000	1 391 000
Romania	487 751	696 794	1 089 000	2 274 000
Slovakia	347 773	135 854	105 000	589 000
Slovenia	42 072	72 481	65 000	179 000
Spain	2 170 910	2 136 551	3 388 000	7 696 000
Sweden	601 327	905 000	547 000	2 053 000
United Kingdom	2 591 000	8 300 000	3 500 000	14 391 000

Most of the data in this section is based on EU-28 food waste study. Furthermore, the estimation by the European Commission is based on a significant element of extrapolation for the retail/wholesale and food service/hospitality sectors in particular [2]. The overall estimates suggest that household food waste contributes the highest proportion, with the food and drink manufacturing sector accounting for most of the remainder as you can see in Table 3 and Figure 1. Also in the manufacturing sector some food waste is largely unavoidable (parings, kernels, bones, carcasses and certain organs of meat products). Other sectors with almost 17 Mt food waste are wholesale/retail sector and food service sector. The manufacturing sector includes the production sector involved in the processing and preparation of food products for distribution [7].

The following Figure 1 shows exemplarily the food waste production in weight percentage by the sectors food/drink manufacturing, household, retail/wholesale and food service/hospitality in EU-27.

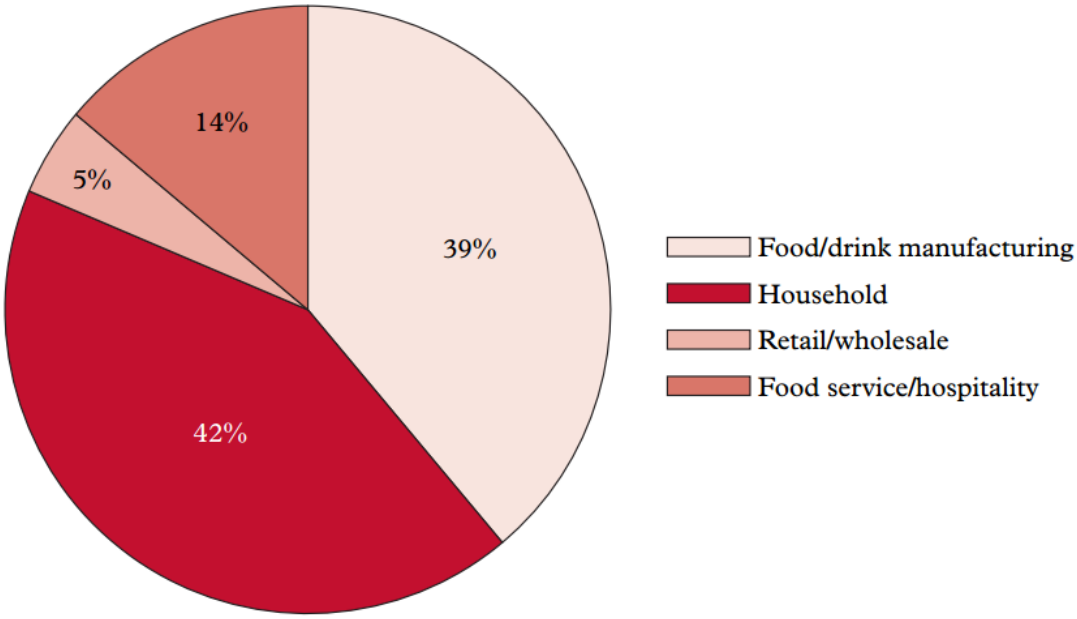

Figure 1: Food waste weight percentage [%] by sector in EU-27 [2].

The household sector was estimated at 42 % (38 Mt) of the total amount of food waste produced. Hence it is the sector with the largest fraction of EU food waste and therefore accounts for an average of about 76kg per European capita. The manufacturing food waste sector produced almost 35 Mt per year in the EU, which amounts in an average of about 70 kg per capita. This estimate however has to be considered as fragile, as there is no clear definition of food waste (particularly as distinct from by-products) among Member States [7].

Due to a limited number of sources, the retail and food service sectors rely even more on extrapolations. According to the estimate, the retail/wholesale sector represents around 4.4 Mt for the EU-27 and close to 8 kg per capita with differences among member states due to economic and technological difference.

The food sector was estimated at about 25kg per capita for EU-27 and at 12.3 Mt for the EU-27 overall. There is a significant gap between EU-15 with 28 kg per capita and 12 kg per capita in EU-12. This is mostly because of a higher trend of food waste in the restaurant and catering sector [7].

Discarded food from households adds up to represent 25 % of food purchased (by weight), according to studies completed by WRAP. Converting the avoidable portion of this food waste into an annual loss, means for the UK, a total annual loss per household of approximately £ 480 or 565 € [2], [7].

With regards to the quantification of EUROSTAT data, important limitations accompany this work as the technical report on food waste across EU-27 [7] mostly represents estimates of national food waste data. Furthermore data submitted to EUROSTAT differs according to their methodologies used from the different Member States (MS) for collecting and calculating the food waste data as MS are free to choose their own methodology. Especially in Eastern Europe, uncertain methodologies chosen for investigating the data may result in less precise data in details. Implications may involve the inclusion of by-products, green waste or tobacco in the data disclosed in some instances. This all may result in variable reliability of EUROSTAT and national data [7].

Table 4: Food waste generation in the manufacturing sector, total [t] and percentage [%] wasted per capita, and waste during food production among EU countries in 2006 [7].

	Food production in tonnes EUROSTAT 2006	FW in Manufacturing sector tonnes (EUROSTAT 2006)	WRAP Manufacturing sector FW tonnes	Population EUROSTAT 2006	FW per capita EUROSTAT	% of food wasted with EUROSTAT data	% of food wasted with WRAP data
EU-27	766 179 686	37 307 575		493 194 250	76	**5**	
Austria	9 914 359	570 544		8 254 298	69	**6**	
Belgium	27 470 839	2 311 847		10 511 382	220	**8**	
Bulgaria	4 849 152	358 687		7 718 750	46	**7**	
Cyprus	0	186 917		766 414	244		
Czech Republic	13 034 071	361 813		10 251 079	35	**3**	
Denmark	9 103 122	101 646		5 427 459	19	**1**	
Estonia	1 143 852	237 257		1 344 684	176	**21**	
Finland	9 845 332	590 442		5 255 580	112	**6**	
France	106 199 337	626 000		63 229 443	10	**1**	
Germany	138 078 334	1 848 881		82 437 995	22	**1**	
Greece	6 170 557	73 081		11 125 179	7	**1**	
Hungary	11 702 284	1 157 419		10 076 581	115	**10**	
Ireland	5 382 309	465 945		4 209 019	111	**9**	
Italy	97 088 841	5 662 838		58 751 711	96	**6**	
Latvia	1 606 037	125 635		2 294 590	55	**8**	
Lituania	4 020 685	222 205		3 403 284	65	**6**	
Luxemburg	0	2 665		469 086	6		
Malta	0	271		405 006	1		
Netherlands	50 834 267	6 412 330		16 334 210	393	**13**	
Poland	47 233 940	6 566 060		38 157 055	172	**14**	
Portugal	12 496 826	632 395		10 569 592	60	**5**	
Romania	10 845 823	487 751		21 610 213	23	**4**	
Slovakia	3 841 080	347 773		5 389 180	65	**9**	
Slovenia	1 176 515	42 072		2 003 358	21	**4**	
Spain	101 939 483	2 170 910		43 758 250	50	**2**	
Sweden	5 197 871	601 327		9 047 752	66	**12**	
United Kingdom	87 004 770	5 142 864	2 591 000	60 393 100	85	**6**	3

Table 4 quantifies the food waste in the European manufacturing sector. Three Member states, with particularly small populations Cyprus, Luxembourg and Malta, lack data [7]. New participant Croatia was not part of the EU in 2006. So that is the reason why Croatia is not shown in the table.

Based on Table 3, food waste of the manufacturing sector is 76 kg per capita. Per capita ratios were also calculated at national level, ranging from 393 kg per capita in the Netherlands to 7 kg per capita in Greece. This high heterogeneity could be consistent with the geographic repartition, economic and technological difference of the EU food industry, which is highly concentrated in certain countries, such as the Netherlands, and less in others, such as Greece [7].

4.1.2 Food Waste Disposal Options

There are different methods in which biodegradable waste is currently being treated. These options are landfill, composting, incineration, AD and gasification. As it is mentioned in the section methodology, biodegradable waste, organic waste and food waste definitions could be quite similar. Hence, Table 5 lists characteristics of organic waste management options to be applied to food waste, too.

Table 5: Characterized organic waste disposal methods, in accordance with [6].

Treatment methods	Characterization within the process	Advantages	Disadvantages
Landfill	With or without methane recovery, legal and illegal dumping	Cheap Simple Equipment	Odour Greenhouse gas emissions
Composting	Open and closed types, central and home composting	Material recycle	Require supervision
Incineration	With and without energy/heat recovery, efficiency of the recovery	Energy recovery Saves space	Expensive Require supervision
AD	Pre-treatment and post-treatment of organic matter	Material recycle Energy recovery	Require supervision
Gasification	Burning for energy recovery	Energy recovery	Effective only with dry streams

For each of these treatment methods there are a number of factors influencing the environmental performance, as presented on Table 6.

Table 6: Number of local factors affecting the environmental impact of methods, in accordance to [6]

Local Factors	Description
Energy recovery and recycling efficiency	Methods, e.g. landfill that utilizes methane for energy production, have a lower environmental impact than those not utilizeing methane.

Table 6: Number of local factors affecting the environmental impact of methods, in accordance to [6], continued

Waste composting / contamination	For food waste a separate collection is necessary in order to get a clean organic fraction. Otherwise it will affect the efficiency of the processes.
Availability of treatment facilities	This depends on the economic and technologic status of the country.
Distance from storage to treatment facility	It is important to have closer facility to source of the waste
Transportation means (truck, train, inland vessel)	Different type of transportation uses different amount and type of fuel.

4.1.3 Causes of Food Waste

Table 7 lists the key causes of food waste and the sectors they impact. Sources of food waste exist at all process stages between farm and fork. Among the four sectors (manufacturing, wholesale/retail, food service and household) investigated, household waste has been most fully analysed in the viewed literature [7].

Causes of food waste e.g. in households and commercial businesses involve: portion size, labelling, packaging and storage issues on the one hand, and awareness, preferences, planning and socio-economic factors on the other. These causes invite two groups of prevention strategies, those that implicate producers and retailers in helping prevent household food waste, by incentivizing the creation and promotion of waste resistant products, and those targeting consumers through educational tools and campaigns.

Table 7: Key causes of food waste and impacted factors [7]

	Manufacturing & Processing	**Wholesale % Retail**		**Food Service and Restaurants**			**Households**
		Distribution & Wholesale	**Retail**	**Hospitality Industry**	**Schools**	**Hospitals**	
Awareness					X	X	X
Knowledge			X		X	X	X
Attitudes					X		X
Preferences					X	X	X
Portion size			X		X	X	X
Planning					X	X	X
Storage		X					X

Table 7: Key causes of food waste and impacted factors [7], continued

Socio-economic factors							X
Labelling			X				X
Packaging	X	X	X				X
Handling		X	X				
Stock management		X	X				
Logistics	X			X	X	X	
Product quality requirements	X		X				
Technical malfunctions	X						

Causes of food waste vary between different sectors as you can see on Table . In the manufacturing and processing industry the logistic, product quality requirements (PQR) and technical malfunctions are the main key causes, but these are not important issues in wholesale/retail (except PQR), food service and restaurants (except logistic) and household.

Wholesale/retail is subdivided in two different classes. They are distribution & wholesale and retail. Distribution & wholesale focuses on storage, packaging, handling and stock management. In addition to that, retails also focuses on knowledge, portion size and PQR.

Food service and restaurants are similar to household in terms of awareness, knowledge, and portion size and also planning. So impact factors differ on preferences in hospitality industry and attitudes on hospitals. Also all food service and restaurants include logistics as key parameter.

These key causes are important to define sources of waste and in order to generate less amount food waste in all different sectors.

4.1.4 Price Difference between different Food Waste Management Systems

Food waste management systems vary and will vary from country to country for number of reasons [8]: Economic and technological differences, geographical dissimilarity and politics are important reasons for different food waste management systems. Recent policies and developments lead to the objective of using waste as a resource and enable the separate recovery of valuable waste material. A study conducted in the UK in 2007 presents the differences between various waste management options [7], shown on Table 8.

Other recently published studies [8], [10] do have breakdown information of the different waste streams in percent but the cost calculations focus more in general on the whole waste streams, in particular on MSW [8] and Bio-waste [10], and not directly on estimated costs of food waste collection and treatment options.

Table 8: Estimated costs of food waste separate collection and treatment options [7].

Costs of implementing separate food waste collection	
Cost of separate collection followed by composting	35 – 75 €/ton
Cost of separate collection of bio waste followed by anaerobic digestion	80 – 125 €/ton
Compared with landfill and incineration	
Cost of landfill of mixed waste	55 €/ton
Cost of incineration of mixed waste	90 €/ton

The environmental, economic and social implications of food waste are of increasing public concern worldwide. The environmental costs of food waste include for example landfill expansion and methane emissions that contribute to climate change [7].

According to WRAPs 2009 report on Household Food and Drink Waste in the UK, the amount of food wasted per year is 25 % of that purchased (by weight). Although data for other member states is unavailable, a similar study in United States [8] found that on average 14 % of household purchases becomes food waste. Furthermore, WRAP estimates that portion of the food waste which could be avoided represents a total economic cost to households of 14.1 billion € per year, an average of 565 € per household per year [2], [7].

In addition, the total cost for municipalities or waste management agencies would depend on the collection method and the level of treatment option selected beside others. Bring site collection system involve the collection of waste at limited numbers of collection points. Although the disconnection in various fractions is possible, higher recycling rates require a switch from bring site collection services to door-to-door collection systems where the top-loaders drive from door to door and empty the containers directly at the users doorstep. As mentioned, these types of alteration results in higher capture rates and less mixed waste streams, on the other hand higher costs (per tonne) of collecting both residual waste and recyclables incur [8]. Since separate collection is crucial for food waste treatment the costs in terms of separate collection has been identified on Table 9.

Table 9: Estimated costs of food waste separate collection systems, EU-27 [7]

Cost of implementing separate food waste collection	
Household containers 10 litres	1 € per habitant
Compostable bags	0.82 € per habitant
Communication campaign	1-5 € per habitant, depending on the density of municipality
Collection vehicles	80,000 € per vehicle*

***the reports do not make any explanations about running costs.**

Externalities, dealt with in the report of [8], are not content of this report. Although it is a complex topic, policy should be aware of them as prevention is better than cure.

4.2 National case studies on food waste statistics

4.2.1 France

4.2.1.1 Introduction

In recent years, France has made significant efforts towards a more comprehensive treatment and management of bio-waste. The basis was prepared in article 204 of the law no. 2010-788 from July 12th 2010 on the national commitment to the environment, also called 'Grenelle Environment II'. It required people or entities that produce or hold large amounts of waste mainly composed of bio-waste to implement a source separation and biological recovery in order to limit greenhouse gas (GHG) emissions and promote the return to the ground [11]. Inter alia supermarkets, agro-food industrial players or restaurant/catering institutions are concerned. The law defines this diversion of biodegradable municipal waste (BMW) from landfill to be fully applied by 2016 and provides gradual limits for implementation until this date.

In May 2015 the Socialist member of the National Assembly of France and former food minister Guillaume Garot proposed a law which would require supermarkets exceeding a footprint of 400m^2 to donate unsold food by contract to human charity organisations. The law, initially unanimously voted for, was already repealed in September 2015 due to a legal technicality. In response to this development the minister for environment and sustainable development called for a voluntary fulfilment of the law content and some supermarkets have already committed to do so.

Reporting standards, definitions and methods are prescribed through the French National Office for Statistics and Economical Studies (INSEE). Food waste is accounted under punctual waste (déchets ponctuels) as this waste stream is described to be generated not within ordinary processes. The organic waste stream includes all other waste products with animal- and plant origin [12], [13].

4.2.1.2 Food Waste Generation

The total generation of food waste throughout different stages of the food chain has been estimated by ADEME (French Environment and Energy Management Agency) and the Ministry of Ecology, Sustainable development, Transport and Housing in the year 2011 [13]. However, this study did not take into account the food waste generated within the stage of agricultural production and estimated it as 'probably not significant'. More complete figures on total food waste for six stages among the food chain (see Figure 2) were estimated by a parliamentary initiative in the year 2014 [14].

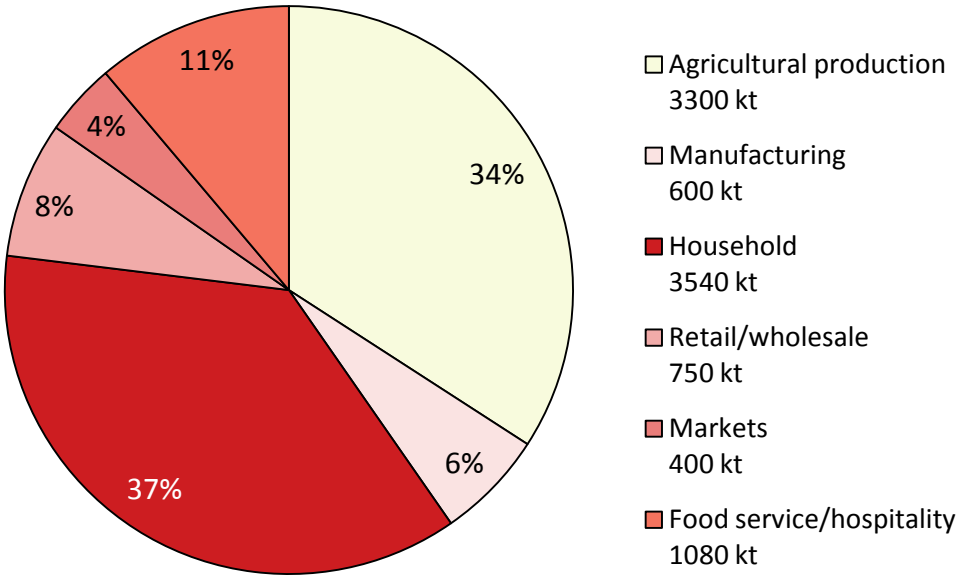

Figure 2: Food waste amount generated [kt] and percentage [%] by sector among the food chain in France 2014. Data: Garot G., (2014) [14]

Figure 2 illustrates the estimated maximum generation of food waste. The study states for two stages among the food chain uncertainty ranges namely a) agricultural production 453 kt to 3,300 kt and b) households 2,212 kt to 3,540 kt. Taking these uncertainty ranges into consideration, the total estimated amount of food waste generated in France varied between 5,495 kt and 9,670 kt in the year 2014. Assuming a population of 64.641 mio inahibtabts in 2014 (http://countryeconomy.com) the normalized food waste generation over all food waste sectors ranges between 85 kg/capita and 150 kg/capita.

Agricultural production is an important economical sector in France and puts the country among the first ranks in regards to economical turnover and labour provision in European countries [15]. Cereals and wine are the main value of France's farming activities. It is the largest producer of cattle and poultry, third largest producer of sheep and fourth largest producer of pork among European countries. Uncertainties and risks (resulting from climatic hazards, water availability, processing capacities, fertilizers, production withdrawals) within agricultural activities are present and might contribute to the loss of food, with a high percentage of this loss being avoidable. Another potentially avoidable reason leading to the loss of food is the fact that late season fruits and vegetables are not harvested because their potential market price is below the labour cost [13].

The **food industry** is characterized by the food processing steps between agriculture and final consumption. Food waste produced in this stage of the food chain is mainly due to unusable parts of animal or plant born raw materials.

A survey by ADEME in 2007 on the characterization of **household** waste shows the decomposition of about 98 kg fermentable waste per year:

- 72 kg of food waste
- 7 kg of packaged food products

- 3.8 kg of other undetermined waste
- 15.1 kg of garden waste

According to the figures above each French person generated 79 kg of food waste per year and the survey suggests that from this amount 20 kg (25 %) is avoidable waste. Another study by the Edelmann group for the food storage brand Albal/Toppits determined in 2011 that 21 % of purchased food by each French person was wasted [13], [16]. In contrast, the consumers reported that they would discard 6 % of their purchased food. Furthermore, the survey concluded that food waste in French households is equivalent to 430 € per person per year.

The **trade and retail** sector is mainly comprised by super- and hypermarkets which are increasingly challenged by the competition of speciality stores and hard discount stores. Policies are being developed by retail companies to withdraw products from the food store before the actual use-by date, in order to protect the safety of consumers [13]. This in turn contributes strongly to food waste.

Food waste from the **market** segment consists of unsold food (fruits, vegetables, fish, meat, cheese, etc.) from local markets (95 %) as well as from large markets (5 %).

The sector of **gastronomy** consisted in 2007 to 49 % of catering and 51 % of commercial restaurants, including school kitchens and related initiatives.

Furthermore, a recent study from ADEME states that total organic waste from agriculture and silviculture (forestry) in France accounted to 46.4 million tonnes in 2013 [17]. However, this amount of organic waste includes, by French reporting standards (see above), no food waste but only non-food products such as paper, textiles, sanitary accessories and organic waste from enterprises and municipalities [20].

4.2.1.3 Food Waste Disposal Options

The treatment of food waste has not been investigated separately by INSEE or ADEME [12], [17]. As it appears within different stages in the food value chain (see Figure 2) the following section describes the treatment of a waste stream which consists to a significant share of food waste: Municipal solid waste (MSW).

France is undertaking efforts to improve the country's performance regarding the collection and treatment of bio-waste. In contract of ADEME a study was carried out in 2013 which evaluated bio-waste management and treatment examples across the EU and world-wide (Austria, Germany, Italy, Belgium, Spain, UK, Canada, USA and Australia) [19]. Moreover, in order to harmonise waste treatment indicators across EU Member States the Ministry for Ecology, Sustainable Development and Energy commissioned a benchmarking report about detailed procedures for reporting on municipal waste structural indicators in 2013 [20]. Figure 3 gives an overview of the treatment of municipal solid waste with its development from 2000 to 2012.

Figure 3: Treatment of municipal solid waste in France from 2000 to 2012. Data source: ADEME (French Environment and Energy Management Agency) 2015 [17]

According to the EU Landfill Directive France is required to limit biodegradable municipal waste going to **landfill** by 2016 to 35 % in comparison to the amount generated in 1995 [21]. In 2010 the percentage was with 37 % close to the achievement of the landfill target. The number of active landfill sites has seen a declining trend over the past two decades with approximately 500 sites in the year 1995 to 238 sites in the year 2012 [17].

In response to the mentioned decrease in landfilled MSW it can be observed that **recycling** and **composting** rates steadily increased over the investigation period from 2000 to 2012. This development is supported by the ambitious national target for material and organic recovery (recycling and composting) of 45 % amongst MSW treatment until 2015 [19]. Until the year 2012 the recycling and composting rates increased to 35.4 % while more recent figures have not been published to this date. The number of facilities for composting (composting centres) and waste selection/recycling (sorting centres) has rapidly grown since 1995. Approximately 50 sorting centres were present in 1995 while by 2012 the number of 390 centres was reached. Composting centres experienced an even steeper development from ca. 110 plants in 1995 to 588 in the year 2012.

No major change is apparent for the **incineration** of MSW in the investigation period 2000 to 2012. Its fraction amongst all treatment options remained relatively steady at about 27 % to 29 %. Similarly the number of incineration units remains unchanged with 126 units since 2003. Before this date their number was decreasing from a peak of about 300 units in the 1990s.

Anaerobic digestion (AD) shows comparatively small fractions among all treatment options over the investigation period. However, it experienced an increase with 0.2 % in 2002 to 1.3 % in 2012. This increase is reflected in the number of total AD plants (installations de méthanisation) in France which more than doubled to 447 in 2012 compared to 2008. The number of AD plants specialised on municipal waste increased from one in 2000 to ten in 2012 [17].

Import and export activities of waste in the year 2013 mostly occurred to and from neighbouring countries in Europe. Germany, Belgium and the UK have the highest shares in imports, while Spain, Belgium and Germany are the main destinations for waste exports The three waste streams predominantly involved in

waste exchanges between countries are metal, paper/cardboard and plastics. In 2013, export and import of waste brought economic revenue of 2.2 billion € [17].

Besides the presence of food waste in MSW considerable fractions of food waste appear also in non-municipal waste such as illustrated in Figure 2. The treatment of non-municipal waste (waste from economic activities) is poorly reported in literature but a recent study from ADEME estimates it to be similar to the treatment of MSW [17].

4.2.1.4 Causes of Food Waste

The causes of food waste in France are very diverse and complex and can be broken down into two major groups of waste causing factors [13], [18]. Both groups of factors have major influences on all stages among the food chain.

Legislative factors

1) **Hygiene legislation**. Regulations and Directives in effect on EU level might be constraints for the reduction of food waste but are at the same time crucial to meet the first priority in the area of nutrition, the safety of consumers. In the year 2011 400 deaths per year are recorded to be caused by food poisoning which calls still for the necessity of hygiene and health regulations. In the gastronomy sector such as in school cafeterias/canteens health regulations prohibit to retrieve surplus food which contributes to food waste as well.

2) **Date labelling**. Products lacking use-by or best before dates are by European legislation not allowed to be marketed. Use-by dates define an absolute time limit for microbiologically perishable commodities (meat, eggs etc.) after which an immediate human danger through consumption can occur. The best before date might be only an indication of how long the product will bear the same qualitative features (creaminess of yoghurt, moistness of bread etc.) as they were present at the production. The excess of this date does not constitute danger to the person who would absorb the product (quality of dairy products has been proven by a French study to remain excellent after three weeks of excess [22]). Date labelling is often said to cause high amounts of food waste which would still be edible without any threat. The dates under discussion are mostly the best before dates but also the confusion of customers of the two available date options.

3) **Size and shape regulations**. The food production stage, such as agricultural processes are most concerned by these regulations. In France, a very high number of ‘unfit’ fruits and vegetables is discarded shortly after harvest because marketing standards [23] would not allow those agricultural products to enter the market.

Business and behavioural practice

1) **Agricultural production**. Overproduction, downgrades and sorting differences might cause crop wastage from 0 to 30% of the actual possible yield.

2) **Food industry**. Wastage of food is partly due to technology and design related processes during manufacturing. Examples are inefficient or poor manufacturing techniques or deficient packaging procedures.

3) **Retail sector**. The relationship between the processing industry and the retail sector is responsible for a fraction of food waste. Contractual penalties for non-deliveries to retail markets, strict terms for returning products to food manufacturers might contribute to an oversupply of products. It is estimated that 8% of fruits and vegetables are lost within the retail sector and also meat as well as fish are experiencing significant losses.

4) **Gastronomy sector**. The study from Lacourt [18] reports that food waste in school cafeterias/canteens has a variety of complex causes: Consumers are less concerned by the cost of waste because the meals are often pre-paid for; the cost of waste is already included in the price of the meal and thus there is no distinction between a finished meal and leftovers to discard; surplus is maintained by management to avoid breakdown of stock; meal quantities are often regulated by directives even though they might vary due the individual consumer demand.

4.2.1.5 Price Difference between different Food Waste Management Options

Table 10 presents the results for France from a financial modelling tool on waste generation and management across the EU-28, developed during an EU funded project from 2012 to 2015 [8]. The tool reports treatment costs for four distinct treatment categories with total 13 subcategories. This information is provided for each of the 28 EU Member States.

Table 10: Waste treatment costs for France, 2012. €/t of waste treated. CHP = combined heat and power, MRF = materials recovery facility. Source: Table adopted from [8]

Treatment option	Composting/ Digestion			Incineration				MBT					Land fill
	Open Air Composting	In-Vessel Composting	Anaerobic digestion	Electric Only	combined heat and power	Heat Only	Combustion only	Bio-stabilisation	Biodrying with no plastics recycling	Biodrying with plastics recycling	AD based MBT	Residual material recovery facility	
€/t	27	47	77	119	132	78	92	88	89	85	89	60	62

The costs in Table 10 represent 'private metrics' which reflect market conditions from the perspective of facility operators or manager. Retail prices, taxes and subsidies as well as a weighted average cost of capital are included.

National records for treatment costs are reported by a contracted study of ADEME for the four following options: Landfilling and incineration of municipal waste as well as Open-Air and In-Vessel composting [19]. The costs constitute average values across the country and are hence appropriate to validate a part of the model results shown in Table 10.

- Open-Air Composting: 15-40 €/t
- In-Vessel Composting: 50-90 €/t
- Incineration: 94 €/t
- Landfill: 64 €/t

It can be inferred from the comparison between the four treatment cost items listed above reported in [19] and the model results in Table 10 that the model underestimates waste treatment costs. This statement is only valid for the three options in-vessel composting, incineration and landfill.

4.2.2 Germany

4.2.2.1 Introduction

In the following, general aspects of the waste management system and waste regulations in Germany are elaborated on and how such translate into the treatment and management of food waste.

Waste management in Germany is subject to **European law** and follows the Waste Framework Directive (2008/98/EC) [1]. It is the basis for waste management regulations in Germany on a federal level and provides the definitions of different waste fractions as well as the principle of waste management hierarchy: 1st prevention, 2nd preparing for re-use, 3rd recycling, 4th other recovery (energy recovery), and 5th disposal.

The first waste disposal act (Abfallbeseitigungsgesetz) was adopted in 1972 which was succeeded by the Kreislaufwirtschafts- und Abfallgesetz (KrW-/AbfG) in 1996 and replaced by the Waste Management Act (Kreislaufwirtschaftsgesetz KrWG) in 2012. It acts as Germany's main regulation for waste management with the following articles relevant for bio-waste management [24]:

- Definition of bio-waste (§3, 7): biodegradable, plant, animal or fungi based materials (garden and park waste, from landscape maintenance, food and kitchen waste from households, catering industry, retail industry and food processing)
- Separate collection of bio-waste, paper, metals, plastics and glass (§11, 1)
- Recycling rates of 65 % until 2020 (§14)
- Product responsibility (§ 23) along the product life cycle.

The Waste Management Act is further transposed into states law in the 16 federal countries (Bundesländer) for those sections which are not regulated on federal level. Correspondingly, states law regulates e.g. the implementation of waste management or waste disposal and collection ordinances for municipal waste.

A separate decree from 1998, with an amendment in 2013, regulates the usage, treatment and control of bio-waste for the application on agricultural, silvicultural and horticultural land [25].

Since June 1st 2005, only pre-treated waste is permitted to be landfilled as regulated in the Waste Disposal Decree (AbfAblV - Abfallablagerungsverordnung) and in a technical guidance report (TA Siedlungsabfall) [26], [27]. Pre-treatment can be accomplished by the two methods incineration or MBT.

Another important law is the Law on Environmental Statistics (Umweltstatistikgesetz - UStatG) which stipulates reporting obligations (type, amount, condition, origin, fate and treatment, reporting interval etc.) on waste for public as well as private bodies [28].

4.2.2.2 FOOD WASTE GENERATION

Food waste is not reported as separate waste stream in Germany but appears within the bio-waste stream. Figure 4 shows the composition of the bio-waste stream (including sewage sludge) in Germany in the year 2012 and the subsequent paragraphs report on the generation of food waste. The separate collection of bio-waste was launched in Germany in 1985 and the waste stream experienced in the last 20 years a steep increase to approximately 15 Mt in 2012 (see Figure 4).

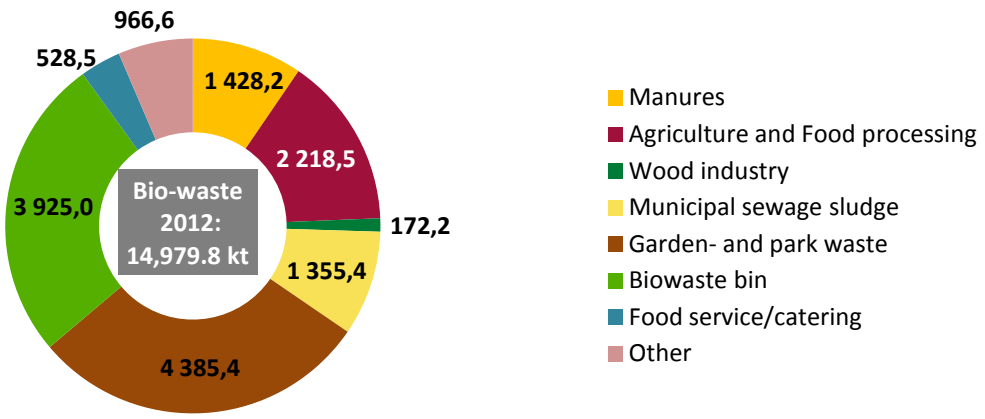

Figure 4: Composition of bio-waste [kt] (including sewage sludge) in 2012: Data source: Federal Environmental Agency - Umweltbundesamt [29]

This increase is illustrated by a report of the federal statistical office of Germany that 9.6 Mt household waste was generated in 2013, thereof 4.29 Mt from the Bio-waste bin and 4.76 Mt biodegradable garden- and park waste [29].

An extensive study on food waste in Germany was conducted by Kranert et al. (2012) in the years 2011 and 2012 [30]. It aimed to comprehensively report on the generated amount of food waste for Germany. Furthermore, this national data supports the EU target on reducing the amount of discarded food until 2025 by at least 30 % [31].

Three different methods are used in the study to estimate food waste in Germany: Data collection, extrapolation and research/analysis of existing studies in other countries. The study reports generated food waste for four sectors among the food chain: Manufacturing, households, wholesale/retail and food service/hospitality (large-scale consumers). Figure 5 presents the sectorial results of the above mentioned study with a total estimated annual amount of food waste in Germany of 10.97 Million tons/year. Assuming a population of 83.017 mio inahibtabts in 2010 (http://countryeconomy.com) the normalized food waste generation over all food waste sectors equals 132kg/capita.

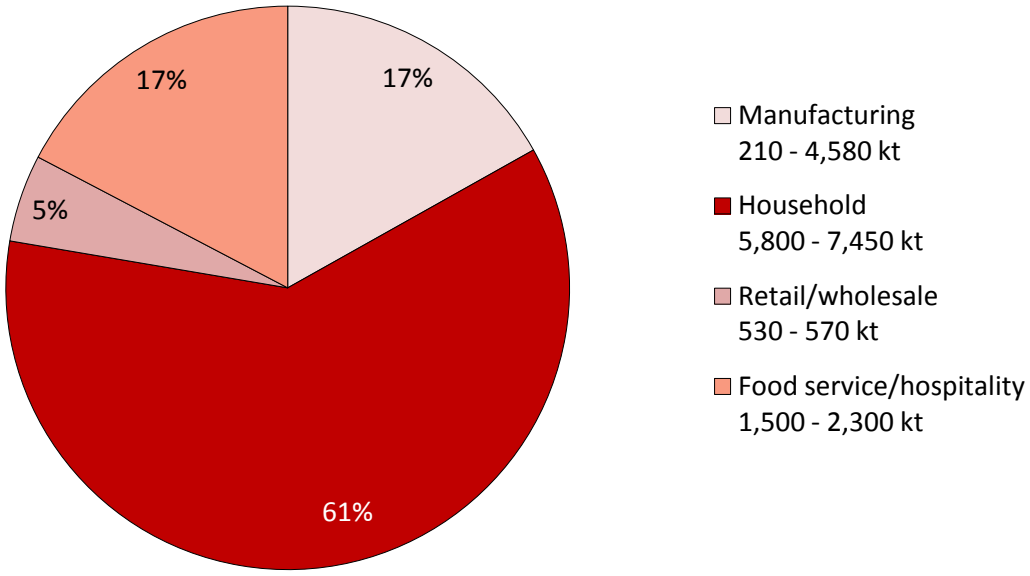

Figure 5: Yearly food waste amount generated, max and min values in the legend, pie chart shows the corresponding median values [kt] and percentages [%] by sector in Germany. Data source: Figures adopted from a study of the University of Stuttgart, Kranert et al. (2012) [30]

Kranert et al. (2012) reported for each sector along the food chain an uncertainty range of generated food waste which is expressed in Figure 5 as max and min values, while the corresponding median value is illustrated in the graph. The study mentions no specific year of investigation but estimates an annual amount of generated food waste in Germany. It can be inferred from the utilized research material that the numbers in Figure 5 represent values for the year 2009 or 2010 [32]. The following paragraphs give more detailed insights into the sectors among the food chain, presented in Figure 5.

Food waste from agricultural production provides the input for **manufacturing** but is not included in the study from the University of Stuttgart because of its complexity to assess [30]. This is acknowledged by the Federal Ministry for Food and Agriculture and accordingly, a study on the estimation of food waste in the agricultural initial production in Germany was carried out by Peter et al. in the year 2013 [32]. This progress study assessed four exemplary agricultural products (wheat, potatoes, apples and carrots) to estimate their waste percentage and extrapolate it for entire Germany. The losses ranged between 3 % for wheat and 11 % for apples in the economical year 2009/2010. However, these results are afflicted with considerable drawbacks as only the losses related to storage of the four products are accounted for. The remaining amount, the difference between storage loss and marketed products, is assumed to be further input to a variety of other cascade uses. However, the study mentions that losses might occur in other processing steps as well (size and shape requirements, minimal market standards etc.) but are not transparently reported for Germany.

Kranert et al. (2012) acquired for the manufacturing stage data from businesses with a production amount of 5.3 million tonnes equalling a 5 % share of the entire food production industry in Germany. Acknowledging that this share is not representative, the study estimates the amount of food waste in the manufacturing stage in Germany from relevant national as well as international literature. The data collection undertaken revealed that the three product groups bakery/pasta, dairy products and fruit/vegetables displayed the highest percentages of avoidable food waste compared to the produced amount. The values ranged between 0.7 % and 2.3 %. It is also stated on a general basis, that with an increasing number of production steps in the manufacturing process the waste amount increases [30].

In regards to **Households**, the study [30] reports the average amount of food waste in Germany to 81.6 kg/capita/year. Out of this amount 62 kg/capita/year end up in the municipal collection system (43 kg/capita/year in the residual waste bin and 19 kg/capita/year in the bio-waste bin). A smaller part of household food waste is discarded in other disposal streams (own composting, sewerage, pet fodder) and is estimated to range from 9 to 30 kg/capita/year. In addition, the study highlights that from the amount of food waste in households,

- 47 % are avoidable,
- 35 % are not avoidable and
- 18 % are partly avoidable.

The avoidable and partly avoidable fractions would translate into a financial loss through food waste of 234 €/person/year. Fruits and vegetables are discarded most often followed by bakery products and self-prepared meals with their residues [30].

89 % of the reported food waste in the **retail/wholesale** sector (Figure 5) is generated in retail and 11 % in wholesale activities. The figures in the latter include not only food waste but also flowers and other organic fractions in varying contents and amount to 0.5 % to 1 % of the entire annual wholesale stock turnover. The study from 2012 suggests for the retail sector, that 1.1% of all food which is purchased is not sold to the customer. However, approximately one third of this amount is passed on to charitable organizations. It furthermore assumes an annual weighted average per retail shop in Germany of 6.5 tonnes of wasted food [30].

The term 'large-scale consumers' is used by [30] interchangeably for the sector of **food service/hospitality** since it delivers all products to the consumer 'out-of-home'. The general assumption on which calculations are based is the amount of food waste per portion in the food service/hospitality sector. This amount varies between 150 and 200 g/portion for different segments. The estimated annual food waste amounts per segment are listed below [30]:

- gastronomy: 837 - 1,000 kt
- company catering: 147 - 400 kt
- accommodation sector: 186 kt
- elderly- and special care homes: 930 - 145 kt
- schools: 75 - 87 kt
- hospitals 65 kt
- universities, children care, correctional facilities and the federal armed forces: <41 kt

4.2.2.3 FOOD WASTE DISPOSAL OPTIONS

The statistical federal office of Germany provides data on the generation and treatment of different waste streams and material groups for the period between 2006 and 2013 free of charge [33]. Data from this source is reported in an aggregated form to Eurostat. Food waste might appear in different sectors of the bio-waste stream (see Figure 4) and two sectors will be investigated in the following paragraphs, agricultural- and silvicultural waste as well as BMW.

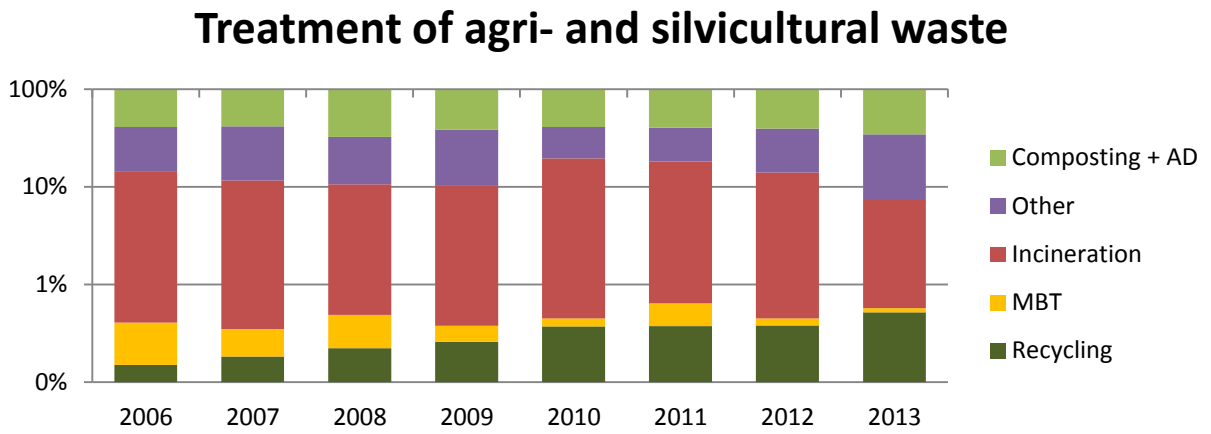

Figure 6: Treatment of waste from agricultural and silvicultural activities in Germany between 2006 until 2013. Data source: Genesis- online database of the federal statistical office of Germany, custom data retrieval [33]

Figure 6 is built on 38 waste material groups from agricultural- and silvicultural activities, displaying the treatment of this waste stream on a logarithmic scale. As this waste almost exclusively comprises organic materials, only marginal percentages were **recycled** from 2006 to 2013 (increasing from 0.15 and 0.5 %). Recycling is the sorting of impure waste streams in order to enable subsequent treatment options. **MBT** exhibits small percentages among all treatment options for the same reasons as for recycling. This treatment type is applied to impure, organic waste streams (e.g. residual waste) as a pre-treatment step. **Incineration**, mostly waste from silvicultural activities, has experienced a decreasing trend from 2010 (19 %) until 2013 (7 %). The treatment option **‚other'** encompasses e.g. small-scale treatment plants or special waste treatment plants and exhibits with between 22 % and 30 % a noticeable fraction among all options. The predominant treatment of this waste stream in Figure 6 has been **composting and AD** with a close-to-stable share of 60 % over all treatment options and the entire investigation period. A division between the amounts for composting and AD is not apparent from the data source, respectively. However, the number of treatment plants over all waste streams in Germany with their associated input and output quantity is reported in the Annual Waste Disposal Report 2013 (Abfallentsorgung 2013) of the Federal Statistical Office [34] and is mentioned later in this report.

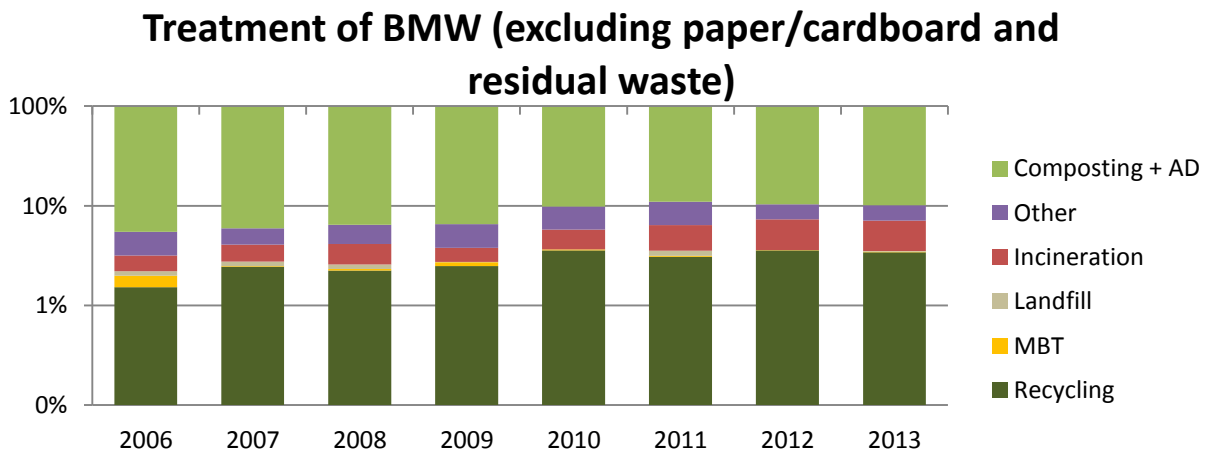

Figure 7: Treatment of biodegradable municipal waste (biodegradable kitchen- and canteen waste, oil- and grease waste, general biodegradable waste, waste from the bio-waste bin, market waste and not otherwise specified municipal waste) between 2006 and 2013. Data source: Genesis- online database of the federal statistical office of Germany, custom data retrieval [33]

Figure 7 shows the shares of different treatment technologies for BMW in percentages on a logarithmic scale. It must be highlighted that waste in this illustration includes neither paper/cardboard- nor residual waste and is thus expected to contain a high share of food waste. **Recycling** showed an increasing trend from 2006 (1.5 %) to 2013 (3.4 %). Within this municipal organic waste stream, **MBT** and **landfill** show considerably low shares with both under 0.5 %, respectively. As the generation of the total waste stream increased over the investigation period, also **incineration** – mostly with energy recovery – increased from 1 % in 2006 to 3.6 % in 2013. The highest share of BMW is converted to compost and biogas and the absolute amount delivered to **composting and AD** facilities has steadily increased from 8,000 kt in 2006 to 8,700 kt in 2013. However, the relative share of composting and AD has experienced a decline from 95 % to 90 % over the investigation period.

Total numbers, input- and output amounts for waste treatment plants in the year 2013 [34]:

- 1,094 sorting- or recycling plants; input: 24,831 kt; output: 24,555 kt
- 60 MBT plants, input: 4,166; output: 3,565 kt
- 1,142 landfills (432 in building phase); input: 42,054 kt, output: 2,028 kt
- 873 incinerators (with- and without energy recovery); input 43,100 kt; output: 10,160 kt
- 2,462 biological treatment plants (Compost and AD), input: 14,658 kt; output: 10,522 kt (approx. 59 % composting and 41 % AD)
    - from the output quantity (3,927 kt compost and 3,601 kt fermentation remainders):
        - ca. 2 % discarded (not certified by the Federal Quality Association Compost [35])
        - ca. 17 % reused
        - ca. 81 % delivered to agri- and silviculture, landscaping and private gardening

Export and import of different waste types mainly involves neighbouring countries with a mean shipment distance between origin and disposal of 500 km. Within the bio-waste stream, 5,342 tonnes of biodegradable kitchen- and canteen waste were exported to the Netherlands, 5,991 tonnes of biodegradable constituents of residual waste were exported to France in the year 2013 and 58 tonnes of waste from food processing were exported to Belgium. States of origin were the western located federal countries North Rhine-Westphalia and the Saarland [36]. In comparison to export activities, import within all waste types has been significantly lower and imports within the bio-waste stream show the same characteristics. 379 tonnes of biodegradable kitchen- and canteen waste and biodegradable constituents of residual waste were imported from Austria to Bavaria, the most south-eastern located federal country in Germany [37].

4.2.2.4 Causes of Food Waste

There has been a multitude of studies related to the causes of food waste in Germany in recent years [30], [38], [40], [39]. The so dedicated research is mostly applying a distinction of causes between the different stages of the food chain. The following paragraphs give information on the different causes of food waste in general, but also include a survey about the behaviour regarding food waste in German households.

Within the **agricultural production** stage the majority of food waste originates from harvest- and from post-harvest losses. Peter et al. (2013) suggest that around 3 % of the actual primary production amount is lost during harvest. Primary causes are mentioned to be technical gaps in the harvesting process and the attempt to balance out natural setbacks in growth by planting more goods than the market can absorb [32]. A WWF (World Wide Fund for Nature) Study from 2015 on food waste in Germany adds to these causes all

mechanical errors which lead to spillage and spoilage (e.g. milk, eggs and animals at transport or slaughterhouse) [38]. In regards to post-harvest losses the same study indicates between 1 % and 5% loss of the primary production, mainly caused by insufficient processes of cleaning, drying and storage. Peter et al. (2013) indicate two main reasons for post-harvest losses [32]:

- Product requirements and – norms: International, European and national standards regulate quality, shape, degree of ripeness, sugar content for fruits, storage technologies etc. Varying for different agricultural products, such regulations govern the fraction of the annual primary production amount which can be marketed.
- Storage: Losses occur mainly through inadequate respiration or evaporation of the stored products caused by non-optimal humidity and temperature during storage.

Manufacturing/food industry: Kranert et al. 2012 groups the causes of food waste into four fields of activity (percentages (%) represent the frequency in answered questionnaires) [30]:

- Quality assurance – 33 % (Sorting out of products with certain product and quality characteristics such as irregular shape etc., internal quality criteria, commercial standards, legal restrictions etc.)
- Technical problems – 29 % (packaging errors, production breakdown etc.)
- Damage and spillage – 18 % (Transport, packaging, storage etc.)
- Overproduction – 17 % (poor planning, irregular demand, returned sales etc.)

Retail and wholesale: Within this stage, the fact that food is discarded because it is not suitable / unfit for sale is the predominant cause for food waste [30]. This can be both, due to an expiration of the indicated dates (use-by or best-before) and due to the perished quality of fruits, vegetables and bakery products. Additionally, the study highlights further contributing causes of food waste:

- Customers' consumption behaviour: perceived lack of freshness.
- Improper handling of perishable food: fruits and vegetables often get damaged due to inadequate storage conditions while displaying in the salesroom.
- Marketing strategies:
- Large product variety, full shelves generate excess stock and over-production.
- Discount sales such as "BOGOF – buy one get one free" contribute to the shift of food waste from the retail to the consumer sector.
- Estimation and ordering of the right amount of products to the right time.

Food service/hospitality: In the WWF study from 2015 [38], the sector consumption losses incorporates both food service/hospitality and households and gives associated general causes of food waste in the entire consumption sector. However, the study of Kranert et al. (2012) treats household and food service/hospitality separately and elaborates on detailed causes in the two sectors. For the latter sector Kranert et al. (2012) reports on the following causes for food waste [30]:

- Lack of knowledge about waste occurrence (awareness)
- Inadequate storage (first in – first out)
- Different degrees of processing (cleaning- and processing losses)
- Lack of knowledge/estimation data about the required number of dishes

- No reuse of prepared but not served food
- Size of the portion (in average 25-33 % of a portion is being left by the consumer)
- Hygiene- and safety regulations (no reuse of still packaged products when the cold chain was broken once. Example: Original packaged but unused food products from the aviation -and the catering sector will be subjected to incineration.)

In regards to **households**, Kranert et al. (2012) specifies the predominant causes of food waste to be societal framework conditions, individual reasons and an overrating of the best-before date [30]. Jörisson et al. (2015) conducted an online survey about the reasons for food waste in German households and concluded the following findings [39]:

- Out of date, too long in the fridge (32 % of respondents), smelted/tasted bad (48 % of respondents), mouldy (78 % of respondents).
- Minor importance: leftover, looked bad, wrong planning of meals, in cupboard too long, wrong package size, did not look like food or ingredient, incorrect storage, served too much, date labelling, insufficient cooking skills.
- The amount of food thrown away in households depends on:
- The household size (household with one person has the highest per capita food waste of around 243 g per person/week in Karlsurhe).
- On the age group (until 40 years slight increase of amount of food waste → decrease of food waste between 40 and 60 years, increase of food waste for age category “more than 60 years”).
- On the shopping behaviour: highest when food is exclusively shopped in large supermarkets.
- On the frequency of shopping: slight increase of food waste when shopping frequency is decreased.

According to a study in North Rhine-Westphalia of the University of Applied Sciences Münster in the year 2012, there are seven central potential arrays of causes of food waste across all product groups and stages along the food value chain [40]:

- Definition of process- and market related standards and quality requirements: quality requirements, product feature demand, product specification, marketing standards, selection depending on optic (consumer).
- Legal framework requirements (food safety).
- Market conventions: demands on freshness, variety and availability of food, high delivery readiness of the production companies and the wholesale.
- Human misconduct/errors: consumer behaviour of great importance concerning unconsumed and discarded food. This array is further investigated by an “LCA study of unconsumed food and the influence of consumer behaviour” from Gruber et al. in the year 2015 [41]. A crucial finding was stated to be the importance of the life-cycle use (consumption) stage where the consumer has considerable influence on decreasing emissions from unconsumed food.
- Technical problems
- Logistics
- Cultural influences

4.2.2.5 Price Difference between different Food Waste Management Systems

Data on costs for waste management systems exclusively for food waste are not transparently reported for Germany. However, the Federal Environmental Agency (UBA - Umweltbundesamt) published and continually updates a best practice document on municipal waste processing and treatment where factsheets on the technical as well as financial details of several treatment options are featured. The following paragraph lists the cost items reported in the factsheets for different treatment options. All costs are mass specific total costs for the each treatment option listed and do not include the potential benefits from realizing the end products, respectively.

- Organic waste composting: 40 – 110 €/t [42].
- Anaerobic digestion (including the treatment of sewage sludge): with back-end composting and selling of energy; depends on the size of the plant: 5,000 t/year: 90-140 €/t; 10,000 t/year: 75 -130 €/t; 20,000 t/year: 50 – 100 €/t; 50,000 t/year → 45 -70 €/t [43].
- Mechanical biological treatment (only for the treatment; without subsequent storage or recovery of combustible material): 40 – 100 €/t [44].
- Incineration:
    - Grate incineration (with exhaust gas cleaning): 80-250 €/t [45]
    - Fluidised bed incineration: Mixed residual waste (with exhaust gas cleaning) 90 – 175 €/t; dried sludge and small matter < 30 mm: 50 – 100 €/t [46]

The European Commission contracted two studies about the costs for waste management across the EU carried out by Eunomia Research & Consulting in cooperation with other research institutes. Both study reports, "Costs for Municipal Waste Management in the EU" from 2001 [10] and "Development of a Modelling Tool on Waste Generation and Management Appendix 5: Financial Modelling" from 2014 [8], contain average costs of different waste treatment options. Due to its timeliness Table 11 lists the modelling results from the study in 2014 in regards the one drawback that the displayed costs are not specific for food waste but for the municipal waste stream.

Table 11: Waste treatment costs in Germany, 2012, €/tonne of waste treated. CHP = combined heat and power, MRF = materials recovery facility. Source: Table adopted from [8]

Treatment option	Composting/ Digestion			Incineration				MBT					Land fill
	Open Air Composting	In-Vessel Composting	Anaerobic digestion (AD)	Electric Only	combined heat and power	Heat Only	Combustion only	Bio-stabilisation	Biodrying with no plastics recycling	Biodrying with plastics recycling	AD based MBT	Residual material recovery facility	
€/t	26	45	80	97	109	54	80	76	84	81	84	57	37

4.2.3 Hungary

4.2.3.1 Introduction

Waste management in Hungary is organized according to a hierarchy of the waste management plans (national, regional and local) which are designed in order to fulfil requirements of the National Environmental Protection Programme. The first period of the national waste management plan (NWMP 2003-2008) set major legal deadlines with a special focus on the reduction of MSW going to landfill and the increase in selective waste collection [47].

Furthermore, this NWMP targeted the sector of biodegradable waste in which food waste represents a considerable fraction. The threshold for the allowed biodegradable fraction within municipal solid waste (MSW) disposed on landfill sites was set to 35% of waste generated in the base year (1995), to be achieved by 2014. In order to reach this target, a national programme to divert biodegradable municipal waste (BMW) from landfills was launched in 2005 [48].

The second period of the NWMP (2009-20014) did not enter into force since no official approval was achieved [49], [50]. However, in 2014 a new 'Act on Waste' was introduced and the current NWMP for the period (2014-2020) was launched.

The Hungarian Ministry of Rural Development provides definitions for different sectors of waste related to food waste in the Waste Management Information System (EHIR):

Biodegradable waste: all organic matter-containing waste, which is biodegradable or can be biologically degraded in aerobic or anaerobic process, including bio-waste

Bio-waste: biodegradable garden and park waste or food and kitchen waste produced in households, restaurants, caterers and retail establishments and similar waste generated in food processing plants

4.2.3.2 Food Waste Generation

The most detailed records on food waste in Hungary were stated by a pan-European study on the generation of food waste conducted by the Bio Intelligence Service (BIOIS) on behalf of the European Commission which uses EUROSTAT data for national food waste statistics [6]. The study provides figures for food waste generated in the four different sectors Manufacturing, Wholesail/Retail, Food Service/Catering and Household from 2006. However, the liability of the data in this study is doubted by Priefer (2013) [51] because it represents estimates of national food waste data. Figure 8 shows the breakdown of the Hungarian food waste generation per sector in the year 2006.

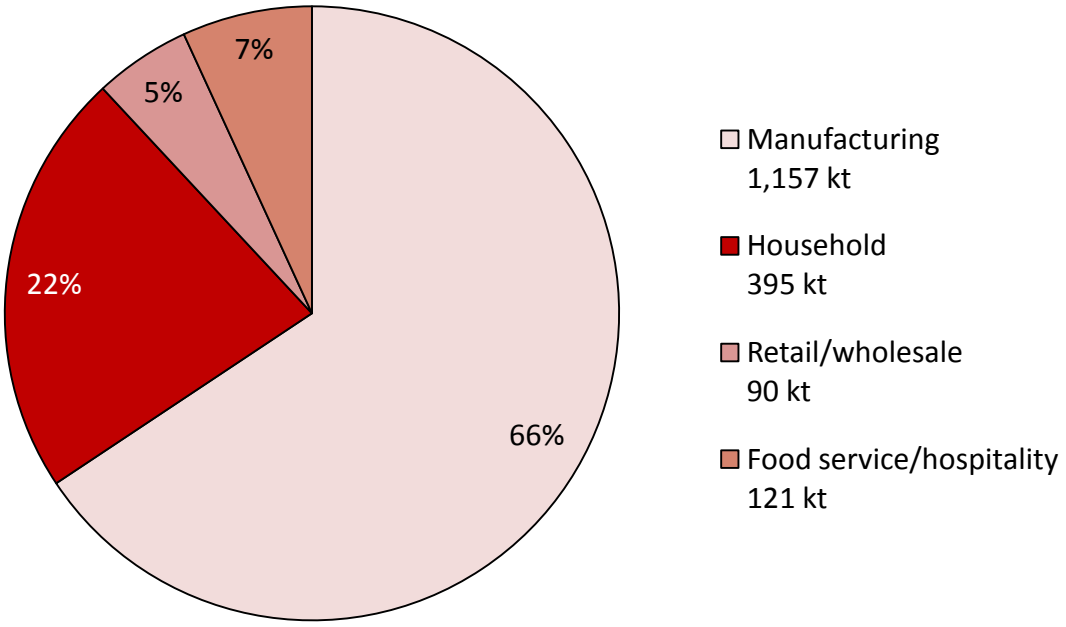

Figure 8: Food waste amount generated [kt] and percentage [%] by sector in Hungary, 2006. Data Source: [7].

According to Figure 8 the total amount of food waste generated in 2006 was 1,763 kt. Assuming a population of 10.066 mio inahibtabts in 2006 (http://countryeconomy.com) the normalized food waste generation over all food waste sectors equals 175kg/capita.

This data reported by [7] can be complemented with national studies on food waste to achieve more accurate and up-to-date figures.

Food waste is not treated as a separate section within the Waste Management Information System (EIHR) [52] but is distributed on different waste types. The five 'waste types' which are reported by the Hungarian Central Statistical Office with data from the Ministry of Rural Development are:

1. Agricultural and food industrial waste
2. Industrial and other economic waste
3. Construction and demolition waste
4. Hazardous waste
5. Municipal solid waste.

Within these five waste types, the majority of food waste might fall into the first and the fifth type. While there is little information and research in the waste type 'Agriculture and food industrial waste' about the contained food waste fraction the 'Municipal solid waste' type is further broken down into contained material groups. A clear picture on the generated amount of food waste in Hungary is, however, difficult to capture since records in the national literature are mainly focusing on the data collection of MSW and the therein contained fraction of biodegradable waste. MSW generated in Hungary is monitored in the Waste Management Information System (EHIR) which was introduced in 2004 [50]. Per capita figures in MSW are available from EUROSTAT [53]. The following figure shows total MSW generated [54] and per capita MSW [53] in Hungary from 2004 until 2013.

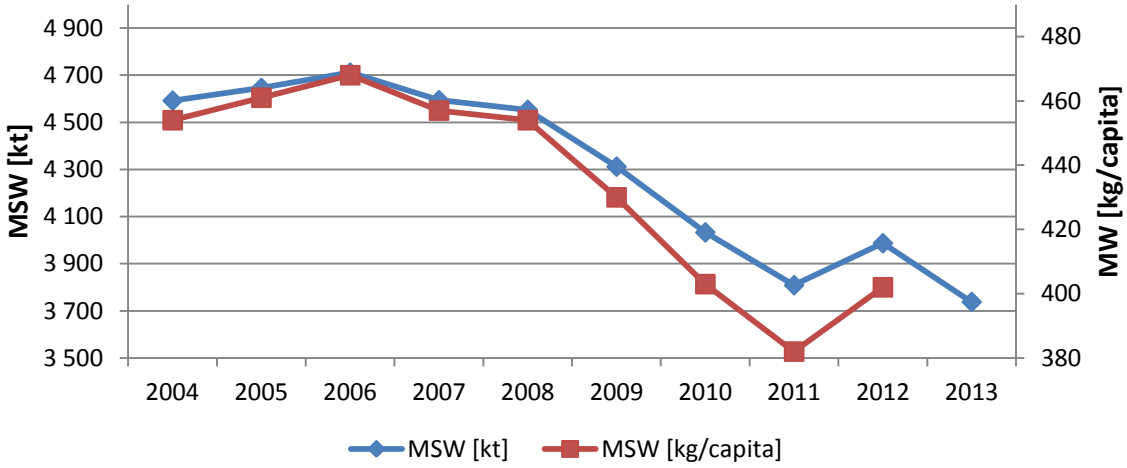

Figure 9: Total municipal solid waste (MSW) [54] [kt] and MSW per capita [53] [kg/capita] generated in Hungary in the years 2004-2013.

The composition of MSW is available in the Waste Management Information System (EHIR) and the following table shows the breakdown of MSW in seven distinct material groups in the year 2011:

Table 12: Composition of MSW in Hungary of the year 2011 [55]

Material Group	Paper	Plastics	Glass	Metal	Organic	Textile	Other
% in MSW	14.5	12.1	3.6	3.7	37.5	3.1	25.5

The material groups ‘paper’ and ‘organic’ are biodegradable and amount to 52 % of total MSW (2011). The content of 52 % biodegradable waste within MSW is reported to be similar over recent years [48], [49]. From the information in Figure 8, Figure 9 and Table 12 it can be inferred that for the year 2006 the fraction of food waste waste within total MSW is approximately 37 % and the fraction of food waste within biodegradable waste is approximately 72 %.

The waste generation of the type ‘1. Agricultural and food industrial waste’ according to the Waste Management Information System (EHIR) followed a strongly decreasing trend from 2004 with 6,250 kt until 2011 with 744 kt where it reached a close-to steady state between 797 kt and 933 kt tons in 2012 and 2013, respectively (see Figure 10).

Figure 10: Total agricultural and food industrial waste [kt] generated in Hungary in the years 2004-2013. Data source: Ministry of Rural development [54]

4.2.3.3 Food Waste Disposal Options

The treatment of waste generated in Hungary is again reported under the five above mentioned waste types '1. Agricultural and food industrial waste', '2. Industrial and other economic waste', '3. Construction and demolition waste', '4. Hazardous waste' and '5. Municipal solid waste'. The Hungarian Central Statistical Office provides datasets from 2004 until 2013 about the treatment methods of these five waste types. The treatment of waste types 1 and 5 are illustrated in Figure 11 and Figure 12 since these types contain considerable amounts of food waste.

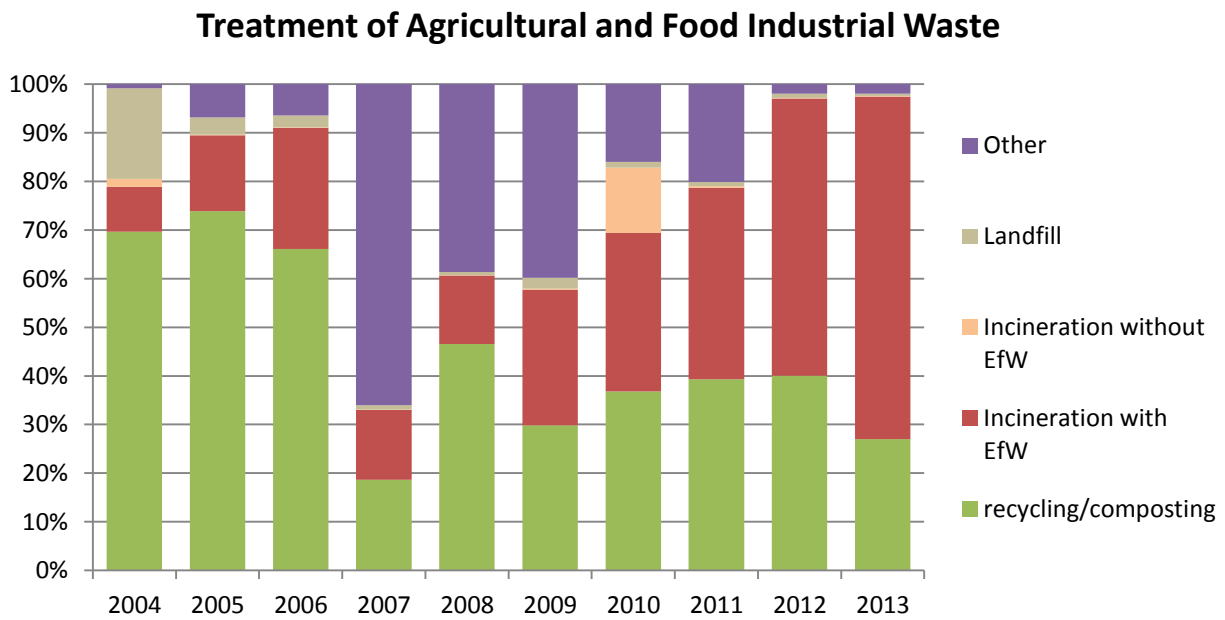

Figure 11: Treatment of agricultural and food industrial waste in Hungary from 2004 to 2013. EfW = Energy from waste. Data source: Ministry of Rural Development, Waste Management Information System (EHIR) [52]

Recycling and composting of agricultural and food industrial waste shows a dramatic decrease over the time period 2004 – 2013 (see Figure 12). This is due to a methodological change in 2008, since definitions for material groups effectively qualifying as waste under this waste type changed. Regulations for the treatment of animal by-product became stricter which led to a decrease of potential recycling of this waste

type [56]. Regarding the incineration of agricultural and food industrial waste it can be observed that the rate is steeply increasing from 2008 with 14% until 2013 with 70%.

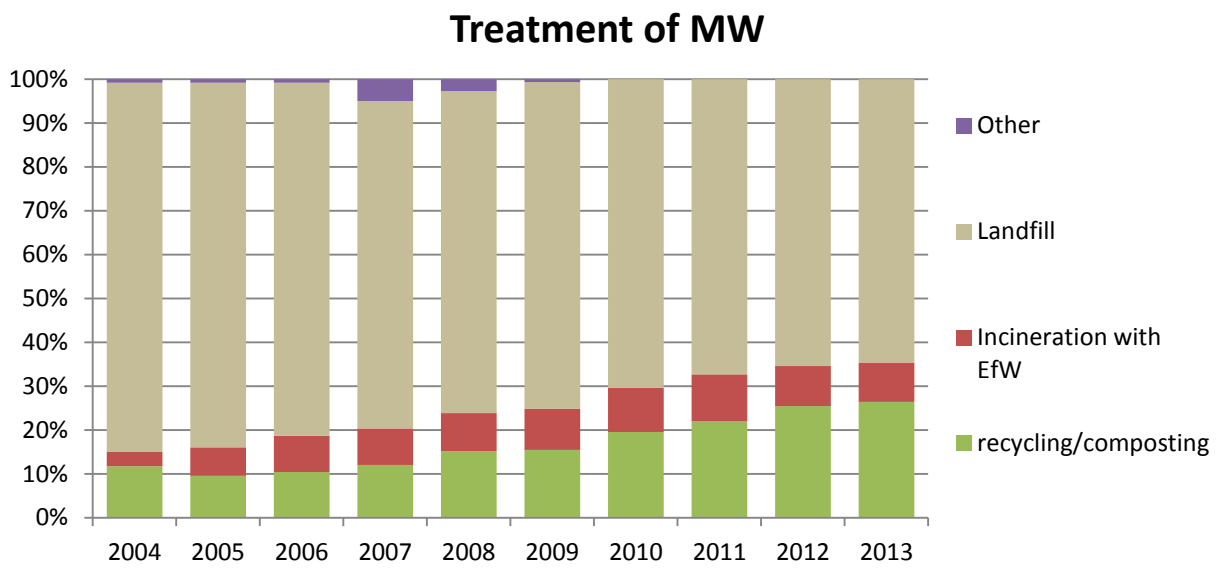

Figure 12: Treatment of municipal waste in Hungary from 2004 to 2013. EfW = Energy from waste. Data source: Ministry of Rural Development, Waste Management Information System (EHIR) [52]

The trend in recycling and composting of MW as illustrated in Figure 12 is increasing since 2005 with 10 % until 2013 with 26 %. The study of the ETC/SCP from 2013 [49] points out that material recycling of metal, glass, plastic, paper and cardboard contributed the highest share to this treatment (18 % in 2010), whereas composting and other biological treatment was involved with a smaller fraction (4 % in 2010).

Incineration of MSW has remained almost unchanged since 2006 with a share of 8 % to 11 % among the different treatment methods. Incineration is seen more environmental friendly in comparison with landfill since it provides the option of recovering energy and reducing further waste volumes [56].

The least environmental friendly treatment according to the study of the ETC/SCP from 2013 [56] is landfill and prevails in the waste type of MSW still as the most common treatment and disposal method. Reasons for the high share of landfill are reported to be the lower expenses for this treatment in comparison to recycling or incineration. However, landfill remains at high expenses for the environment as nutrients, heavy metals or other toxic compounds are leached into the soil and groundwater and greenhouse gases are emitted and valuable land space is lost. Landfill is furthermore described to be harmful to air, soil and water and to be detrimental for human beings, flora and fauna.

The percentage of total bio-waste recycled in Hungary was calculated in a study from the institute for technology assessment and systems analysis [51] to approximately 10 % based on EEA data in the year 2010.

The capacity for the treatment of biodegradable waste in Hungary has increased in the last years. 45 composting plants holding a compost product licence are in operation in Hungary. The associated total quantity of the compost end-product is 250 to 300 kt per year. Based on estimations from the Hungarian Compost Association 150 composting plants with a total capacity of 750 kt will be reached by 2016 [57]. Regarding the pre-treatment of biodegradable waste, six mechanical-biological treatment plants are in operation in Hungary with a total throughput of 300 kt per year [58]. Five anaerobic digestion plants were

operating in Hungary in 2009, the resources used are mostly agricultural waste like manure in combination with agricultural residues.

The Hungarian National Waste Management Plan (2014-2020) contains a forecast on the treatment of municipal waste as well as bio-waste which is featured in the following table:

Table 13: Projected treatment of municipal waste in Hungary from 2014-2020. Source: National Waste Management Plan (2014-2020)

Municipal waste [kt]	2014	2015	2016	2017	2018	2019	2020
Collected waste (total)	4,100	4,150	4,200	4,250	4,300	4,350	4,400
Landfill	2,690	2,590	2,550	2,560	2,580	2,600	2,640
Energy recovery	410	410	410	410	410	410	410
Reuse in material	800	850	880	900	910	920	930
Total bio-waste [kt]	**1,271**	**1,287**	**1,302**	**1,318**	**1,333**	**1,349**	**1,364**
Biological treatment (composting, biogas)	200	300	360	380	400	420	420
Deflected bio-waste (energy+biological treatment)	327	427	487	507	527	547	547
Landfilled bio-waste [kt]	**944**	**859**	**815**	**810**	**806**	**801**	**817**

4.2.3.4 Causes of Food Waste

Imprecise Information: A large contribution of generated food waste in Hungary evolves in the manufacture and retail/wholesale sector. Research within the EU funded project FoRWaRD in cooperation with the Hungarian food bank pointed out that imprecise information on the real amount of food required in the retail sector are often the cause for food waste [59]. Sale forecasts produced by retail chains are used as a basis for wholesalers/suppliers to produce a certain amount of products. The retail sector does, however, not take responsibility for such lists/forecasts and if just a fraction of the forecasted food is bought by the retail chain the remaining amount of products will be (food) waste.

Quality vs. price trade-off: Food waste is also reported to result from the manufacturing sector and associated attempts to reduce production costs. If the quality e.g. for packaging is lowered to achieve savings in the production, the staple products might be damaged more easily during transportation and loading which in turn increases food waste [59].

Product warranty: The primary cause for generated food waste at the consumer level is the fact that expired quality/shelf-life goods are legally classified as waste, while a significant part of these goods are not dangerous to human health and could still be consumed for a limited period of time. Many consumers are also not aware of the meaning of food product labelling such as “to be consumed until...” and “best before...” which also contributes to food waste [60].

Food security: The manufacturing industry entrusts the definition for safe consumption of products to the authorities. Some branches of the industry (e.g. meat and poultry) see a food safety risk in further utilizing expired quality/shelf-life goods while others (e.g. canning industry) would consider the further utilization but do not want to take the responsibility for this food safety decision [60].

4.2.3.5 Price Difference between different Food Waste management Options

Costs for different waste treatment options specific for Hungary as well as for the other EU Member States are generated in the model of waste management and generation and displayed in the associated report [8]. The following table shows the waste treatment costs extracted for Hungary:

Table 14: Waste treatment costs for Hungary, 2012, €/tonne of waste treated. CHP = combined heat and power, MRF = materials recovery facility. Source: Table adopted from [8]

Treatment option	Composting/ Digestion			Incineration				MBT					Land fill
	Open Air Composting	In-Vessel Composting	AD	Electric Only	CHP	Heat Only	Combustion only	Bio-stabilisation	Biodrying with no plastics recycling	Biodrying with plastics recycling	AD based MBT	Residual MRF + Combustion	
€/t	24	43	67	47	80	70	71	63	73	69	73	49	28

The costs in Table 14 represent 'private metrics' which reflect market conditions from the perspective of facility operators or manager. Retail prices, taxes and subsidies as well as a weighted average cost of capital are included.

Taxes on waste categories in Hungary could be indentified for the sector of Landfill to increase from €20/tonne in 2015 to €40/tonne in 2016. The tax for mechanical biological treatment is reported to half the price of the landfill tax.

4.2.4 Norway

4.2.4.1 Introduction

The Norwegian regulatory framework on waste management was developed in the early 1990s and revised and simplified in the following years. A ban on landfilling of easily degradable organic waste was imposed in 1992 taking full effect in 2002. An extension took place in the year 2009 prohibiting all landfill of biodegradable waste with a total organic carbon content of more than 10 % or where ignition losses exceed 20 %. In any case, all waste must be treated before it goes to landfill [61].

In October 1999, the Norwegian white paper in Environmental Policy and the State of the Environment was introduced which declared a set of national targets guiding the way to a resource efficient and waste reducing economy [62]. One target set recovery rates (=recycling, energy recovery and biological treatment) of total waste amounts to 75 % until 2010 with a further increase to 80 %. This target was reached in 2012 with 81 % waste recovery. Another national target aims at a total waste reduction and requires that the growth in quantity of generated waste will be considerably lower than the economic growth expressed in GDP. However, the Norwegian Environmental Agency reports that for the period from 1995 to 2012, the waste generation grew by 50 % while the GDP increased by 45 % [61],[63].

4.2.4.2 Food Waste Generation

For the total generation of food waste in Norway a collective estimate from two literature sources is used. The ForMat business project, establishing collaboration between producers, retailers and research institutions to combat wastage of food in the period 2009 to 2015, calculated the generation of food waste in the three sectors manufacturing, households and retail/wholesale in the year 2011 [64]. ForMat aims to support a 25 % food waste reduction by the end of 2015 in comparison to 2010. The continuation of this work will be ensured by the Matvett project after the lifetime of ForMat. Data for the food service and hospitality sector is derived from a study undertaken by J. Marthinsen et al. in the year 2012 [65]. Figure 13 shows food waste generated for four stages of the food chain with a total amount of 501 kt. Assuming a population of 5.051 mio inahibtabts in 2012 (http://countryeconomy.com) the normalized food waste generation over all food waste sectors equals 99kg/capita.

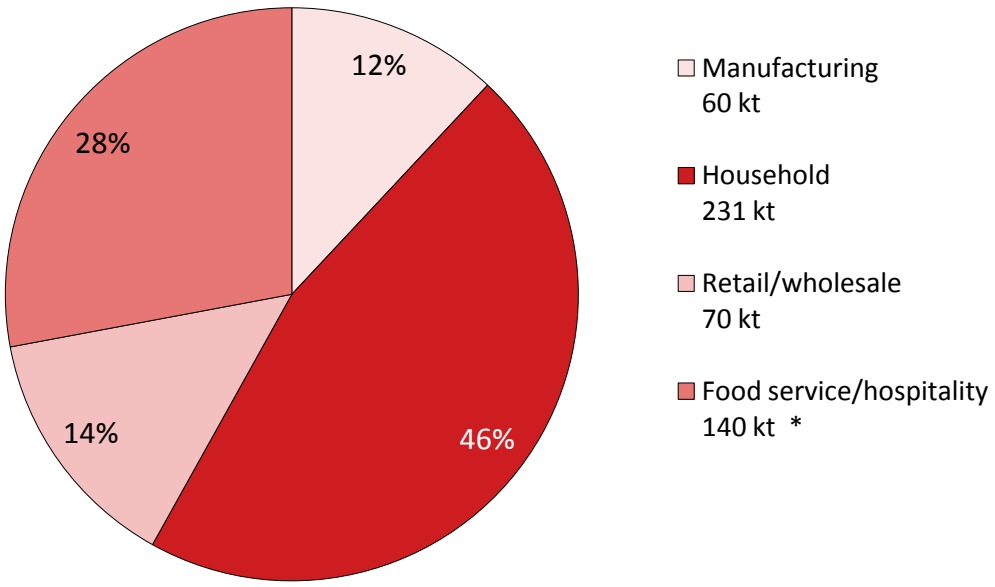

Figure 13: Food waste amount generated [kt] and percentage [%] by sector in Norway. Data from 2011 based on Hanssen & Schakenda (2012) [66] and (*) based on Marthinsen et al. (2012) [65] for food service/hospitality

The statistical office of Norway collects and publishes information on the wastage of food as well as on other waste sectors for free access (Statistics Norway, https://www.ssb.no/). The here available data on food waste is partly more up-to-date than the above presented in Figure 13 but is not reported for all of the four mentioned stages among the food chain, necessary for a close-to-complete overview.

The following paragraphs will give further brief insights into the four stages of food wastage illustrated in Figure 13. The ForMat project, supported by the Norwegian government, aimed at establishing networks between the four most important actors in the food value chain (producers, retailers, research institutions and consumers) in order to develop annual statistics of food waste. The project addresses nine product groups (frozen food, fresh fruits and vegetables, fresh bakery products, ready-made food, fish, meat, eggs, dairy products and dry goods) and aligns all research and outcomes to those methodological groups. Within this central methodology the ForMat project attempts to collect information of different food chain stages as standardized and uniform as possible.

Manufacturing: Fresh bakery products were ranked highest in regards to food waste among all food product groups in the research period 2009 to 2013. The report shows, that approximately 14 % of total produced fresh bakery goods are wasted in the production stage in 2013. In average of all nine product groups, 4.3 % of the total produced food was wasted at the production phase in 2013. The quality of data collected within the manufacturing stage by the ForMat project is subject to constant improvement. In order to reach the project's aim and build a reliable data basis on current and future food waste components in Norway ForMat provides standardised methodologies to an increasing number of respondent manufacturers. These methodologies are defined and demarcated through a ForMat study dedicated to a mapping method for food loss in the food processing industry [67].

Households: The ForMat study collected data on food waste in households by means of bi-annual questionnaires from a total of 12,000 respondents in the period 2010 to 2014. For the nine product groups consumers responded to discard between 5 % (e.g. some dry goods) and 31 % (pan leftovers forgotten in the fridge). Statistics Norway reports on the average household food wastage from consumers in the year 2011 that each inhabitant discarded 78 kg of food waste, of which 46 kg was still edible [68]. On the household level Gjerris and Gaiani (2013) [69] estimate that 21 % of the total food bought per year is wasted, 204 kg of total 952 kg, respectively. It is furthermore stated within the ForMat project that on average young adults (19-26) and young families (29-39) discard the most food [70].

Retail and Wholesale: The 70,000 tonnes of food waste from the retail/wholesale sector in 2011 (see Figure 13) are composed of 2,000 tons (approx. 3 %) from the wholesale stage and 68,000 tons (approx. 97 %) from the retail stage. Within **wholesale** fruits and vegetables generated by far the highest percentage of waste, amounting to approx. 1 % waste compared to the amount sold in the year 2013. The average of wasted food in the wholesale stage was 0.24 % of the entire food sold. In regards to the **retail** stage the respondents for the data collection increased from 29 shops in 2009 to 89 shops in 2013. This development marks on the one hand a dramatic change in the data basis during the investigation period but provides on the other hand the opportunity to increase the data quality for future investigations. In average the investigated retailers wasted 3.4 % over all food categories compared to the food sold in 2013 while fresh baked goods showed among all categories with 8.6 % the highest loss compared to the sales value.

Food service and hospitality: This sector is defined to cover all operations of preparing and serving food outside homes and encompasses restaurants, hotels, canteens and catering. Food waste in this sector has been less thoroughly researched compared to the other three sectors (see Figure 13) and therefore constitutes a more uncertain data source. This sector encompasses a variety of operations which might appear in terms of reporting in other sectors (e.g. catering and fast food partly generate waste ending up as household waste; leftovers are flushed from plates and pots and succeed into sewage). Marthinsen et al. 2012 [65] state that out of the 140,000 tons food waste in the food service and hospitality sector 94,000 tons were avoidable. Furthermore, the study suggests that as an average in Nordic countries 27 kg food waste per inhabitant originates from the food service and hospitality sector and 18 kg hereof were avoidable.

4.2.4.3 *Food Waste Disposal Options*

The treatment of food waste is not reported separately in Norway but is subsumed under other waste streams. The following data is acquired from Statistics Norway and displays the treatment of two waste streams, wet organic waste and household waste, in which food waste constitutes large fractions.

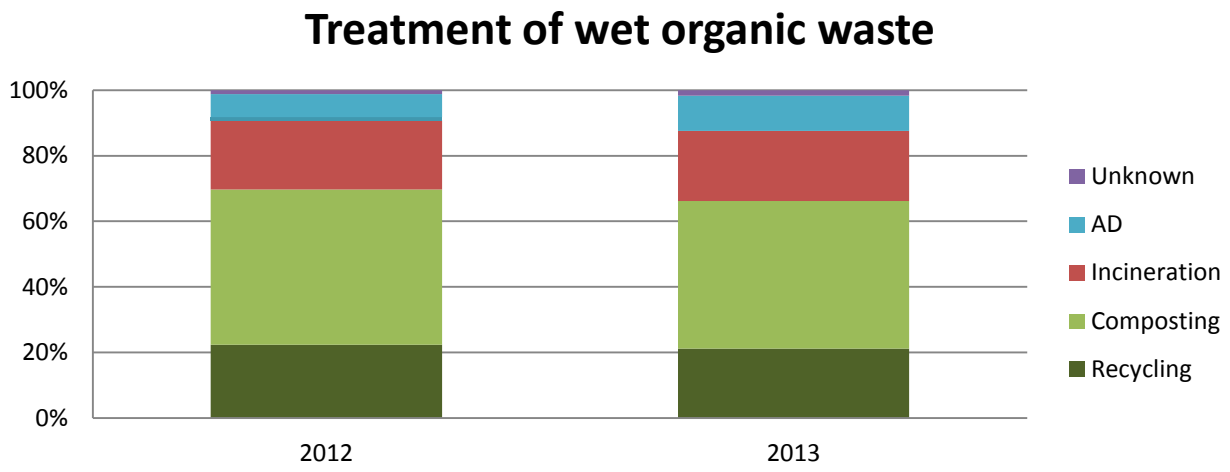

Figure 14: Treatment of the wet organic waste fraction (total biodegradable waste excluding park- and gardening-, wood –, paper and cardboard wastes as well as sludge) among the total waste generated in Norway in 2012 and 2013. Data Source: Statistics Norway; Waste accounts, 2013.Published June 2015 (ssb.no)

Figure 14 shows the treatment of the wet organic waste fraction among total waste in Norway. This waste stream excludes park- and gardening waste, wood waste, paper and cardboard as well as sludge from the year 2012 onwards. Wet organic waste is defined as easily decomposable organic waste "[...] like discarded food and processing waste from the manufacturing of food products, etc." [71]. This definition suggests that wet organic waste mainly composes of food waste but might also include other material groups. In 2011 the methodologies and categories for the accounting of wet organic waste changed so that a visualization of the post-2011 period would not result in a comparable graph to that in Figure 14. Wet organic waste is present in household waste (8 % among total household waste in 2014) and Figure 15 shows the treatment of this waste stream from the years 2012 until 2014.

Both, the **recycling** rates presented in Figure 14 and Figure 15, show decreasing trends in the observation periods, respectively. Statistics Norway reports that the recycling rates of household waste exhibit a steeper decrease compared to the recycling of the wet organic waste stream among total waste in Norway. Recycling of bio-waste means predominantly the usage as fodder for animal livestock [72].

Wet organic waste shows with 47.8 % in 2012 and 45 % in 2013 (see Figure 14) overall higher composting rates compared to the composted fraction of household waste (between 11 % and 12.5 %, see Figure 15). This difference can be explained by the nature of the two waste streams, with wet organic waste being more suitable for composting (and AD) than drier household waste with a mixture of organic and inorganic substances more suitable for incineration. However, the composting rates of both, wet organic waste and household waste, show decreasing trends in the investigation periods. In 2011, Norway had 62 centralised biological treatment plants with a material capacity of 455,000 tonnes (86 % composting and 14 % AD) [63].

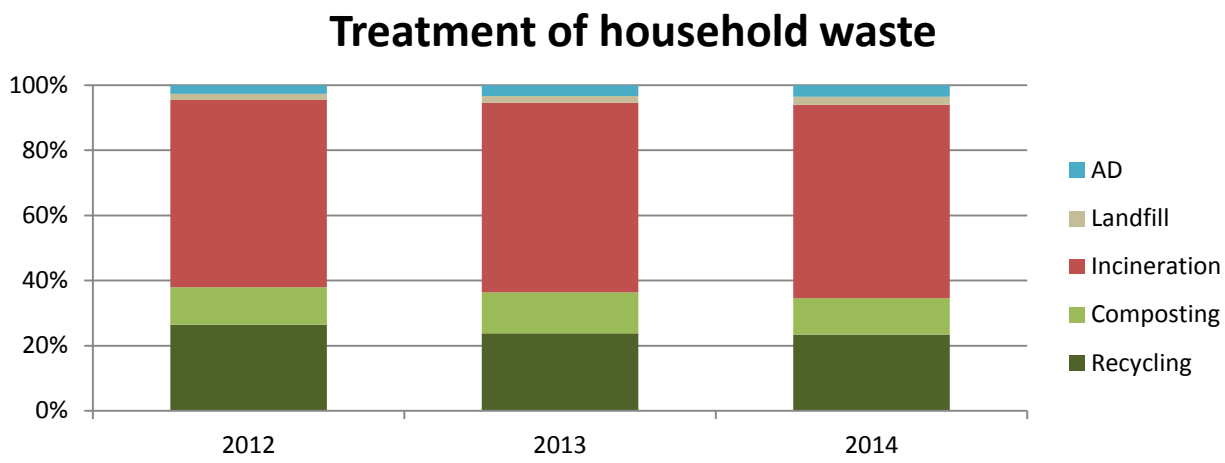

Figure 15: Treatment of household waste in Norway from 2012 to 2014. Data Source: Statistics Norway, Waste from Households, July 2015 (ssb.no)

It can be inferred that the decreasing trends in composting and recycling observed in both waste streams (wet organic – and household waste) are directly linked with increasing waste **incineration** rates. A comparison by Statistics Norway of incinerated waste amounts shows that in 2014 twice as much of total waste was incinerated than compared to the year 2004. This growth is associated to recent efforts of the waste-to-energy sector in Norway as waste (especially the biogenic fraction) is seen as a renewable energy resource to substitute fossil sources [73].

The already mentioned national regulation imposing a ban to **landfill** biodegradable waste from 2009 onwards explains the absence of the landfill category in Figure 14 . Household waste (see Figure 15) is still being landfilled with slightly increasing amounts and percentages from 1.8 % in 2012 to 2.4 % in 2014. The reason for the still practiced landfilling of household waste lies in the composition of this waste stream and the associated fact that the contained non-biodegradable substances are still permitted to landfill [68].

The total generation of biogas from **anaerobic digestion** (AD) has been growing in recent years in Norway, as illustrated in Figure 14 and Figure 15. In 2012, 34 plants for AD treatment existed of which 6 were specialized in solid waste treatment, 5 in manure treatment and 23 in sewage sludge from wastewater treatment [74]. A national biogas strategy was presented by the Norwegian Ministry of Climate and Environment in the year 2014, demonstrating “considerable potential for biogas production until the year 2020 and the potential for a further increase after that.” [75]

The **export and import** activities of waste in Norway are not reported separately for food waste but for total waste streams by Statistics Norway. In the year 2013, export of waste for final treatment and disposal played with 1,713 kt a greater economical role than import of waste with 399 kt, being approximately 15 % and 4 % of the total waste generation in that year, respectively. A study from Becidan (2015) specified one of the export destinations of MSW for final treatment and disposal to be Sweden, receiving several thousand tonnes per year [73].

4.2.4.4 Causes of Food Waste

The ForMat project studied the causes of food waste in various stages among the food chain [64]. In the stage of **manufacturing/production** the following root causes have been identified:

- Expiry times of products are shorter than industrial thresholds would allow.

- Products damage during storage.
- Errors during production, packaging or labelling.
- Products do not comply with other standard requirements.

In the **retail stage** actors most often named one cause of food waste to be prevailing above others - food cannot be sold because it has past the indicated expiry date. Further important causes are:

- Amount to be ordered: Estimations are difficult, especially seasonal products and those sensible to weather conditions (e.g. barbecue items).
- Retail units (at delivery) contain often more consumer units than a shop can sell.
- Range of products is too wide: If purchases are diminishing in periods many product groups show increased waste.

Consumers are situated at a later position on the food chain and thus strongly affected by relayed causes from earlier stages (i.e. manufacturing, wholesale and retail). These causes are passed on from stage to stage and encounter consumers mostly at the interface with retailers (e.g. shopping). In this interface, the following statements were most often named to be causes for food waste:

- Expiry dates induce selective consumer behaviours without empirical evidence or knowledge. E.g. if a number of items from the same product with different expiry dates is available to choose from, those with the earliest expiry date are often not selected for purchase, even though they might be perfectly fit for human consumption.
- Quality of the packaging or products itself: Greatly affected by the processing steps (number, length) prior to selling.
- Number of products in primary packaging units is often too large for consumers.
- Additionally to the causes imposed from prior stages in the food chain, consumers discard food for a range of other reasons:
- Too much food is bought and expires/becomes unfit for consumption.
- Expired food is thrown away instead of checking its further usability.
- Quality of products is reduced during home transport or inappropriate storage conditions.
- Many people justify wasting food if it is used to generate biogas.
- Meal portions (cooked or purchased at kitchens) are often too big and residuals have to be discarded.

The ERA net SUSFOOD project COSUS (COnsumers in a SUStainable food chain) attempts to respond to a part of the above named consumer originated causes of food waste [76]. It was instituted by the Norwegian University of Life Sciences for the duration from 2014 until 2017 and is mostly directed to Nordic countries. Suboptimal food is the focus of this research project as it attempts to understand consumer behaviour and encourage a (more) sustainable food choice. One of the first project-derived research insights into this topic are published by a study on “Consumer-Related Food Waste: Causes and Potential for Action” [77]. It calls for more awareness amongst consumers through educating them in ‘food skills’ on how to assess food as well as manage and plan food purchasing and handling.

As the **food service/hospitality** sector directly interacts with consumers to serve food outside their homes it is situated on a late stage on the entire food value chain. Recent research about food waste in the

hospitality sector has predominantly focused commonly on the four Nordic countries (Denmark, Finland, Norway and Sweden) [65], [78]. According to the Danish Diet & Nutrition Association in 2011 94 % of canteen leaders in the Nordic hospitality sector are aware of avoidable food waste and that something needs to be done against it [79]. Moreover, the association states general statistics on food waste in the Nordic hospitality sector, summarized and quoted by [65]:

- 16 % of canteen leaders indicate to know exactly how much food is lost,
- 74 % indicate to have a feeling on the amount of food loss,
- 19 % report to have avoidable food waste from pre-prepared food, and
- 95 % specify that food is wasted 'outside' the kitchen.

Survey results in the hospitality sector assessed by Marthinsen et al. 2012 [65] and specifically edited by Sundt, 2012 [78] on the specific causes of food waste are the following (sorted by importance for the generation of food waste):

- Purchasing routines
- Menu planning
- Internal education/training on costs
- Production planning
- Routines for right portions
- Storage routines
- Utilize unused food in other recipes
- Training on environment and waste
- Routines for following up on buffets
- Reporting on costs (food/total costs)

4.2.4.5 Price Difference between Different Food Waste Management Systems

As prices neither for food waste- nor for other waste management systems are transparently published for Norway, average costs for the year 2011 for two different waste treatment options are reported from the Norwegian Waste Management Association [72]:

- Biological treatment (combined cost for composting and AD): 74 €/tonne
- Incineration with energy recovery 72 €/tonne.

The above named costs represent the most important treatment options for organic waste (compare waste treatment options in Figure 14 and Figure 15). The figures show considerable waste fractions treated by recycling or disposed of to landfill. However, landfilling of biodegradable waste is prohibited since 2009 (see Introduction) and according to the Norwegian Waste Management Association recycling of biodegradable waste means the usage as fodder for animals for which costs can vary greatly [72].

4.2.5 United Kingdom

4.2.5.1 Introduction

Waste management in the UK is regulated by the National Waste Strategy. It is a devolved matter, thus administrations of Scotland, Wales and Northern Ireland are responsible for developing waste strategy and policy in those regions. Despite differences in the specifics of policy measures, national priorities for waste have been consistent with each other [80].

The Department for Environment Food & Rural Affairs published the Waste Management Plan for England in 2013 [81]. The plan builds upon the "waste hierarchy" in order to pave the way towards a zero waste economy as part of the transition to a sustainable economy.

The Government has a range of measures to encourage the separate collection of bio-waste in the UK (constantly updated government policy paper on waste and recycling [82]); however, local councils are responsible to decide whether to offer a separate collection [81]. The UKs Waste and Resources Action Programme (WRAP) defines food waste as all food and drink discarded throughout the entire food chain and has divided it into three types of waste: **unavoidable** waste, **possibly avoidable** waste and **avoidable** waste[83].

It is becoming a priority for local authorities in the UK to divert food waste from disposal and by May 2011 47 % of local authorities in the UK were providing a food waste collection service to householders. Furthermore, an increasing number of local authorities are looking for opportunities to collect food waste from small businesses and schools as well [84]. Initiatives in the topic are mainly championed by WRAP, which launched the Love Food Hate Waste campaign in 2007 to help deliver practical ways to reduce food waste [85]. WRAP also expanded an agreement with the food industry, called the Courtauld Commitment which is a voluntary agreement aimed at improving resource efficiency and reducing waste within the UK grocery sector [86], [86].

A 2013 report from WRAP revealed that the amount of food and drink thrown away that would be suitable for consumption fell by 21 % between 2007 and 2012 [86]. In accordance with the waste hierarchy the Government supports the redistribution of surplus food to humans, and if not suitable for that purpose then used for animal feed (under strict conditions) [88]. In the case of unavoidable food waste, which cannot be prevented or redistributed for consumption, the government has identified anaerobic digestion (AD) as the best technology currently available for treatment. AD is incentivised through renewable energy subsidies and the Government has also adopted an Anaerobic Digestion Strategy and Action Plan to overcome barriers to the uptake of the technology [81].

However, the 2015 market report from the Anaerobic Digestion and Biogas Association (ADBA) calls attention to the stagnation of separate waste collection in England, which can hinder the development of the British AD industry [89]. Separate collections of food waste have been increasing in Scotland, Northern Ireland and Wales because of new legislative requirements. In England (84 % of the UK population), separate food waste collection is not available for 58 % of households (neither on its own nor mixed with garden waste), due to the absence of policy favouring segregated food waste collections [89].

Despite the challenges the sector is facing, the UK opened its 106th AD plant in 2014 increasing the total number of plants in operation to 388 (of which over 91 are food waste AD facilities) which have an electrical equivalent capacity (electricity and biogas) across all sectors of over 447 MW [90]. Furthermore, ADBA estimates that with reasonable policy changes over 500 plants could be opened by 2020 in the UK [89].

Although data on waste in the UK is widely available, different reporting standards remain the main source of unreliability. On the one hand the UK is obliged to report to the EU where data has to be calculated in accordance with the Waste Framework Directive, however local authorities in England may also use an alternative measure [91]. Therefore data from different sources cannot be reconciled without considerable assumptions. Data on waste can be obtained from three main sources:

- Reports made by the Department for Environment, Food and Rural Affairs (Defra) which are calculated in accordance with the Waste Framework Directive to be reported to EUROSTAT, such as UK Statistics on Waste 2010-2012 [91].
- Other sources managed by Defra (for example the WasteDaraFlow (WDF) website (*http://www.wastedataflow.org/*), the UK's waste reporting and data collection system for municipal waste, where data on waste collected by local authorities can be found).
- Reports conducted by WRAP, which include specific data on food waste.
- According to Downing et al. (2015) "the UK data on food waste [compiled by WRAP] is generally considered to be significantly more accurate than for other countries" [88].

The Waste Framework Directive [2008/98/EC] requires operators submitting waste data to use the set of definitions of the European Waste Catalogue (EWC) for a consistency in analysis and reporting. The exception is local authority waste data which is reported under categories specific to the data collection system WDF [92]. WDF aims at complying with different conditions in the four UK countries (England, Wales, Northern Ireland and Scotland) and at supporting evidence-based decision making [93].

4.2.5.2 Food Waste Generation

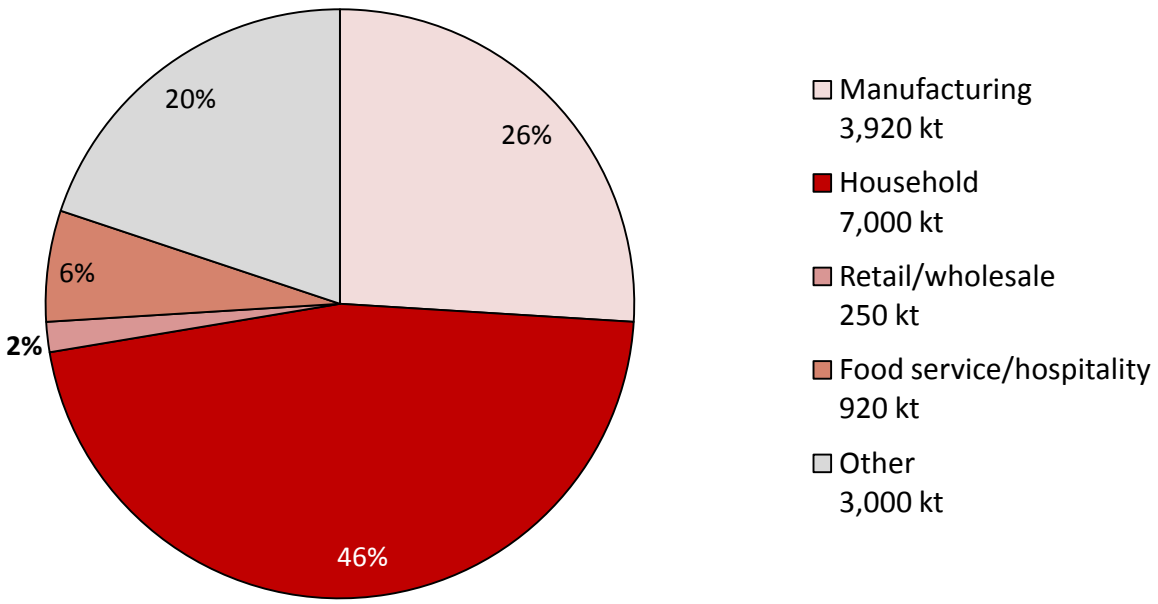

Figure 16: Food and Drink waste amount generated [kt] and percentage [%] by sector among the food chain in the UK 2013. Data source: [94]

The latest data on food waste is reported by WRAP for the year 2013. It is estimated that 15 Mt of food and drink was wasted in the food chain in the UK in 2013. Assuming a population of 64.1 mio inahibtabts in

2013 (http://countryeconomy.com) the normalized food waste generation over all food waste sectors equals 235kg/capita.

Around one third of the 41 Mt food purchased (mainly for use at home) becomes waste. Most of the avoidable food becomes wasted because it is not eaten in time and the most commonly discarded foods in this category are bread, potatoes and milk. Unavoidable food waste, on the other hand, is inedible and could never be sold such as mussel and shellfish shells, teabags, coffee grounds, fruit/vegetable peel, pips and stones [94].

Food waste, along with other forms, falls within the category of organic waste which represents the largest proportion of household waste at 42 % [95].**Households** are responsible for close to half of total food waste (7 Mt) and make up the highest proportion of waste generation in the food chain. According to the Department for Environment, Food and Rural Affairs, 4.2 Mt (60 %) were avoidable, 1.2 Mt (17 %) were possibly avoidable and 1.6 Mt (23 %) were unavoidable out of the 7 Mt of household food and drink waste [88]. As a report by WRAP in 2008 an average household wasted 270 kg of food each year (5.3 kg per household per week) of which 170 kg (3.2 kg per household per week) or 60 % could have been avoided [96].

The overall waste estimate for the food **manufacturing sector** is 4.9 Mt per year out of which 3.9 Mt (78 %) represents food waste and the remainder is packaging waste and other wastes. Although 90 % of the food and drink manufacturing sector consist of smaller companies (with less than 100 employees), WRAP estimates that those are only responsible for less than 4 % of the total waste production [97].

According to WRAP, the **Hospitality and Food Sector (HaFS)** was responsible for 919,300 tonnes of food waste in 2013 out of which 683,600 (74 %) were avoidable and 235,700 (26 %) were unavoidable. Around 40 % of food waste (excluding drink waste) arises within restaurants and pubs, and a further 26 % from education and healthcare sectors [98].

The **Retail Sector** is responsible for 2 % of the total food waste generation, but some retailers are involved with charities and organisations to help them redistribute this surplus food [94].

The **other sectors** of the food chain are estimated to be responsible for an additional 3 Mt of food waste. These include, for example, food thrown away by consumers out of home (e.g. from home-made lunches at work, as litter, in litter bins) and the pre-factory gate stages of the food supply chain [98].

4.2.5.3 Food Waste Disposal Options

This chapter is divided into two sections. The first section presents waste disposal in the UK broken down to the different sectors along the food chain, following the same structure as in the previous chapter. This section consists of data from researches conducted by WRAP. In the second section, the treatment of waste collected by local authorities in England is presented. Although the data in this section is not specific to food waste, it shows the advancement of different treatment options of waste collected by local authorities over time.

Treatment of food waste along the food chain in the UK

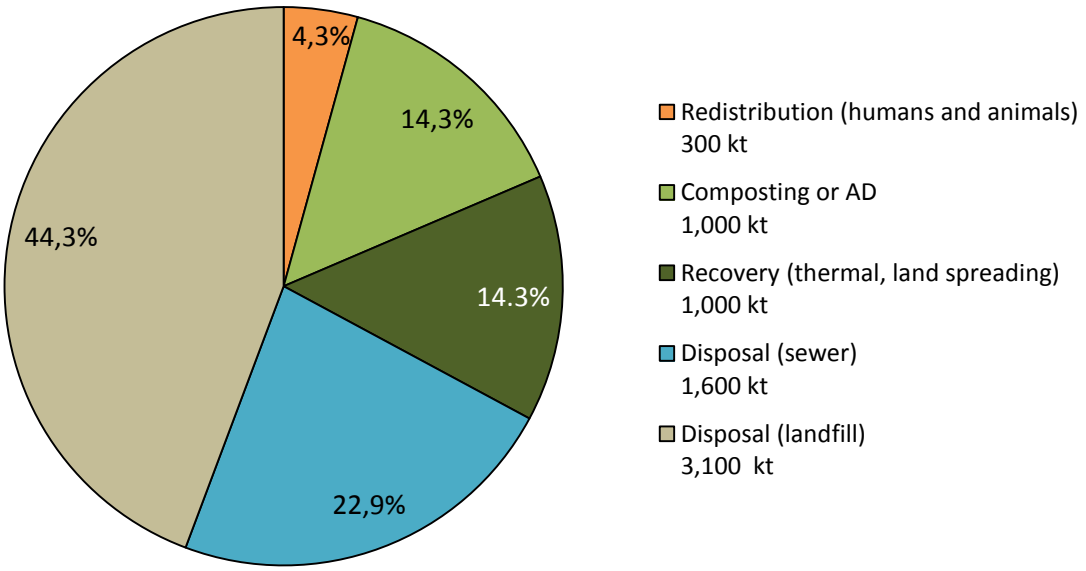

Figure 17: Treatment and disposal options for household food waste by amount [kt] and percentage [%] in the UK, 2014. Land spreading is the process of coating the food waste (or other organic waste) to the soil thereby providing agricultural benefits by enhancing the physical, chemical and biological characteristics of the soil [99]. Data source: [88]

Figure 17 shows the treatment of total 7 Mt of food waste generated by households. Most of the collected food waste (4.7 tonnes or 67.2 %) is not separated from other fractions collected by the local authorities and becomes disposed of either via sewer or landfill. The availability of composting windrow or in-vessel composting varies between local authorities. This implies that the amount of household waste sent to landfill also varies among local authorities [88]. ReFood, an internationally active company with the aim to divert food waste from landfill, launched the "Vision 2020 – Achieving zero food waste to landfill" encouraging a wide range of industrial, civil and scientific stakeholders towards this ambitious aim [100]. Most of the food waste which is collected separately is composted using in-vessel composting, but a small (but growing proportion) goes to AD [101].

WRAP assumes that nearly all food waste in the **manufacturing sector** is avoidable, because the vast majority of the generated waste is not classed as waste but rather as a by-product of some sort. Although a small proportion of manufacturing waste still remains unavoidable, the majority of this material is disposed to animal feed [98].

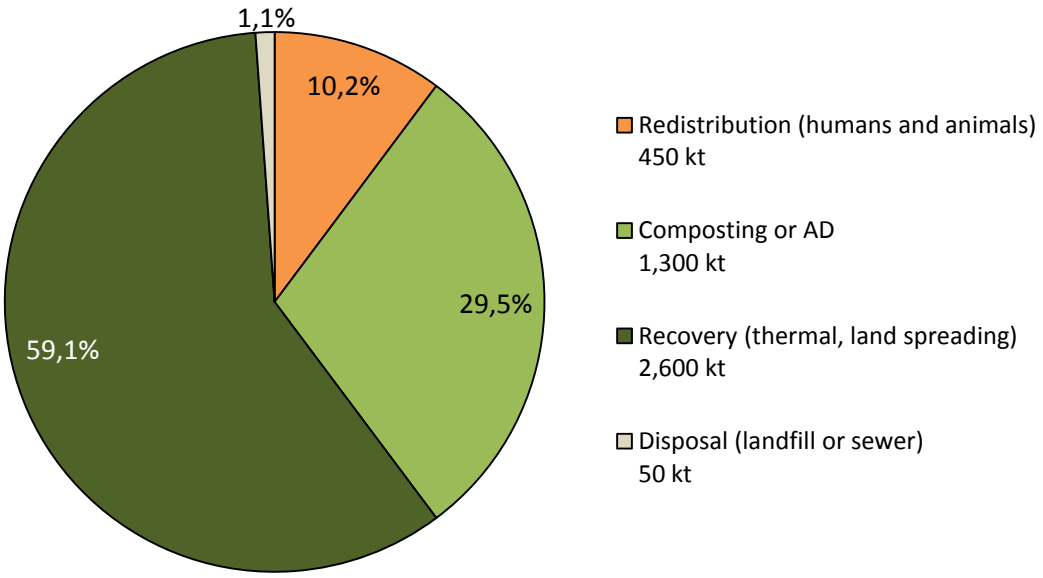

Figure 18: Treatment options for food waste related materials in the food manufacturing sector by amount [kt] and percentage [%] in the UK, 2014. Data source: [88]

Figure 18 shows the treatment of materials related to food waste in the **manufacturing sector**. WRAP estimates that the overall food waste generated in the manufacturing sector is around 3.9 Mt. Figure 18 also shows other 0.45 Mt of material which is food redistributed to humans and animals; however, it is not considered as waste therefore it is not included in the overall estimate of 3.9 Mt [97]. Most of the food waste is recovered by thermal treatment or land spreading (2.6 Mt), while the rest is composted or sent to AD (1.3 Mt).

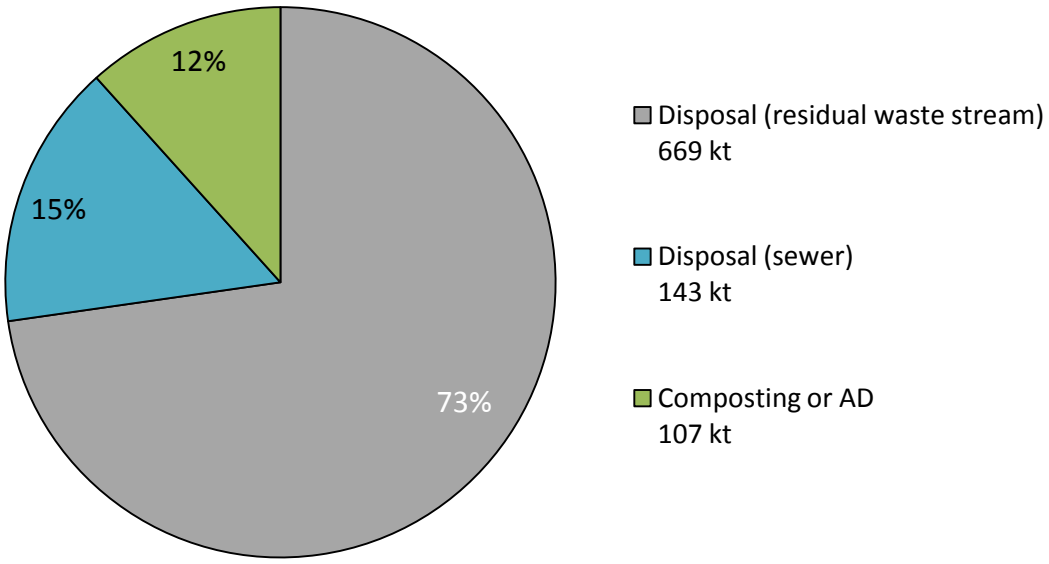

Figure 19: Disposal and treatment options for food waste in the hospitality and food sector (HaFS) by amount [kt] and percentage [%] in the UK, 2013. Data source: [19]

Figure 19 illustrates the disposal of food waste in the **HaFS.** The sector is responsible for generating 2.87 Mt of waste, out of which approximately 920 kt are food waste while the remainder falls under other types of waste such as packaging waste [88]. According to WRAP, 75 % of the food waste fraction (920 kt) is avoidable but only 12 % (see Figure 4) are recycled by either composting or AD [98]. 88 % of food waste is not recycled but goes either to the residual waste stream (73%) or is disposed of via sink disposal units (15 %).

The **Retail Sector** generates 0.25 Mt of food waste [94]. WRAP could not identify the disposal route for much of the food waste from retail, but information from Courtauld signatories suggests that about half is recycled (via on-site AD plants or composting [88]) and half sent for recovery (primarily via thermal treatment) [102]. However, the amount sent to landfill is currently unknown [88].

Treatment of waste collected by local authorities in England

Prior to 2010, the term 'Municipal Waste' as used in the UK was used in waste policies and nationally reported data to refer to waste collected by local authorities. Responding to a consultation and negotiations in 2010 on meeting the EU Landfill Diversion Targets, the terminology was changed by Defra introducing the terms **Local Authority Collected Municipal Waste (LACMW)** and **Local Authority Collected Waste (LACW)** [103].

LACMW includes household waste and business waste collected by the local authority being similar in nature and composition [103]. LACW is a broader term which encompasses all waste collected by or on behalf of a local authority. Included are household waste and all other waste under control of a local authority. This means that besides waste of the LACMW stream, LACW includes also non-municipal fractions such as construction and demolition waste [92]. Although LACMW might be a better basis for estimations on the amounts of food waste collected by local authorities, that data is not available, because local authorities report only LACW to WasteDataFlow.

As mentioned earlier, in the UK the separate collection of food waste is decided on a local level by authorities on a voluntary basis. In spite of this voluntary decision, the number of local authorities offering separate food waste collection has increased from 69 in 2010 to 2011 to 89 in 2012 to 2013 [88], however, ADBA reported a halt in this growth [89]. Besides this, 79 authorities collected and recycled 'combined mixed garden and food waste' in 2012 to 2013. As a result, the total amount of food waste that was separately collected and recycled in the UK increased by 86 % from 134 kt to 249 kt between the periods 2010/2011 and 2012/2013 [88].

Specific annual data for food waste is not reported by local authorities; therefore shows the treatment of LACW based on data from WasteDataFlow [104]. The figure only includes data from England but this gives a good overview of the UK since the majority of LACW in the UK is generated in England. For instance, in 2009 over 80 % of the total LACW in the UK was collected by local authorities in England (26.5 Mt of 32.5 Mt) [105].

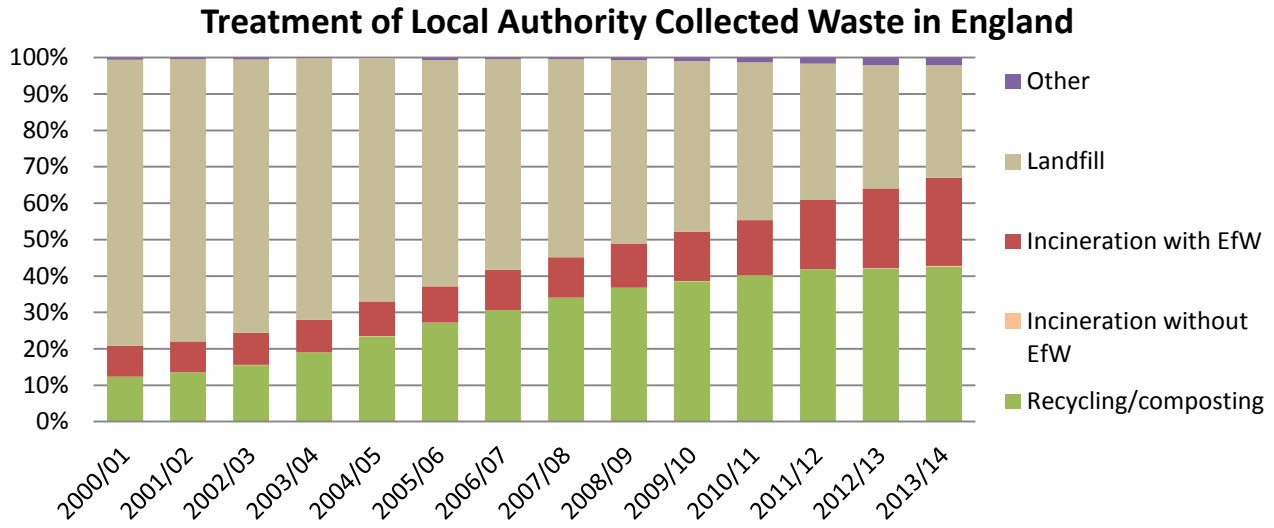

Figure 20: Treatment of waste collected by local authorities (LACW) in England from the reporting periods 2000/01 to 2013/2014. EfW = Energy from waste. Data source: [104]

Figure 20 shows a significant decrease in the proportion of waste sent to landfill. This decrease is not only in relative but also in absolute terms. Due to the heavy taxation of landfilling (elaborated in the last chapter) the amount of LACW sent to landfills decreased from 22.4 Mt in 2000 by around 75% to 7.9 Mt in 2014. At the same time, incineration with energy recovery increased by close to 260% from 2.4 Mt in 2000 to 6.2 Mt in 2014, while the amount of recycled/composted LACW increased from 3.4 Mt to 10.9 Mt from 2000 to 2014 [104].

As it can be seen above, in most of the cases there is no specific data available for the amount of food waste treated by anaerobic digestion, because literature shows mixed data on waste being composted and sent to AD. However, ADBA gives a recent and presumably accurate data on food waste sent to AD, based on its insights to the AD market in the UK. It estimates that in the UK in 2015, approximately 1.6 Mt of food waste is being sent to AD compared to 0.3-0.4 Mt in 2010 [89].

4.2.5.4 Causes of Food Waste

The roadmap from ReFood on the Vision 2020 investigated UK's food supply chain in order to gain an "understanding of where and why food waste is generated" [100]. From farm to fork, the study points out causes for food waste in the six stages agriculture, food & drink manufacturing, food distribution, grocery retail, catering & hospitality as well as households.

Agricultural sector: Food waste is mostly arising from the two categories, livestock and arable farming, while wastes from livestock farming is believed to be mainly unavoidable. Within arable farming activities 30 % of vegetable crops fail to fulfil exact market standards based on their physical appearance and are thus not harvested. Another cause of growing surplus crops is poor forecasting and planning [100].

Food and Drink manufacturing: The roadmap Vision 2020 identified in close cooperation with the Institute of Grocery Distribution (IGD) the main reason of food waste to be under- and overweight products, trimmings, technical errors, contamination of machinery [100]. WRAP specified the most food waste in the manufacturing sector is generated during peeling, washing, slicing, trimming and preparation, or result from incorrect storage, contamination, stock damage, spillage, spoilage, "off-spec" (products not meeting the specified or standard requirements) production or plant shutdowns [88].

Food distribution: As the roadmap Vision 2020 specifies, causes of food waste in the logistics sector of the food chain are closely linked to manufacturing and retail activities being e.g. packaging errors, inaccurate temperature control settings and contamination. However, this sector is suspected to generate more food waste than is actually reported. The reasons lay often in the lack of planning, unforeseen circumstances or human error and as a result food waste incidents (e.g. truck load accident) are frequently written off as 'natural shrinkage'. Another potential cause of food waste is the rising fuel costs which drive suppliers to consider lightweight packaging for foodstuffs. However, this might result in a high vulnerability of goods for transport damage and eventually loss [100].

Retail: According to WRAP food waste in the retail sector arises due to incorrect storage, contamination, stock damage or expiry, stock mark down (economic waste) and theft [88]. In addition, the Vision 2020 roadmap mentions two further important causes in this stage to be over-ordering due to the unacceptability of 'imperfect' food' and by encourage consumers to buy (and waste) more due to marketing multi-buy deals [100].

Catering, Hospitality and Food Sector (HaFS): For consumers in the case of out of home consumption, the three main causes of food waste are the portion being too big (41 %), ordering too much food (11 %) and ordering food which includes things the consumer does not like (11 %)[88]. A research from WRAP in the year 2013 showed that when deciding whether to leave food and what part of the meal to leave, customers consider the cost and value of what they have actually ordered. Therefore, most of the food left at plates is chips (32 %) and vegetables (18 %) [94].

The non-consumer related waste in the Hospitality and Food Sector is generated during peeling, washing, slicing, trimming and preparation, or result from incorrect storage, contamination, stock damage or theft [88].

Household: A research on consumer behaviour conducted by Lyndhurst (2015) for WRAP surveyed 1,865 Great Britain householders aged 16+ in 2006, where the main reasons for food being wasted in the home were [106]:

- *"buying too much – particularly due to the temptation of special offers such as buy one, get one free deals;*
- *buying more perishable food – often as the result of trying to eat more healthily;*
- *poor storage management – not eating food in date order (choosing food on impulse, often driven by 'spontaneous' and 'top up' shopping);*
- *ad hoc, rather than methodical, 'spring cleaning' of stored products;*
- *high sensitivity to food hygiene – one in five said they wouldn't take a chance with food close to its 'best before' date, even if it looked fine;*
- *preparing too much food in general;*
- *not liking the food prepared – 22% of families with children stated that not liking a meal was a cause of food waste;*
- *lifestyle factors – such as not having the time to plan meals, or having fluid work and social patterns (particularly true of young professionals); and*
- *evidence of a lack of awareness and understanding of the environmental implications of food waste."*

4.2.5.5 *Price Difference between Different Food Waste Management Systems*

Table 15: Waste treatment costs [€/t] of waste treated in the UK, 2014/2015. CHP = combined heat and power, MRF = materials recovery facility Source: [107]

Treatment option	Composting/Digestion			Incineration with energy recovery			Mechanical Biological Treatment (MBT)			Landfill	
	Open Air Composting	In-Vessel Composting	Anaerobic Digestion	All facilities	Pre-2000 facilities	Post-2000 facilities	Material recovery facilities (MRF)	MRF – contracts stated in 2014 (UK)	MBT/Mechanical Heat Treatment – Household waste	Gate fee only	Gate fee plus landfill tax
€/t	17-74	33-104	15-83	50-183	50-156	90-183	-60-119	-46-47	94-149	12-76	124-187

The fees in Table 15 are a result of a survey conducted by WRAP between December 2014 and March 2015. The pricing of municipal waste management services can be complex; therefore WRAP suggests users of this information to consider that [107]:

- Gate fees vary considerably for similar treatment/disposal options within and between regions/countries;
- Gate fee information for individual treatment options might not be directly applicable if multiple services are being procured;
- Gate fees are directly influenced by the precise terms of individual contracts;
- Gate fees may not be reflective of current market conditions, particularly where the market is evolving rapidly;
- The year on year changes in gate fees might also result from different sampling;
- The gate fees are presented in nominal terms with no adjustment being made for inflation.

The UK introduced a Landfill Tax in 1996 which sets a clear path for favourable waste treatment options and deters waste going to landfill [108]. The amount of tax levied is calculated according to the weight of the material disposed and whether it is active (all biodegradable wastes including BMW) or inactive waste [80]. In 1996 the tax rates were EUR 9.7/tonne for active and EUR 2.8/tonne for inactive waste [107], which in a dramatic rise increased to EUR 114.7/tonne for active and EUR 3.61/tonne for inactive waste by 2015 [109]. The aim of these year-to-year increases has been to give a strong economic incentive to diverting biodegradable waste from landfill due to the high environmental impacts of this waste type when sent to landfill [107]. The predictability of this escalator also allows local authorities and businesses to make more profound long term investment decisions in alternative waste treatment plants [109].

5 DISCUSSION

This report provides insight of different food waste management systems in EU-28 and more specifically for FR, DE, HU, NO and the UK. As methodology a literature research was chosen and contributed by internal discussions. During this research any data from the listed sources was not altered in any way. With regard to food production there were difficulties concerning data collection in small countries. Furthermore, difficulties with acquiring data led to rounding numbers and using average numbers out of the literature. This causes a less accurate interpretation. Also data concerning food waste generation is not always easy to determine in some Eastern European countries due to insufficient information. This led to the usage of average numbers when there is not enough information. An example herefore is, that no national statistics for the generation of food waste were published for Hungary. Instead, estimations on the food waste amount from an other (EU-wide) report had to be used. However, this data is seen to be less exact as compared to potential national sources (see section 4.2.3.2). There is a need for further studies to collect reliable data for Eastern European countries.

With this study it can be shown that even more in-depth investigations on national level are often too unspecific in regards to the required data (food waste generation, treatment, causes and treatment costs). It was also shown that data acquired from local/regional actors among the (food) waste chain deliver frequently the most reliable data. This in turn causes a relatively tedious procedure to collect data on a desired geographical extent.

Literature research is the basis of this study. However, finding reliable data is complicated due to a tremendous number of research that has been conducted. On the one hand, this enables to cross check outcomes of research, but on the other hand results of the studies differ in time frame and methodology. In other words, even though there is amount of research being done regarding the same topic they do not have the same perspective on goals and scope, time frame and most importantly methodology. That is the main reason for using one main data source for the general overview on the circumstances in the EU.

In contrast, for the country-specific studies a wide variety of national sources needed to be used since EU reporting requirements do neither specify food waste nor bio-waste as a seperate stream. This is reflected in the EUROSTAT database (http://ec.europa.eu/eurostat/data/database), as it presents data for each Member State specific to different waste streams which contain food waste among other material groups or are part of food waste. Additionally, treatment options for waste streams are represented on the EUROSTAT webpage in an aggregated manner not allowing the distinction into the specific treatment methods of interest for this report (see METHODOLOGY).

All in all it became clear in the process of this task that there is a need for research on detailed data on food waste management. There is especially a need for Eastern European countries in terms of reliability. If there is a need for detailed information of one country or region further research is required.

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