Source separation of MSW

An overview of the source separation and separate collection of the digestible fraction of household waste, and of other similar wastes from municipalities, aimed to be used as feedstock for anaerobic digestion in biogas plants

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Foreword

This report examines the source separation of the digestible fraction of household waste and of other similar wastes from municipalities, prior to anaerobic digestion (AD). This is a topic of increasing worldwide relevance, as nations seek sustainability in the management of their organic wastes.

Global quantities of wastes are continually increasing, with the growth in the world population and increasing urbanisation. Waste management faces serious challenges around the world, especially in urban areas, moving away from disposal to waste prevention, resource recovery and recycling. Considerable efforts are being made to limit the overall production and the harmfulness of waste, and to limit the negative impact of waste on the environment and on human and animal health, as well as to mitigate the financial costs of waste management. Separation of wastes at source, including source separation and anaerobic digestion (AD) of the digestible waste fraction from households, is an integral part of such efforts, enabling recovery of value from the separated waste fractions through the production of cleaner, improved quality materials for energy recovery and recycling. Source separation helps divert organic wastes from landfill and from incineration, thus reducing the overall emissions of greenhouse gases and the negative environmental and health effects related to these waste disposal methods. Increased public awareness and active commitment and participation of citizens in local collection schemes are required.

The report is intended to provide municipalities and decision makers with guidance on the source separation of the digestible waste fraction from households and commercial origins, with the aim of obtaining a clean, high quality material, suitable for used as feedstock for anaerobic digestion in a biogas plant. The report contains documented information, which, when complemented by analysis of the local waste situation, should assist municipalities to design and implement sustainable policies for solid waste management.

The digestible household waste, as referred to in this report, includes not only food waste and green garden waste from households, but also similar digestible wastes from institutions, digestible municipal park and garden trimmings, vegetable residues and discarded food from markets and catering businesses, outdated food from supermarkets etc. The term "digestible wastes" used in the report defines organic waste materials, which can be easily decomposed by the anaerobic digestion process. The term "similar wastes" refers to municipal solid wastes, similar in nature and composition to household wastes, produced by commercial, industrial and institutional organisations.

The report provides an overview of the global waste situation and highlights the key incentives behind source separation of household waste for AD treatment in biogas plants. It describes some commonly used source separation and collection schemes for food waste from households and the process of their implementation, mainly based on experiences from United Kingdom and Sweden, countries that have gained experience and positive results in this area. To disseminate best practice and facilitate learning, the report also describes examples of successful municipal source separation schemes for digestible household waste from Sweden, United Kingdom and South Korea.

Much of the information presented is based on the literature sources listed in the references. It is worth noting that it was difficult to find specific consolidated data on the production and treatment of digestible wastes either nationally or globally. The main part of the existing literature refers to the larger categories of "organic wastes", and of "biowastes", in which digestible wastes are included, but are combined with other wastes. (See also 'Glossary, terms, abbreviations').

The chapters of the report address the following topics:

- **Chapter 1** reviews the municipal waste arisings, the importance of the organic fraction and the options for separating and treating this fraction.
- **Chapter 2** examines some of the methods available for source separation of the digestible fraction of household and municipal waste and the factors that influence the success of the operation.
- **Chapter 3** provides guidance on how to establish a source separation scheme for food waste and discusses experiences in establishing such schemes.
- **Chapter 4** discusses drivers for source separation
- **Chapter 5** discusses the economics of source separation
- **Chapter 6** provides examples of successful schemes of source separation of food waste.

1. Introduction

1.1 Global arisings of municipal and associated organic waste

Although many countries are trying to limit production of wastes through implementation of policies for waste reduction, increasingly large amounts of wastes are produced on our planet every year. It is estimated that global municipal solid waste (MSW) generation is approximately 1.3 billion tonnes per year and this amount is expected to increase to 2.2 billion tonnes by 2025 (World Bank / Hoornweg and Bhada-Tata, 2012).

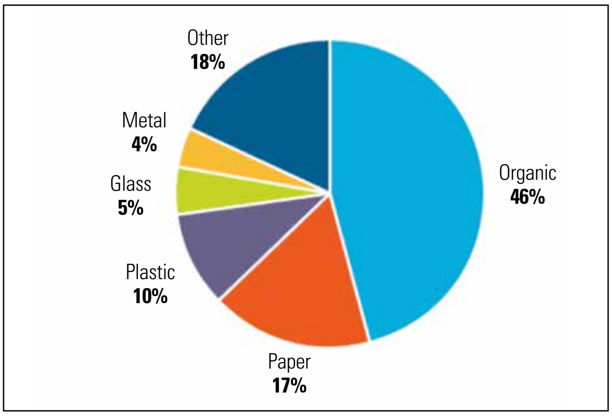
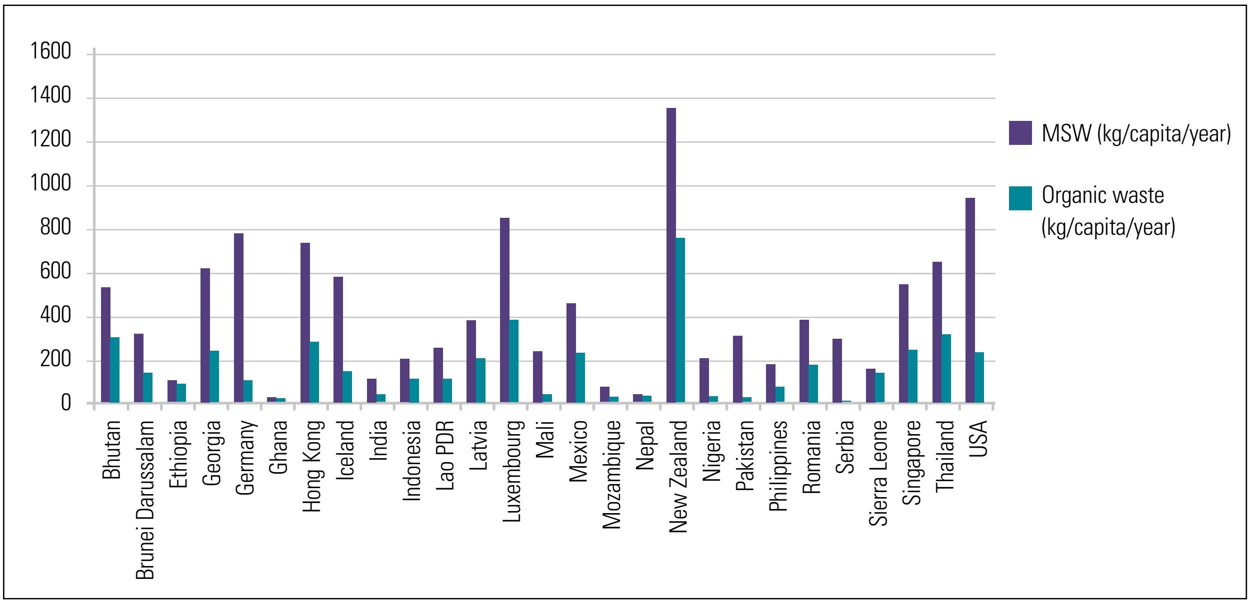


Figure 1: Composition of municipal solid waste (Source: World Bank/ Hoornweg and Bhada-Tata, 2012) Note: It must be pointed out that data used to compile the chart are not from a single year.

Figure 2: Annual municipal and organic waste arising per country



A large share of the global MSW is categorised as organic waste. The World Bank (2012) estimate for global municipal solid waste composition in 2009 is shown in Figure 1. This shows that 46% of municipal solid waste was reported to be organic waste, defined as food scraps, yard or green waste (leaves, grass, brush), wood etc.

The figure masks both regional and national differences in the definition and composition of municipal waste. There are significant differences between regions. The World Bank (2012) data indicates that the East Asia and the Pacific Region has the highest fraction of organic waste (62%) compared to OECD countries, which have the least (27%). The total amount of organic waste is highest in OECD countries. In general it appears that as a country becomes more affluent the volume of organic waste, as a proportion of the total waste produced, will decrease while paper and plastic waste will increase.

Using World Bank data on municipal solid waste arisings and data on the proportion of organic content, a graphical representation was made (Figure 2) of organic waste arisings (kg/capita/year) for a selection of countries. This highlights the variance in annual arisings across the globe and shows that there are significant quantities of organic waste produced in many countries. It is clear that organic waste represents a large fraction of municipal waste in many low income countries.

Not all of this organic waste would be suitable for anaerobic digestion (AD). Wood and other lignin containing waste materials are typical examples of organic wastes that are not suitable for AD. These wastes are usually treated using alternative technologies, such as composting or combustion with energy recovery. Data are not available on the proportions of the different fractions of materials that make up the organic content of waste, but it is suggested that depending on the geographic area and the income level, food waste represents 23 – 67.5% of MSW (IPCC, 2001). In the United States alone, the annual production of food waste is approximately 27 million tonnes (Mt) (Burrows, 2013). An analysis of the composition of food waste in different countries has been reported (VALORGAS, 2011). The implications of source separation on the compostion of the residual waste stream have also been assessed (Climenhaga et al. 2013).

Table 1: Food waste generation in EU-member states (tonnes)

	Manufacturing	Households	Other sectors	Total
EU (27 countries)	34,755,711.00	37,701,761.00	16,820,000.00	**89,277,472.00**
Austria	570,544.00	784,570.00	502,000.00	**1,858,000.00**
Belgium	2,311,847.00	934,760.00	945,000.00	**4,192,000.00**
Bulgaria	358,687.00	288,315.00	27,000.00	**674,000.00**
Cyprus	186,917.00	47,819.00	21,000.00	**256,000.00**
Czech Republic	361,813.00	254,124.00	113,000.00	**729,000.00**
Denmark	101,646.00	494,914.00	45,000.00	**642,000.00**
Estonia	237,257.00	82,236.00	36,000.00	**355,000.00**
Finland	590,442.00	214,796.00	208,000.00	**1,013,000.00**
France	626,000.00	6,322,944.00	2,129,000.00	**9,078,000.00**
Germany	1,848,881.00	7,676,471.00	862,000.00	**10,387,000.00**
Greece	73,081.00	412,758.00	2,000.00	**488,000.00**
Hungary	1,157,419.00	394,952.00	306,000.00	**1,858,000.00**
Ireland	465,945.00	292,326.00	293,000.00	**1,051,000.00**
Italy	5,662,838.00	2,706,793.00	408,000.00	**8,778,000.00**
Latvia	125,635.00	78,983.00	11,000.00	**216,000.00**
Lithuania	222,205.00	111,160.00	248,000.00	**581,000.00**
Luxembourg	2,665.00	62,538.00	31,000.00	**97,000.00**
Malta	271.00	22,115.00	3,000.00	**25,000.00**
Netherlands	6,412,330.00	1,837,599.00	1,206,000.00	**9,456,000.00**
Poland	6,566,060.00	2,049,844.00	356,000.00	**8,972,000.00**
Portugal	632,395.00	385,063.00	374,000.00	**1,391,000.00**
Romania	487,751.00	696,794.00	1,089,000.00	**2,274,000.00**
Slovakia	347,773.00	135,854.00	105,000.00	**589,000.00**
Slovenia	42,072.00	72,481.00	65,000.00	**179,000.00**
Spain	2,170,910.00	2,136,551.00	3,388,000.00	**7,696,000.00**
Sweden	601,327.00	905,000.00	547,000.00	**2,053,000.00**
United Kingdom	2,591,000.00	8,300,000.00	3,500,000.00	**14,391,000.00**

Food waste defined as (EC, 2010): "waste that is composed of raw or cooked food materials and includes food loss before, during or after meal preparation in the household, as well as food discarded in the process of manufacturing, distribution, retail and food service activities. It comprises materials such as vegetable peelings, meat trimmings, and spoiled or excess ingredients or prepared food as well as bones, carcasses and organs".

In European Union (EU) countries, biowaste (Glossary, terms, abbreviations) usually represents between 30% and 40%, but can range from 18% up to 60% of the municipal solid waste (MSW). The biowaste part of MSW comprises two major streams: green waste from parks, gardens etc. and kitchen waste (European Commission JRC-IPTS, 2012). The annual production of MSW biowaste in the EU amounts to 118 to 138 Mt (European Commission, 2010). Annual food waste generation in the 27 EU countries (EU27) is estimated to be approximately 89 Mt, or 179 kg per capita (based on 2006 population of 493 million). This waste stream should be suitable for anaerobic digestion. According to Barth et al (2012), the amounts of separately collected and treated organic material differ greatly between the EU Member States. The authors indicate that the estimated potential of total recoverable biowaste and green waste fractions of MSW (where organic household waste is included) is around 80 million tonnes, of which only about 24 Mt (30%) are currently separately collected, although there are reservations about the reliability of this data. It is estimated that 70-90% of the source separated organic household waste is composted in the EU, thus only a minor share is treated by AD.

The principle source of data on food waste generation in the EU is EUROSTAT. A preparatory study on Food Waste across EU27, produced on behalf of the European Commission (European Commission, 2010a), provides data for food waste generation from manufacturing, Household and 'Other Sectors' defined as Wholesale/ Retail sector and the Food Service/Catering sector for Member States. In comparison to World Bank data, figures are presented for food waste alone, excluding agricultural slurry and manure, but including animal and vegetable wastes. Based on data from these sources, an estimate of food waste for these three sectors is presented in Table 1 for each EU-member state, for the year 2006. It must be noted that there may be variations in the way data is recorded between Member States.

Of the four sectors examined, EU27 households produce the largest fraction of food waste with an average of about 42% of the total (38 Mt or approximately 76 kg per capita), although its share varies between different member states.

A breakdown of food waste from 'Other Sectors', suggests that the wholesale/retail sector generates 4.4 Mt for the European Union (approximately 8 kg per capita), with the food service sector generating 12.3 Mt for the EU27 (25 kg per capita).

A report from the Food and Agricultural Organisation (2011) on global food losses and food waste suggest that roughly a third of food produced for human consumption is lost or wasted globally, amounting to 1.3 billion tons per year. The total per capita production of edible parts of food for human consumption is, in Europe and North-America, about 900 kg/year and, in sub-Saharan Africa and South/Southeast Asia, 460 kg/ year. In Europe and North America per capita food loss is estimated to be 280-300kg/year, whereas it is only about half that in sub-Saharan Africa and South/Southeast Asia at 120-170kg/year. This is shown in Figure 3 where the losses between production and retailing dominate the picture in low income countries, whereas industrialised countries produce a high fraction of waste on the consumer side. However, whether the waste arises before or after the consumer side, it should all be suitable for AD.

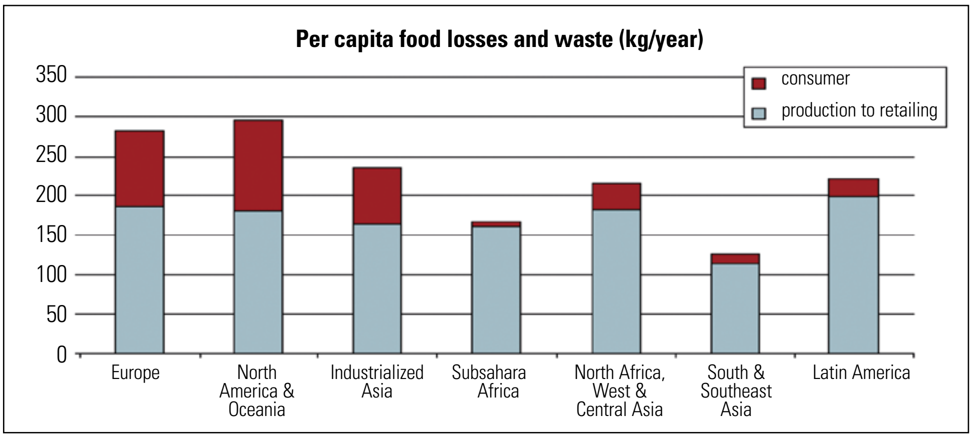


Figure 3: Per capita food losses and waste, at consumption and pre-consumption stages (Source: Food and Agricultural Organisation, 2011)

The impact of waste prevention and resource efficiency initiatives is likely to increase in the future, and food waste per capita may well start to decrease.

Recent data on organic MSW treated by AD or composting facilities are not available. For the EU, data presented in Figure 4 clearly show that for 2006 the potential for organic waste recovery and recycling was very substantial. The uptake of organic waste treatment processes has subsequently increased as separate food waste collection systems have been implemented. Consolidated data for other regions was not available at the time of publication of this report, although literature suggests that a few facilities exist for the AD of MSW outside Europe. Waste Management World (WMW, 2013) provides reports for two large-scale AD facilities treating municipal waste in Canada and one facility in USA.

1.2 Technical options for treatment of source separated organic wastes

There are several technical options for the treatment of organic wastes. The most common are the anaerobic digestion (AD) for biogas production, composting and mechanical biological treatment (MBT). For these technologies waste can be source separated or, in the case of MBT, mechanically separated in dedicated facilities. In the EU it has been demonstrated that source separation is the best method for AD. Implementation of source separation and of subsequent treatment options for the digestible/organic fraction of the MSW is the result of a complex decision process based on several factors. These include policy targets, local needs and conditions, the feasibility of using available technologies, the quality of collected wastes and applicable socio-economic effects.

1.2.1 Anaerobic digestion

Anaerobic digestion (AD) is a controlled microbiological process, in which digestible materials decomposes in the absence of free oxygen. The anaerobic digestion process takes place in many oxygen free natural environments. The industrial process takes places in a specially designed digester tank, which is part of a biogas plant. The output of the AD process is biogas and digestate. Biogas is a methane-rich gas, (45-80% methane content), which can be used as renewable fuel for direct combustion, co-generation (renewable electricity and/or heat generation), or it can be upgraded to biomethane (typically >94% CH_4) and injected into the gas grid, or used for vehicle fuel. Digestate is the byproduct of the AD process, the residues left after decomposition of the organic waste feedstock. Digestate exits the digester tank as a sludge-like or liquid product, rich in plant macro and micro nutrients, which can be applied on farmland

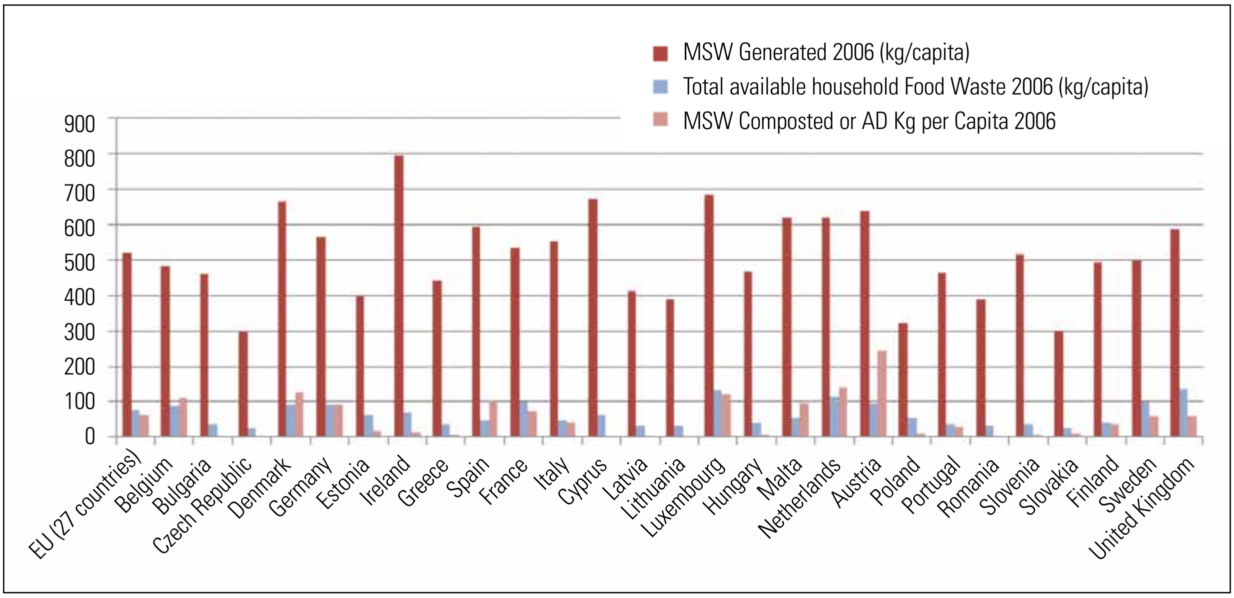


Figure 4: MSW generation, available food waste and MSW treated at AD and composting facilities in 2006

as fertiliser or as soil conditioner, provided that it meets the strict quality requirements imposed for such application (Al Seadi and Lukehurst, 2012).

The best practice for digestible waste materials destined for AD is separation at source, as they need to be of high quality (i.e. free from physical impurities) in order to ensure stable operation of the anaerobic digestion process. Chemical and biological impurities must also be strictly monitored and limited to allow safe and beneficial utilisation of digestate as plant fertiliser (Al Seadi and Lukehurst, 2012). Chemical pollutants, contaminants, toxins, pathogens or other physical impurities which cannot be decomposed into harmless compounds by the AD process, or by the additional treatments applied pre- or post- digestion, must not be present in AD feedstock materials. Their presence not only disturbs the AD process, it also prevents spreading of the digestate on farm land. In practice, feedstock materials contaminated with such impurities are excluded from AD when digestate is to be used as fertiliser.

A variety of AD technologies are available today for the treatment of the organic fraction of the household waste and of other types of digestible MSW. A simple classification of the AD used for MSW is shown in Table 2, based on the digestion method and the dry matter content of the substrate.

Additional sub-categories of the AD process include partial or full stream digestion. AD can be a single stage, multi stage or batch process. Based on the content of total solids (TS) of the substrate to be digested, the AD processes can be low solids (LS), containing less than 10% TS, medium solids (MS), containing about 15-20% TS, and high solids (HS), ranging between 22 and 40% TS (Verma, 2002). The AD treatment of MSW in Europe was dominated in the 1980s by LS processes. During the last decade, HS processes have become increasingly popular as they have proved to be more robust. The ability of HS processes to handle feedstock that may be loaded at a high rate into the digester (so with a high organic loading rate (OLR)) means that they require a smaller reactor volume per unit of production, which in principle makes them cheaper than the LS processes. However, HS processes need more powerful, and thus more expensive, components such as pumps to handle high dry matter feedstocks.

AD is today a standard technology for the treatment of organic waste in Europe. Source-separated household waste and other similar wastes can be digested without any other co-substrates, for example at the Cassington AD plant in Oxfordshire, United Kingdom (Figure 5), or they can be co-digested with other feedstock types (e.g. agricultural biomass and residues and/or other digestible wastes from various food and agro-sectors and industries). The number of plants treating the digestible fraction of household waste in Europe grew from 3 biogas plants in 1990 to 195 in 2010, with a total capacity of 5.9 million tonnes per year, and a predicted doubling of current capacity every 5 years (EC-JRC-IPTS, 2012; Burrows, 2013). About 3% of the organic fraction of municipal solid waste produced in Europe in 2010 was treated by AD, representing 20%–30% of the biological treatment capacity of organic wastes from house-

Table 2: Overview of AD systems used for MSW

AD method	Process type	Dry matter %	Examples of technology providers
Mono digestion (only MSW)	Dry	20–30	Valorga Kompogas (single phase, plug-flow) Dranco (single stage) Linde
	Wet	2	BTA
Co-digestion (with animal slurries, other wastes, crops etc)	Wet	8–15	Danish joint co-digestion plants (CAD)
Integrated/combined	Dry	20–30	AIKAN – Integrated dry AD and composting CAMBI – Integrated Hydrolysis + two stages AD

Figure 5: The Cassington AD facility in Oxfordshire, United Kingdom. The biogas plant processes source separated municipal and commercial food waste (Source: www.biogas.org.uk)

holds (Burrows, 2013). In addition, about 7500 co-digestion AD plants, treating animal manure and slurries in combination with organic wastes from food industries and source separated household waste were in operation in Europe in 2010.

1.2.2 Composting

Composting is the term used for the decomposition process that occurs naturally in the environment, in the presence of atmospheric oxygen. For example, when leaf foliage falls from trees to the forest floor, bio-microbial activity transforms it into humus and nutrients, which are up-taken up by the root system of the trees. The technical process of composting is essentially a controlled and accelerated version of the natural process.

Compost is used as soil improver and as fertiliser for plants. Its application to land brings humus and slow-releasing macro and micro nutrients to the soil, contributes to moisture retention and improves soil structure and texture. Using compost made from recycling, such as organic wastes, is considered environmentally sustainable (WRAP, 2003).

Compost can be produced on a small scale, for example an individual household, or on a large industrial scale for market purposes. Small scale composting, also called home composting can be done in the backyard of private residences, or in smaller farming activities using the source separated organic fraction of the domestic waste, garden waste, as well as various solid animal manures and bedding, household toilets, etc. Home composting can be carried out using various methods and materials: compost bins, worm bins, composting toilets, grub composting, using fly larvae, bokashi composting, using special microorganisms etc. There are also ‘in-vessel’ composting systems, which can be used for example at educational premises, hospitals, hotels or on sites with commercial kitchen operations.

For industrial scale composting, a range of composting methods and techniques are available such as in-vessel composting, windrow composting, tunnel composting, aerated static pile composting, vermiculture, etc. The result is a variety of compost products, often quality certified for specific uses. More information on composting in Europe is available from European Commission 2000.

1.2.3 Anaerobic digestion versus composting

AD of source separated wastes offers sustainable alternatives to landfilling, incineration and even to composting, ultimately providing renewable energy and fertilisers. The choice between various treatment options for organic waste and the comparative merits of composting versus anaerobic digestion, depends on the one hand on the nature (suitability) of the waste material and the feasibility of the technology, and on the other hand on the local conditions and needs as well as on the policy, objectives and targets of the local community.

From an environmental point of view, AD is considered more beneficial than composting due to displacement of fossil fuels and lower greenhouse gas (GHG) emissions. According to a technical, economic and environmental analysis of composting and anaerobic digestion undertaken in Ireland (Murphy and Power, 2006) AD can save up to 1,451 kg CO_2/t of waste treated compared to 1,190 kg CO_2/t in the case of composting. A similar conclusion was reached following a study published in United Kingdom (DEFRA, 2011, quoting Beck, 2004). The report indicates that scientific evidence based on life-cycle analysis shows that AD of food waste is environmentally better than composting and other recovery options. For garden waste and mixtures of food waste and garden waste, dry AD followed by composting is environmentally better than composting alone. Defra (DEFRA, 2011) indicates that composting is environmentally preferable only when organic wastes such as garden waste or mixtures of food waste and garden waste are not suitable for dry anaerobic digestion.

Environmental impacts of landfill of waste

Methane has a very high global warming potential: Over a period of 100 years, each molecule of methane (CH_4) has a direct global warming potential which is 25 times higher than that of a molecule of carbon dioxide (CO_2) (Solomon et al, 2007). In 2001 IPPC estimated that 6-12% of methane emissions to the atmosphere originate from landfill, contributing significantly to overall greenhouse gas emissions. It has been shown that most greenhouse gas emissions from landfills originate from the decomposition of paper and of various organic/digestible waste materials. Landfills may also be subject to water infiltration resulting in leaching of polluting compounds from the site. The leachate can contaminate soil and groundwater. According to IPCC (2007), the methane emissions from landfills are stabilizing in high income countries, due to increased landfill gas recovery, decreased landfilling, and decreased waste generation as a result of local waste management decisions including recycling, local economic conditions and policy initiatives (IPCC, 2007). In low income countries, GHG emissions from waste, and especially fugitive methane emissions and leakage from uncontrolled waste dumping and from landfills without gas recovery, are increasing due increased urbanization and rapid increases in population (Figure 6).

Figure 6: Landfill deposits pose the risk of uncontrolled air, soil and water pollution. Image from Mumbai landfills (Source: Shutterstock).

1.2.4 Mechanical Biological Treatment (MBT)

MBT (Mechanical Biological Treatment) is the term used for a family of treatment systems using a combination of mechanical and biological processes to separate and transform the residual waste into several outputs (Read and Godley, 2013). MBT is not a final disposal solution for the treated waste and can therefore be considered a mechanical biological pre-treatment, as it is the case in Germany and Austria.

MBT is designed to further treat mixed collected or residual municipal solid waste. The main aim is to extract further value from the waste and to recover the energy contained in it while facilitating recycling and diversion of waste from landfills. The mechanical processes are designed to separate out the dry recyclables such as glass and metals, while the biological processes aim to reduce water content and to handle the organic-rich fraction of the incoming waste.

Along with the inorganic outputs, an MBT plant can produce an organic waste fraction which will be further composted or treated by anaerobic digestion. Composting and AD can be part of the same MBT facility. The quality of the compost as well as of the digestate produced by MBT plants can be problematic from the point of view of safe recycling through application on soils, due to their content of chemical pollutants which often exceed the prescribed limit values. For similar reasons, digestates from MBT can be difficult to use in a beneficial way and subsequently result in a disposal cost that will have a significant negative impact on the long-term viability of MBT.

1.3 Why should we source separate household wastes?

Mixed wastes from municipalities are often landfilled. Left to degrade naturally in landfill sites, organic wastes from households and municipalities have very high methane production potential thus have a negative impact on the environment.

In order to decrease the environmental and health effects associated with landfilling, waste management is

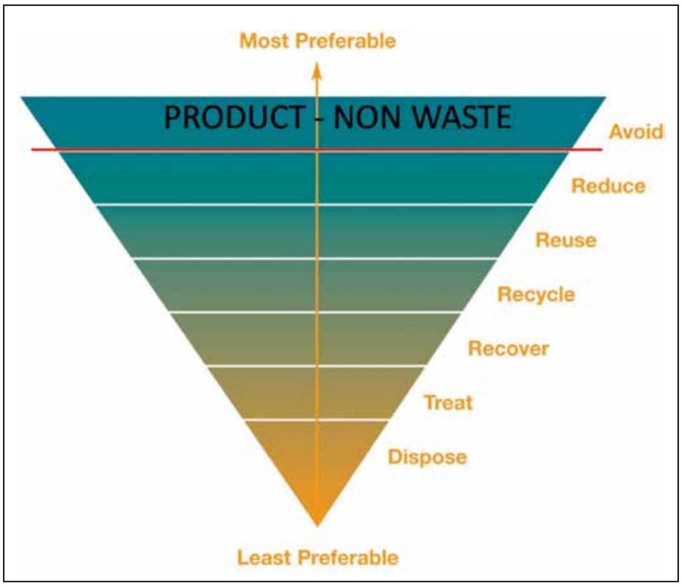


Figure 7: Waste hierarchy (Adapted after European Commission, 2008)

nowadays moving away from disposal and towards waste prevention, reuse, recycling and energy recovery, as shown in Figure 7, illustrating the 'waste hierarchy' according to the EU Waste Directive (European Commission, 2008). The ranking of waste management options is according to their environmental impact, where waste avoidance, the most environmentally friendly alternative, is situated at the top of the inverted pyramid. Separation of the organic/digestible fraction of municipal waste prior to landfilling, and the treatment of this fraction by AD or composting, is in line with the sustainable waste management hierarchy. The waste hierarchy is the guideline for waste policies in EU and other OECD countries, and is also being adopted in emerging economies.

Mixed waste collection increases the risk of contamination of recyclables and reduces their marketing possibilities (Hoornweg and Bhada-Tata, 2012). The best way to overcome this problem is to use source separation of waste as it minimises the risk of cross contamination from other waste materials, thereby ensuring a high quality feedstock for AD treatment (Figure 8), and maximising the volume of the collected material.

Consumers around the world increasingly demand higher food quality and safety, and in many places the crop farmers and the food processing industries accept digestate as fertiliser for crop production, although only if the waste used as the feedstock for AD has been source separated (Avfall Sverige, 2013). There are mandatory quality standards for the AD feedstock materials in many countries. Positive lists of feedstock materials as well as national standards and certification protocols for the digestate have been adopted in many places (Avfall Sverige, 2013), (Al Seadi and Lukehurst, 2012). More information about quality standards of digestate and how to manage digestate quality is available in the IEA Bioenergy publication "Quality management of digestate from biogas plants used as fertiliser, by Al Seadi and Lukehurst (2012).

Figure 8: Source separation ensures the high quality, necessary for anaerobic digestion. Source: BiogenGreenfinch Ltd, quoted by Al Seadi and Lukehurst (2012)

2. Systems for the source separation of organic wastes

This section outlines the collection systems for the separation of organic/digestible waste to be treated by AD. The aim is not to compare the collection systems or to provide detailed guidance on each type of collection, but to give an overview of the different approaches. Ultimately, the type of collection adopted in a municipality is dependent on existing collection systems (i.e. residual waste and dry recycling materials), as well as wider needs and pre-conditions, including type of housing and street layout.

2.1 Wastes that can be source separated

The report deals with the source separated, digestible waste from households and with similar digestible wastes from other sources. Digestible wastes are produced by municipalities as well as by manufacturing and retail sectors. Two key types of wastes are concerned: food waste and yard/garden waste. The digestibility of the source separated material refers to its ability to be easily degradable through AD. Apart from digestibility, there may be additional regulatory criteria to consider for specific types of waste. Within Europe for example, the handling and treatment of animal by-products, such as food waste containing meat and other materials of animal origin, is governed by Regulation Number 1069/2009 (European Commission, 2009). The regulation stipulates which waste categories are allowed to be treated by AD, prescribing the minimum requirements for the temperature and residence time within the AD process (See Chapter 4.2.4. Animal By product regulation - ABP).

2.2 Approach to collection

In assessing the most appropriate waste collection method, there are a number of key factors to consider, as shown in Figure 9. The impacts of these factors are discussed in Chapters 2.3 to 2.5, and further in Chapters 3 and 5.

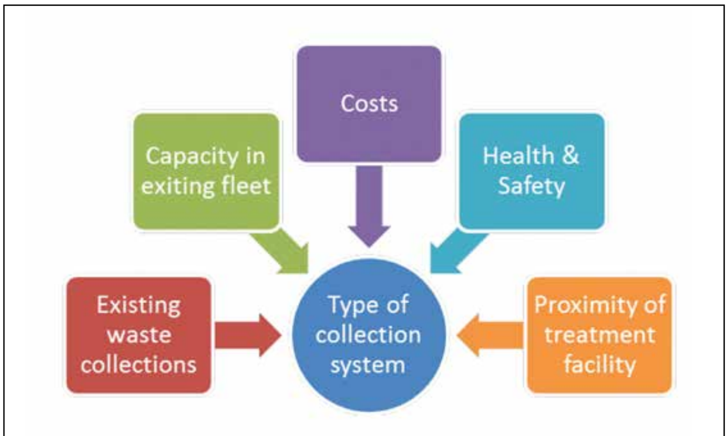


Figure 9: Factors to consider in selecting an appropriate collection method

2.3 Operations – resident/ waste producer

There are two types of collections that can be used:

- Material collected direct from properties (residential, institutional, commercial etc.); or
- Material collected from communal collection points.

The approach to adopt for digestible waste collection is to a large extent dependent on the approach used for collecting residual waste and dry recycling materials, as this will encourage participation in the segregation process.

An important aspect to consider is the infrastructure that will be provided or required by residents or the waste producer, i.e. any additional bins or liners for using the service. Further information on this is provided below.

A vital aspect for any collection scheme that should not be underestimated is the need to collect high quality material. To produce a good quality digestate it is vital that the collected material is free from contamination. To achieve this, it is important that clear guidance is provided to residents /waste producers on the type of digestible waste accepted in the scheme, and that this is monitored by the collection crew. This is easier to achieve where collections are direct from the property as opposed to communal collections. Users that do not adequately comply can be targeted for further guidance and support. Further information on quality is provided in Chapters 3.7 and 3.8 and by Al Seadi and Lukehurst, 2012.

2.3.1 Collections direct from properties

The frequency of collections is ultimately dependent on local needs and existing services. The following text draws from UK and Swedish experiences, but there are lessons learnt and commonalities with systems in other countries. The key types of collection systems include bins/sack collections or multi-apartment compartment bins, which are described further below.

Bin/sack collections

In the UK for example, a weekly collection of waste and recycling has historically been provided for residential properties using bins or sacks. However, the UK has seen a considerable shift in collection approach with 'alternate weekly collection' becoming increasingly common to maximise the usage of food waste and dry recycling schemes. This typically involves the following frequency of material stream collections:

- Weekly collection of food waste (typically via a 30 litre container)
- Weekly collection of dry recycling stream(s) (often via a 240 litre bin)
- Fortnightly collection of residual waste/refuse (140 or 240 litre wheeled bins used)

and

- Fortnightly collection of garden waste (via sacks or 240 litre wheeled bins). Note that householders often must pay an additional charge for the garden waste service.

Figure 10: Source separation of food waste in a separate bin (Source: Falu Energi och Vatten)

This type of scheme has become popular in the UK as they enable the same vehicle fleet to be used for residual and garden waste on alternate weeks, thus minimising the additional cost for collections.

Similarly in Sweden, one of the oldest and most frequently used systems for food waste is collection in separate bins (Figure 10), which normally complements the bins used for collecting combustible MSW. The size and the design of the collection bins varies depending on the collection source, (single houses or apartment buildings), and on the technical solutions adopted to facilitate collection. In countries like Sweden, the size of bins for a single house is typically 140 litres. Sizes of 190, 130, 120 and 80 litres are used as well, but less frequently. In the case of apartment buildings, the size of bins varies (140, 190, 240, 370, and 400 litres). Such bins are commonly stored indoors and are therefore often of solid material, but perforated bins or bins with open lids to maintain good ventilation are also used some places. The material of the collection bags used in the separate bins is usually paper, but bags of biodegradable plastics (bio-plastic) as well as plastic bags are also used some places.

Collection of separate waste bins from single houses is normally done with side loading vehicles with one or two compartments. For the two-compartment vehicles, the usual size distribution is 60-70 % for the combustible waste and 30-40 % for the food waste. The waste bins are emptied automatically with a lifting device on the vehicle. This requires the customer to place the bins in a designated place, ready for collection. In the case of apartment buildings, rear loading vehicles are predominantly used. They come in different designs and can have multiple compartments. The cargo space in these vehicles can vary from a few cubic meters up to 25 m^3. Concerning the waste vehicles, the loading height and vehicle lifting equipment are of importance from a work environment point of view.

For businesses and industrial companies a normal bin size is 140 or 190 litres. Bins of 120, 130, 240, and 370 litres are also used some places. An inner bag of paper or bio-plastic is sometimes used, as the food waste from businesses and industries often has high moisture content. Collection of waste from the separate bins is usually made with rear loading vehicles. Lifting devices are often used to collect bins from a loading dock.

Multi-compartment bins

The multi-compartment bin system is predominantly used in Sweden for single houses and is therefore more common in areas and municipalities with a majority of single houses. The bins are divided into two or four compartments if used for apartment buildings or businesses and industries.

Two compartment bins

This bin has an intermediate wall and with a capacity of 190, 240, or 370 litres. One side is intended for food waste and one side for combustible waste.

Four compartment bins

This system normally consists of two 370 litres bins. Both bins have an intermediate wall and are emptied into a two compartment collection vessel. This means that each bin has four compartments, so double bins means separation into eight waste fractions, as shown in Figure 11.

Figure 11: Example of separation of different waste fractions in four compartment bins in the city of Trelleborg, Sweden (Source: PWS Nordic AB)

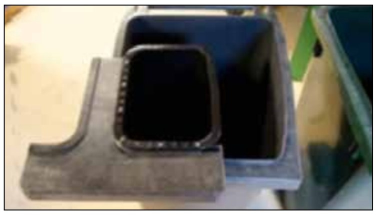


Figure 12: Insert for food waste in a 190 litre bin (Source: PWS Nordic AB)

For households in a municipality with four compartment bins that do not wish to have full sorting into eight fractions in the home, there is an alteration of the 190, or 240 litres bins with an insert for food waste collection (Figure 12). This facilitates collection without having to change the type or normal route of the collection vehicles.

In a multi-compartment system, the waste bags used are normally made from paper, but bags, but bags of bio-plastic and plastics can be used as well. For collection of the four fractions in a four compartment bin, a special, multi-compartment vehicle is required, able to handle bins from 80 to 660 litres, and to empty all fractions in 15-20 seconds. In addition, a “survival bag” approach is sometimes used for the collection of digestible waste, where separate bags are provided for different waste streams: dry recycling, residual waste and digestible wastes. These bags are then collected together in a single vehicle and segregated at a centralised facility. This system is in use in other European countries as well. Experiences with this scheme are mixed. The potential for contamination is relatively high as the bags can split or break open during collection or during subsequent off-loading/loading operations. A summary of the main systems used in Sweden for the collection of source separated food waste from households is presented in Table 3.

For commercial and industrial premises a food waste grinder installed under the kitchen sink is the frequent solution adopted by businesses producing large amounts of food waste. The ground food waste is stored in a tank which is regularly emptied by a vacuum tanker/suction vehicle. There are various levels of complexity of such systems, with single or several grinders connected to the same tank.

Table 3: Overview of main systems used in Sweden for source-segregated household food waste collections

	Two compartments	Multi-compartment	Optical sorting
Common bin sizes	140, 190 l houses 140, 190, (370) l apartment buildings	370, (240) l houses Not available for apartment buildings	Same as prior to source separation
Sorting equipment	Bag holder of plastics or wire rack, often ventilated	Bag holder of plastics or wire rack, often ventilated	Optional bag holder
Bags	Paper, bio-plastic, (plastic)	Paper, bio-plastic	Plastic, but other alternatives can be investigated
Vehicles	One and two compartment vehicles, side or rear loaded	Multi-compartment vehicles	Regular vehicle
Common collection intervals	Houses: every second week Apartment buildings: every week	Food waste: every 14 day, other bins: from every 14 day to every 6 weeks	Same as prior to source separation
Suitable areas	House areas, apartment buildings, industries	House areas, smaller industries	House areas, apartment buildings, industries
Work environment	Collection staff might be exposed to heavy bins, transporting bins, microbial dust	Collection staff might be exposed to heavy bins, transporting bins, microbial dust	Does not change the working environment. Plastic bags decrease the risk of exposure to microbial dust.
Continuous quality control	Visual control during collection and delivery to treatment facility	Visual control during collection and delivery to treatment facility	Visual control during collection and delivery to treatment facility
Other	The most common system today	Sorted and collected fractions give an income	The system demands an optical sorting facility

Large grinder systems

Food waste grinders can be integrated into a workbench or just consist of a wide inlet, in both cases positioned in a way so that it follows the working flow in the kitchen (Figure 13). The grinder can be batch-fed or continuous-fed, with automatic water addition when the grinder is in use. All types are equipped with a safety lock or a similar device to prevent injuries to operators or damage to equipment. Some models are fitted with magnets to capture cutlery or other metallic objects. The collection tanks (Figure 14) are made of glass fibre, stainless steel, or plastic. Typical volumes for separate tanks range between 2 and 3.5 m^3.

Figure 13: Two examples of throw-ins for large grinding systems (Source: Stockholm stad)

Figure 14: Two examples of a tank for large grinder systems (Source: Stockholm stad)

Smaller grinder systems

For smaller and simpler systems with the grinder directly connected to the waste tank, the tank size rarely exceeds 1 m^3 (Figure 15, right). Other solutions, with food waste tanks placed in the kitchen, can have volumes up to 2 m^3 (Figure 15, left).

One of the key aspects to consider in the collection of waste from commercial and institutional properties is the quantity of packaged food. This is particularly the case for food waste from supermarkets, for example damaged food, or items that have passed their expiry date. Where large quantities of packaged food waste are generated, these are typically collected via a bin collection, and the material depackaged at a central treatment facility.

The use of bins and caddies is another key aspect to consider for the collection of digestible waste that has a high food waste content. Bins can be used to provide suitable storage for food waste and to help prevent against access by vermin. In addition, use of small kitchen caddies may be used for interim storage for the food waste. For residential properties a caddy of typically 8 litres is used within kitchens, in combination with an external bin of 30 litres (Figure 16). In commercial/institutional properties a 30 litre bin is often used for internal storage and the contents later transferred to a larger external bin prior to collection, or alternatively a larger wheeled bin used for internal storage which is then transferred outside for collection.

Starch or paper liners are often seen by residents as part of the system for collecting food waste. Surveys and consumption trends suggest that residents prefer to use liners so that food waste storage containers used to securely transfer food from the internal kitchen caddy to the external bin can be kept clean and hygienic (WRAP, 2008).

Some of the key advantages and disadvantages of using liners are summarised in the Table 4, which was developed following research results from the WRAP food waste collection trials (WRAP, 2008).

Figure 15: A grinder and a tank connected device (left). A simpler solution, with a grinder in the kitchen connected to the waste tank placed in a garbage room (right). (Source: Stockholm stad)

Figure 16: The 6 litre and the 30 litre bins for source separation of food waste (Source: WRAP 2009a)

Table 4: Advantages and disadvantage of liner use

Advantages	Disadvantages
• Makes the process cleaner for users • Many users prefer to use liners • Potentially higher capture rates and yields achieved • Potentially higher participation rates achieved • Collections are easier for crews – food waste doesn't stick to containers and all food waste is emptied from the container • Collection chambers in vehicles are kept cleaner and chances of spillages/leakages are reduced	• Adds costs to the service, if they are supplied free of charge to waste producers • Can be time consuming to set up distribution, if not done by collection crew • Wastage of liners, if distributed inefficiently and to non-participating properties • Additional cost to waste producer • Depends on willingness of waste producer to purchase liners • Needs to be specified to the dimensions of the caddy

Figure 17: Starch liner (Source: WRAP)

Figure 18: Paper liner (Source: WRAP)

Figure 19: Communal kitchen waste bin in Jasper, Canada

Two widely available types of degradable liners are used for food waste collections.

- Starch liners, made from starch based polymers or biopolymers (Figure 17). They are available in a number of different specifications based on their size and thickness.
- Paper liners, made from a high moisture resistant paper (Figure 18)

The type of liner selected for use depends on:

- The requirements of the treatment facility
- The cost to the municipality, if liners are provided free of charge to the users
- The cost to the users/waste producers, if they must purchase the liners

In some instances, facilities may accept non-degradable plastic if de-packaging equipment is installed at the facility. However, this is not typical of most existing operations facilities.

2.3.2 Communal collections

Communal collections can take place at a neighbourhood level, through the use of neighbourhood collection bins, or at more centralised locations such as household waste recycling centres. With this approach, the material has to be brought to the collection point by residents/waste producers, and it is therefore vital that a liner/bin is provided for residents/waste producers to transport the material to the communal bin. Communal collections are often adopted for apartment blocks or where the predominant method of waste collection has been designed for this approach. This is common around Europe and the Middle East where daily collections are made from central locations. Figure 19 shows the neighbourhood bins used in Jasper, Canada for the collection of kitchen waste.

To encourage participation by residents in a digestible organics collection scheme, communal bins should be situated within walking distance from residents' homes where possible. If this is not the case, bins should be placed in convenient locations so users are not forced to make an extra trip, for example in supermarkets or areas on commonly used routes in the vicinity of their homes.

A range of systems can be used for communal collection points, using a standard bin, or alternatively more specialist systems using underground containers or vacuum systems.

Underground containers

There are several types of underground containers on the market used for different waste fractions, such as combustible waste, packages and food waste. Some types are custom made for the collection of food waste. Retailers make a distinction between semi-underground systems, where one part is over ground, and fully underground systems, where the whole system is underground. Both systems are briefly described below.

Semi underground

Within the group of semi underground systems (Figure 20), there are containers for food waste collection of different types:

- Vessels in polyethylene with a collection system for leached water. The inner bag can be made of paper or

Figure 20: Semi underground container (Source: Sansac)

Figure 21: Throw-in, with the possibility to control the quality of the waste (Source: PWS AB)

Figure 22: Examples of throw-ins (Source: Envac)

bio-plastic. For this type, the lid of the container is opened and the full polyethylene bag is lifted.

- An outer vessel of polyethylene, where the food waste is collected in a reinforced bag, emptied from the bottom. The reinforced bag is connected to the lid of the container, so an inner bag cannot be used.
- A container emptied from the bottom. The original design allows collection of 3 m^3 but the volume can be adapted. An inner bag cannot be used because the lid does not open during collection; instead the waste is emptied from the bottom.

Special adaptions, according to customer needs, can be made for the collection of food waste:

- The throw-in hatch can be fitted with locks.
- Smaller volume (e.g. from 0.6 to 1.5 m^3).
- Polyethylene vessels.
- A design with a bowl-shaped bottom, allowing collection of both food waste and leachate in the collection vehicle.

Fully underground

This system means a completely underground container (Figure 21) emptied from the bottom. The container has inlets above ground, placed in a concrete casing. Different types of inlets are available.

Special adaptions can be made for the collection of food waste:

- The inlet can be fitted with locks.
- Smaller volume (0.7 to 1.6 m^3), special adaption offered by some retailers, according to customer needs.
- Equipped with a double bottom, where the bags are collected on a net and leachate is collected in the bowl-shaped bottom (180-450 litres); this means that both food waste and leachate can be collected in the vehicle.
- A division in the collection vessels prevents the leachate from rocking from side to side when the container is emptied.
- Epoxy coating for protection against corrosion.
- Inspection possibilities for the collector, through an extra hatch on the inlets.

Vacuum systems

A vacuum system is an automated system, primarily suitable for apartment buildings and in some appropriately adapted urban areas. It complements the sorting system of food waste in the residential areas, where vacuum systems are installed for two or more fractions. The system is based on the principle that waste is transported by an air flow, created by one or more fans. The vacuum systems can be stationary or mobile.

Stationary vacuum systems

A stationary vacuum system is a closed system in several buildings or whole areas. The inlets are places either indoors or outdoors (Figure 22).

The waste is stored temporarily on the top of a closed valve, (Figure 23). Below ground, a pipe is connected to the terminal with interim storage of compressed combustible waste and non-compressed food waste. This is also where the fan, creating the air flow in the system, is placed. During collection, the valve is opened and the waste is transported at a speed of 70 Km/h up to 2 km. This process is repeated 2-5 times per day. For systems

Figure 23: Picture of a stationary vacuum system (Source: Envac)

Figure 24: Picture of a mobile vacuum system (Source: Envac)

with separate fractions, the collection process is carried out separately.

Mobile vacuum systems

The principle is the same as for the stationary system, but instead of being connected to an interim storage, the waste is stored in a vessel underground, and transported by vacuum to a collection vehicle (Figure 24).

2.4 Collection of materials by the municipality

The key approaches to the collection of material by the municipality or its contractor are:

- Collect digestible waste separately, using a kerbside or specially adapted vehicle
- Collect digestible waste separately, but at the same time as other wastes or
- recyclables, using a split bodied vehicle, or at the same time as recyclables, using a compartmentalised vehicle or pod system.

Where material is destined for composting facilities, food and yard/garden waste are sometimes mixed together in a single vehicle. Collecting food waste separately from garden waste is often an advantage in cases where regulatory controls exist for materials that contain animal by-products. Where this is the case, segregation of food waste from yard/garden waste means that only the food waste needs to be treated by an approved process; this helps reduce the overall costs for treatment. However, combined food and yard/garden waste collections are often adopted where there is an existing yard/garden waste collection, thereby reducing the capital costs for purchasing an additional external bin, as well as reducing the impact on collection arrangements. As waste collected this way typically contains wood waste from gardens, this approach is better suited for an in-vessel composting system, but not recommended if the waste material is destined to be treated by AD.

The choice of collection vehicles and how they are operated by crews is a vital element in developing efficient and cost effective services. Decisions on choice of vehicle will depend on:

- Geography
- Number of properties requiring collection/quantity of material to be collected
- Property types
- Nature of the service to be offered for the collection of digestible waste
- Nature of existing dry recyclables/refuse collection system and vehicle fleet
- Health and safety considerations
- Cost

Figure 25: Collection vehicles used for organic waste collection in the UK

Table 5: Options for bulking

Delivery procedure	Advantages	Disadvantages	Comments
Direct tipping into skips	• Minimal involvement for site staff. • Skips remain sealed when not being filled – minimising odour problems.	• Skip size is limited to tipping height of delivery vehicle. • Delivery operation can be interrupted during skip exchange. • Limited chance of spillage.	• Suitable for a digestible waste collection service that generates smaller quantities of material.
Direct tipping onto floor	• Minimal involvement for site staff. • Greater storage capacity, therefore less interruption to deliveries.	• Waste remains exposed. • Risk of odour and vermin nuisance. • Seepage may be a problem. • Potential for vehicles to carry waste out of the operational area on their wheels. • Risk of spillage from loading shovel during carrying and loading.	• Good housekeeping and odour control management needed. • Potential problems can be minimised by continuous loading into bulk export containers or trailers using a body/trailer exchange approach rather than full loading into an empty unit as a single operation.
Forklift transfer	• Some site staff requirement during delivery. • Allows use of larger skips. • Limited number of skilled forklift operators will be used, therefore minimising the chance of any mishaps.	• Possible interface risks between forklift truck and delivery vehicles. • Limited chance of spillage. • Skips may not remain fully sealed between deliveries.	• Spillage problems will be minor and easily rectified by the forklift operator.

Some examples of collection vehicles are shown in Figure 25. In addition, alternatives that may be considered include a mixed collection system using the survival bag approach where the digestible waste is collected in a separate bag to other wastes, and then collected in the same vehicle and separated at a centralised facility.

The type of collection vehicle will ultimately be determined by the vehicle capacity and the suitability of the existing waste collection fleet. In some cases, new vehicles will be required. Other related considerations include the impact on staffing requirements and health and safety considerations.

2.5 Bulking and treatment

The need for bulking (collecting together small loads) or intermediate transfer of digestible waste prior to transfer to the treatment facility is dependent on the proximity of the treatment facility to the collection area. This can be done at a transfer station or by vehicle to vehicle transfer.

Bulking may involve tipping of the digestible waste into a reception container or into skips with a hydraulic or retractable lid. This is dependent on an appropriate vehicle being used, which is able to empty directly into the containers, (Figure 26) or a stillage/pod system, which can be emptied by a forklift truck. Alternatively, vehicle to vehicle transfer can also be used. Some advan-

Figure 26: Bulking of organic waste in containers. Collection vehicle tipping (left) into a waste container (middle and right).

tages and disadvantages of loading procedures for bulking at an intermediate facility are shown in Table 5.

If a treatment facility which has sufficient capacity to process the digestible material is located nearby, bulking may not be required. However, discussion with the operator will be needed to agree a suitable method of delivering the material for processing at the processing plant (e.g. for AD treatment).

The treatment facility may offer additional treatment capabilities, which may impact on the approach used to collect the material. This may include:

- Optical sorting
- Bag opening
- Depackaging of food

Optical sorting

Optical sorting is based on households sorting their different types of waste into different coloured bags, one colour for each waste fraction (Figure 27). The system and has been used for decentralised separate waste collection introduced for the first time in Scandinavia in the 1990s. Different coloured bags are collected using in the same vehicle. Collection of coloured bags can also be achieved in vacuum and underground systems. At the waste treatment plant the different coloured bags are separated using optical sensors. Bag opening methods are used to open and empty the contents of bags for further treatment.

Figure 27: Optical sorting of multi colored plastic bags, Vänersborg AD plant, Sweden

De-packaging of food waste

The presence of packages can be a particular prevalent for food waste from commercial and industrial sources (e.g. supermarkets). Special de-packaging equipment is used when treatment facilities accept packaged food. The equipment removes the outer packaging from the food, enabling the food waste and packaging material to be further processed separately (WRAP, 2009b).

2.6 Lessons learned

When developing collection schemes for digestible wastes, there are some key aspects which need to be considered:

- It is vital that a thorough assessment of the quantity of digestible waste available and the likely uptake of a collection service for this stream is completed, as this will influence the scheme design (including the selection of containers provided to scheme users), collection approach, vehicle type, and associated labour requirements.
- Communicating a new scheme is vital to attract users to the service, as well as ensuring that the scheme is used correctly to minimise contamination in the collected material. In addition, an appropriate enforcement policy is needed to ensure that a consistent approach is used to reject contaminated material at the point of collection.
    - The provision of suitable containment for use externally and internally is vital, and it may be beneficial to provide liners for ease of use.
    - It is important to obtain clear information on the specification of material that a treatment facility is prepared to accept, including the types of waste accepted as well as the type of liners accepted.

3 Setting up a food waste source separation system

This section describes the experiences gathered from the introduction of source separation schemes for digestible household waste in Swedish municipalities. The information is derived in large part from a Swedish report "Tools for introduction of a system for collection of source separated food waste" by Anderzén and Hellström (2011).

3.1 Time line for the introduction of a source separation system

Experience from Sweden indicates that the process of introducing a source separation and separate collection system for organic/digestible/food waste takes a minimum of three years from the preliminary study to full implementation. The time needed depends on the size of the municipality, the choices made, and the resources available for the implementation. An example of a typical timeline overview for the introduction of a food waste collection system in Sweden is shown in Table 6. The table shows that various elements can be executed in parallel. The shaded areas indicate the shortest duration in an estimated time interval for different elements.

3.2 Pre-study/feasibility study

The first step in setting up a source separated collection is to carry out a feasibility study. The aim is to gather the necessary information that will enable the municipality to set objectives for the collection and biological treatment of food waste. The results of the feasibility study should enable a decision to be made as to whether collection of food waste should be introduced and, if so, why. It is vital that the feasibility study estimates the quantity of digestible waste available for collection, as well as the system of collection that could be adopted.

3.2.1 Estimate of waste quantities

The estimate of digestible food waste quantities is first and foremost based on the results from the municipality's own collection analysis and possibly on literature data. There is a difference between the waste quantities produced within a municipality and the quantities which can be assumed to be collected. This depends on the participation rate of citizens and the capture rate. The participation rate is the share of households and businesses that source separate their food waste. The proportion of food waste which is separated from the total waste is the

Table 6: Timeline for introduction of food waste collection system (Source: Anderzén & Hellström, 2011)

	1 year 2 years 3 years 4 years 5 years 6 years 7 years	
Preparation		
Pre study	4 to 6 months	
Objectives	3 to 6 months	
Stakeholder consultation	1 to 3 months	
Decisions taken in the City Council	3 months	
Investigation for the introduction	4 to 8 months	
Organization of collection		
Contracting organization	6 months to 5 years	*Existing agreement to be reviewed, procurement of entrepreneur*
Collection in-house	1 to 2 years	*The operating organization to be reviewed, reorganization, purchase of vehicles*
Optical sorting	1 to 3 years	*Building permits, construction of facility*
Treatment		
Procurement	3 to 6 months	
Own facility	3 to 5 years	
Introduction		
Purchase of equipment	3 to 5 months	
Fee/Regulations/Consultation	4 to 6 months	
Information to households and businesses	3 to 6 months	*Ongoing information during the introduction*
Introduction in various stages	1 to 5 years	

3.2.2 Collection system

A review of the potential types of collection systems that could be considered is also an important part of the feasibility study. The choice of collection systems should be made based on the objectives set for the collection.

3.2.3 Scenario analysis and assessment of costs

In order to compare different alternatives for both treatment and collection, scenario studies or options analysis can be an appropriate tool. Aspects like environment, energy, costs etc. are compared against each other and against the collection scheme objectives to determine the most suitable option. It is also recommended, at an early stage, to make a rough assessment of the additional costs for separate collection of food waste and biological treatment.

3.2.4 Internal and external stakeholder engagement and influence

As early as possible, it is important to engage all stakeholders, from collection staff to managers and decision-makers. The same is required for other administrations or units within the municipality or other organisations affected by the implementation of a new collection scheme. It would be useful to engage additional stakeholders such as institutions responsible for environmental and health protection, housing associations, tenants associations, non-governmental organisations, planning and construction teams, education and healthcare establishments which have catering/food production on site, and other potential scheme users. Engaging the media at an early stage will help to promote a positive and coherent message about potential changes to existing schemes and services.

3.3 Objectives

Setting clear objectives for the scheme will help to facilitate decision making and provide a clear direction for the feasibility study. The objectives should reflect the municipality's aims for the collection, for example:

- Energy recovery through the production of biogas
- Recycling of nutrients
- Specific proportion of households and businesses separating food waste
- Specific proportion of food waste collected for biological treatment
- Achievable purity of the collected food waste
- Specific separation rate for participants

In order to be reached, the objectives must be SMART: Specific, Measurable, Attainable, Relevant and Timely. In the case of setting a proportion of food waste to be biologically treated, a baseline of what is the total potential for collection needs to be determined. Objectives may be developed as part of an overarching local, or regional waste management strategy/plan, or as a result of the feasibility study.

An analysis of the economic impact, or alternatively a rough budget, can advantageously be used when the objectives are presented to help decision makers with the approval process. Showing a long term financial benefit as well as an environmental benefit can often outweigh short term and initial investments.

3.4 Investigation of main elements for scheme implementation

The introduction of a system for food waste collection is planned according to the well understood objectives.

3.4.1 Choosing the appropriate collection system

The choice of the collection system should be made taking into account objectives and conditions of the respective municipality. Collection from detached houses, multi-dwelling units and businesses or a combination of all types of household and commercial premises will be affected by a number of different factors; this should be reflected in the choice and design of the collection system. One or several complementary systems may be needed. It is also important to take into account how the food waste will be pre-treated in order to know which types of waste collection bags/liners are accepted by the respective AD treatment plant.

There are some important parameters to consider when choosing a collection system:

- Quality of collected waste
- Work environment
- Client or scheme user
- Cost
- Pre-treatment and associated AD treatment facility
- End products (biogas, digestate) and their use

- Objectives of the overall waste management plan
- Regional and national goals

A good way to increase the knowledge of the scheme to be introduced is to test the collection system over a short trial period, within a designated geographic area and with a restricted number of participants.

3.4.2 Frequency of collection and container size / capacity

The choice of collection system will impact the frequency of collection. Individual households, multi-dwelling units and businesses may have different requirements. It is important to keep in mind that separate collection of food waste will result in a reduction of residual combustible/disposable waste in the overall system for collection.

3.4.3 Project plan

Before the actual introduction of the collection system, it is necessary to make a project plan. The project plan should contain a schedule for purchase of bins, vehicles and equipment for household collection, placement of bins and, if needed, construction of a facility for bulking or pre-sorting as well as for when to provide and how to distribute information to scheme users. The schedule and the need for equipment depend on the system's participation rate, collection frequency and container size and capacity.

The management of the project is set out in the project plan, and should be complemented by engagement with stakeholders. The pace of implementation should be fixed in the project plan, as it is connected with the accessibility of human resources. It is recommended to include in the project plan a strategy for how to control and maintain the quality of the collected food waste, in order to ensure that the material has the high quality required for the use as AD feedstock (Al Seadi and Lukehurst, 2012).

The project plan should also clarify how the collection bins/liners/bags will be distributed (if these are used). Decisions need to be taken whether or not liners or bags should be provided free of charge for residents and/or businesses or whether a charge should be made.

This decision is likely to vary from country to country, based on the approach used for collection of other waste streams. The different requirements for detached houses, multi-dwelling units and businesses must be considered as well.

3.4.4 Contracts and staff

In the case of contracting organisations, existing agreements need to be examined with the contractor. This will show whether existing contracts can be amended to accommodate the source separation/separate collection of digestible waste, or if procurement of new services will be needed. If contract amendments are needed, it should be checked if penalties are to be paid to the existing contractor. In organisations where the collection takes place through direct management or in-house, the existing resources need to be quantified to evaluate whether the switch-over will require recruitment of additional staff resource and training.

The estimation of human resources needs must be related to the planning of communication and information measures. Door knocking campaigns and support should also involve the landlords and the non-profit housing associations and operators. The residents of the municipality as well as the operators usually have many questions, especially in the initial period. It is equally important to have suitable human resources available for inspections, follow-ups and improvements regarding the quality of the food waste.

3.4.5 Communication and information plan

The communication plan defines who needs to be informed about the new scheme and any subsequent changes to the existing schemes, when this should be done, and how often. The aims of the communication and information plan must be correlated with the requirement of human resources.

3.4.6 Budget

A budget, reflecting the costs of the implementation of source separation and separate food waste collection and the estimated operation costs must be elaborated. The budget should be updated if changes of the initial conditions occur.

3.5 Container size / capacity

Dialogue and consultation with owners of multi-dwelling units will be required to determine the size or capacity of the food waste container for collection. The system change means that the volumes of residual and combustible waste are reduced. It is therefore good practice to have prepared a clear quick reference guide for the transition towards separation of the digestible waste fraction. In some cases, a visit is also needed to assess the requirements of each collection site and to reach a suitable solution for the size and location of the specific food waste disposal point.

Collection from restaurants, large-scale kitchens and stores will experience large variations in terms of food waste volumes. This makes it difficult to develop a general model on what size of container is needed, so adjustments during the first weeks will be necessary. It may also be necessary to provide guidance and assistance to businesses to help them quantify the volume of food waste they produce. This could be in the form of a site visit and a review of current waste management operations. Since the food waste volumes vary, under- and over-capacity of bins might become an issue, especially for systems using separate bins or multiple compartment waste bins. Over-capacity can result in empty bins, indicating that the residents or customers do not separate their food waste. Under-capacity will result in crammed or overflowing bins. By carrying out follow-ups with customers during the first weeks of implementation, a system for evaluating capacity can be made, based on observations and lessons learned.

3.6 Work environment

When introducing a collection of food waste it is important to avoid using inappropriate or impractical waste collection points. The transition to a new scheme can also be seen as an opportunity to improve or relocate certain waste collection points from a work environment point of view. The opportunity to visit all larger disposal and collection points for multi-dwelling units and businesses can be combined with an assessment of the bin and/or container capacity. The choices of suitable bin sizes for systems using separate bins need to be made in close cooperation with the collection staff and the contractor.

Mechanical systems, such as automated vacuum collection and underground containers can ease the waste collection contractor's workload. Waste disposal systems with a tanks in either large-scale kitchens or restaurants with large volumes of food waste are other examples. Regardless of which system is used, communication with the staff is crucial in order to find an optimal solution.

3.7 Information and communication

Information and communication are important tools to achieve a successful introduction of separate collection of food waste. The information should clearly explain the reasons for separating food waste aimed for biological treatment. It is important to identify and use as many information channels as possible. Drawing up a communication plan can be helpful. This should always make sure that the information going out to households and businesses is easily understandable, complete and correct from the start. Using a knowledgeable and independent person to review the clarity of the information is always worthwhile.

Involve people in their own community decisions and actions, to avoid "not my business"– syndrome, and ensure "maximum participation".

It is also useful to raise awareness about the purpose of the separation of food waste before the implementation takes place. A clear strategy for how digestate and biogas will be used builds credibility and motivation. It is important to disseminate practical information about how to participate, and about how home owners and housing cooperatives can receive help to alter their source separation areas. Before the source separation becomes operative, clear instructions on how to proceed must be available. There is an on-going need for information, so that information must be provided continuously and repeatedly, in order to keep up the interest and the engagement. More importantly, new households need the right information to get started with source separation.

Communication and feedback of results are also as important as communicating how to use the scheme. Having the information translated into different languages is also a good idea. Attention should be paid to active press releases and to answering letters in newspapers. There are multiple ways to disseminate information:

- Direct information to the households, through door knocking, alternatively by phone calls
- Through arranging information meetings, alternatively on behalf of property owners and housing cooperatives
- Hot-lines/ human resources, to answer questions over the phone
- Making visits at multi-dwelling units and businesses
- Labels with clear information on bins/chutes where the food waste is thrown away
- Information brochures
- Leaflets/letters to households
- Environment calendars
- Web sites
- Campaigns
- Media
- Social media (e.g. mobile / web based messaging)
- Information desks in e.g. stores or other public places

3.8 Follow-up and feedback

It is important to follow up on the results from the collection scheme, so that the households and businesses participating in the source separation receive a feedback on their performance. Results that can be of interest are quantities collected (e.g. tonnes of food waste collected), goods produced and fields of use (e.g. number of bags of fertiliser produced and associated cost savings). Feedback of results should also be provided to the organisation operating the scheme. The contracting organisation and its staff must be interactively involved in all phases, to be inspired and motivated, and to motivate others.

3.8.1 Waste composition analysis

Comprehensive and frequent food waste composition analyses are often required, to allow evaluations of the quality of the collected material. Waste composition analysis enables direct calculation of the proportion of food waste that is sorted, as well as the quality of waste separated. They also make it possible to quantify and map the volumes of waste which has been wrongly sorted as food waste and volumes of food waste wrongly sorted as residual/combustible waste. The results of the composition analysis can be used to provide feedback and to indicate the improvement potential of the system in quantity as well as quality. There are also examples of extended waste composition analyses, mapping the proportion of unnecessary or avoidable food waste and food leftovers.

3.8.2 Lessons learned

Introducing a new collection system will be a significant transition for the municipality as well as for clients and will requiring sufficient staff resources. The speed of implementation needs to be weighed against the resources available. The time needed is also highly dependent on the size of the municipality, the choices made and the way it is managed. Good points of reference for choosing a system for collection of food waste and a type of biological treatment are the products to be produced, since they help clarifying the purpose of the separate collection. The usefulness of such products helps justify the additional costs of the new system, especially in the initial period of implementation.

Continuous feedback of information is important to motivate and engage municipality and contractor's staff, as well as the householders and businesses participants. Starting implementation of a food waste collection scheme within a test areas and then evaluating the system by specifically looking at information and communication, vehicles, routes, sizes/capacities etc. is recommended. Errors can easily be identified and improvements introduced before the system is implemented in other areas. It is a good idea to start with some local businesses such as caterers and schools, as they can act as a model for other businesses afterwards.

When implementing a source separation system for food waste, always remember:

- A well thought out and structured information strategy is one of the keys to the success of the introduction of a source separation system for food waste.
- Personalised mailings, literature, TV/ads, visits, exhibitions, radio, social media and employment of students for knocking on doors are a few ways to broadcast details of a new collection system.
- Feedback is also a very important element for success, both in terms of the introduction of a system and its longer-term performance.
- Support and dialogue with those who will be affected by changes: public housing, private property owners, tenants' association, etc. is important, so that everyone is aware and welcomes the introduction of source separation of food waste.
- It is important to highlight quality from the outset. Be sure to have the quality controls and monitoring set up in an early stage. Plan carefully and have plenty of time between stages of scheme implementation. Make sure the customers will know in advance what is going to happen and when.
- Municipalities must establish sample areas to

  easily identify and deal with incorrect source separation, use of bags/bins, collection vehicles and storage spaces.
- Underestimation of human and financial resources, both during the preparation phase and the operational phase can be avoided by learning from the lessons and the experience of other municipalities, with established source separation schemes.
- Setting goals for the collection of food waste is important. Management and monitoring of progress and success requires specific and clear targets.
- Attention must be paid to the collection of food waste in educational and healthcare institutions.
- In Europe, the animal by-products regulation requires special attention, trade documents and cleaning of transport vehicles.

4. Key drivers for source separation of digestible waste from municipalities

There are various elements which act as key drivers for source separation of municipal digestible wastes. Some of the most important refer to specific national policies and regulations, taxation systems and other economic tools, environmental and climate protection targets, production of renewable energy and industry and consumer demands.

In Europe, some of the most powerful drivers for source separation of digestible wastes from households and municipalities have proved to be the policies and regulations aiming to help mitigate climate changes and to divert organic wastes from landfills. Along with these, improved resource utilization efficiency and preservation of natural resources, less environmental pollution, protection of human and animal health, food safety and improved life quality are important drivers in Europe and around the world. Political targets aiming to increase the share of biofuels/renewable energy and the security of energy supply are further incentives for source separation of digestible wastes. Consumers and food industries in many high income countries impose restrictions on the recycling of waste products as fertilizer, unless they originate from source separated waste. Furthermore, mandatory quality standards for these products are in force in many countries.

A recent study aiming to identify the key drivers for the development of waste management systems, based on case studies of waste management in Sweden, concluded that selection of municipal solid waste treatment technology depends on specific socio-economic and environmental factors (Zaman, 2013). The key drivers were grouped into the following three categories:

- Social drivers are factors like personal behaviour, local waste management practice, patterns of consumption and generation of waste
- Economic drivers are for example, the resource value of waste, the economic benefit from waste treatment facilities and level of landfill tax
- Environmental drivers are the global climate change, the environmental movement and public awareness

Anaerobic digestion, along with dry composting, pyrolysis-gasification and treatment of waste using plasma arcs were seen by this study as the "potential emerging technologies for waste management systems" in Sweden.

4.1 International agreements

Efforts are being made by the international waste community to identify key issues and create a strategy that will deliver significant climate benefits in the waste sector. Two of the most important international conventions in the field of waste management and climate change, with an impact on source separation of household waste, are the United Nations Framework Convention on Climate Change (UNFCCC) and the Basel Convention (BC) (UNEP, 2010).

4.1.1 The United Nations Framework Convention on Climate Change (UNFCCC)

The UNFCCC 1992 (FCCC/INFORMAL/84 GE. 05-62220 (E) 200705) focuses on development, application and transfer of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of GHG in the waste sector. It promotes the transfer of environmentally sound technology, knowledge and know-how from high income countries to developing countries.

4.1.2 The Basel Convention (BC)

The Basel Convention focuses on hazardous wastes as well as overall waste management, highlighting the need of wastes management in a manner which protects human health and the environment against the adverse effects which may result from such wastes. Furthermore, the convention emphasises the contribution of waste management to climate goals, GHG emissions reduction and protection of resources.

4.2 Driving forces in EU-member countries

There are specific EU directives forming the overall policy framework, targets and objectives as well as the practical guidelines for waste management which promote source separation of digestible wastes in the EU-member countries. The most important pieces of legislation, highlighted in this Chapter, are the Landfill Directive, the Waste Framework Directive, the Renewable Energy Directive and the Animal By-Products Regulation. Additional information on drivers can be found in Chapter 9, "Further Reading".

4.2.1 The EU Landfill Directive

Directive 1999/31/EC on landfill of waste (European Commission, 1999) sets targets for diverting waste from landfill, including biodegradable waste. The Directive defines biodegradable waste as any waste that is capable of undergoing anaerobic or aerobic decomposition (like food and garden waste, paper and cardboard, etc.). The total amount of municipal waste going to landfill must be reduced to 35% of the 1995 level by 2016. Intermediate steps of 75% of the 1995 level by 2006 and 50% by 2009 were also defined. Also, countries with a heavy reliance on landfill were given extended times to reach the 35% target. As a consequence, landfilling of organic wastes was banned in countries like Denmark, Sweden, Austria, the Netherlands and Germany in the first decade of the 21st century. Many other EU countries are moving away from landfilling as an option for waste management, and many of the existing landfilling sites have been closed.

One of the expected effects of the Landfill Directive and of landfill diversion is that digestible waste is diverted to anaerobic treatment plants. The most successful countries in terms of recycling and energy recovery from organic wastes are indeed those where landfilling of organics is banned. However, landfill bans alone are not a guarantee that the main share of the diverted organic wastes from landfills is source separated and supplied to AD. Incineration rates increased in most European countries as a result of the EU Landfill Directive, where 20–25% of the total municipal solid waste was incinerated in 2006, according to ECCPT (IPCC, 2007). Countries with high incineration ratios include France, the Netherlands, Sweden and Denmark. In Denmark, in spite of the landfill ban, there has been very little source separation of the digestible fraction up to now and most of the organic waste diverted from landfills was incinerated, as Burrows (2013) also observed. This situation is expected to change in the coming years, as a result of the Danish Government efforts to make resource management more sustainable, on one hand by increasing the source separation of wastes, including the digestible fraction of household waste, and on the other hand by diverting such wastes from incineration to AD (recycling with energy recovery). This is reflected by the new Danish strategy for resource management, symbolically named "Denmark without waste" (Danish Ministry of the Environment, 2013), published in October 2013. The strategy foresees inter alia an increase of the source separation of digestible household waste, which is to be used as AD feedstock for biogas production. Apart from the overall socio-economic benefits of AD, economic benefits for the citizens involved in source separation are anticipated, due to lower costs of AD treatment compared with incineration. In the United Kingdom, instead of a landfill ban, an escalating landfill tax is used as a driver to divert waste from landfill. The aim is to make recycling a better financial option for the waste producers and to allow the time necessary for the development of the infrastructure and treatment capacity for alternative treatment options, such as AD (Burrows, 2013).

4.2.2 The EU Waste Framework Directive

The revised EU Waste Framework Directive (WFD), 2008/98/EC was published in 2008 as the legislative framework for the collection, transport, recovery and disposal of waste in all EU member countries, along with the permitting, registration and inspection requirements (European Commission, 2008). The WFD emphasizes the waste hierarchy (See Chapter 1.3 of this report). It stipulates that waste prevention and waste reduction as well as reducing the harmfulness of wastes are the main priorities in the waste hierarchy in EU member countries, followed by the recovery of waste through recycling and re-use, which transform wastes into valuable sources of energy and /or secondary raw materials. Waste recovery, reduction of emissions of greenhouse gases and effective resource utilisation are important targets of the waste management policies across EU member countries. Corresponding waste management measures must be taken to avoid any potential risks for human and animal health and any harmful effects on the environment caused by the waste materials or by the way they are managed. According to the Directive, the EU Member States are obliged to establish separate collection of waste where it is technically, environmentally and economically feasible, in order to meet the necessary quality standards for recycling.

4.2.3 Promotion of the use of energy from renewable sources

Directive 2009/28/EC, known as the EU Renewable Energy Directive, represents the framework for promotion and support of renewable energy production in the EU. The directive stipulates the mandatory energy targets for EU member countries and the specific measures to be taken in order to ensure a significant increase in the production of renewable energy and the use of biofuels in Europe (European Commission, 2009a). The main aim is to minimise the environmental impact of transport and energy production sectors in Europe. Thus, the Directive contains sustainability criteria for biofuels, related to requirements of greenhouse gas (GHG), emission savings and land-use. The fulfillment of the sustainability criteria for biofuels is mandatory, in order to be counted towards the renewable energy targets, and to be eligible for financial support as stipulated in the Directive.

4.2.4 Animal By-products regulation (ABP)

The European Animal By-Products Regulation (ABP) 1069/2009 (European Commission, 2009) sets out the rules for recycling, disposal and destruction of animal by-products which are declared not suitable for human consumption. The initial version of the regulation, that came into force in Europe in 2002 (1774/2002), was primarily designed as a measure for preventing transmission of bovine spongiform encephalopathy (BSE) and of foot and mouth disease (mononucleosis). The renewed version of the ABP Regulation, 1069/2009, stipulates which categories of animal by-products and in which conditions these are allowed to be treated in biogas plants. For specific animal by-products, batch sanitation by pressure sterilization or by pasteurisation at 70°C for 1 hour is required and limits for particle size and for indicator organisms such as Escherichia coli, Enterococcaceae and Salmonella are set. More information about the European ABP regulation is also available in the IEA Bioenergy report Quality management of digestate from biogas plants used as fertiliser (Al Seadi and Lukehurst, 2012). References to the EU ABP regulation are made in many parts of the world.

4.3 Driving forces in countries outside EU

The driving forces behind the source separation of household waste intended as feedstock for AD are similar to the ones identified within the EU: diversion of waste from landfill, mitigation of climate changes and development of renewable energy systems. Landfill bans, similar to those in the EU, have been implemented in municipalities in North America and Canada, with the same aim of moving waste treatment and management up the hierarchy, to focus on prevention, reuse and recycling. The bans are usually implemented within a framework of existing policy measures, such as landfill taxes (Burrows, 2013). In other parts of the world, in low- and middle-income countries, the primary motive of source separation is often socio-economic rather than environmental, due to the low pollution potential of the materials that are usually separated, as indicated by Lardinois and Furedy (1999).

4.3.1 Driving forces in Switzerland

Switzerland is one of the pioneer countries concerning recycling and source separation of waste. The amount of recycled MSW is growing steadily, allowing Switzerland to stabilise the amount of incinerated and landfilled MSW in 1990. Today, slightly more than half of the MSW produced is source separated. About a third of the recycled MSW consists of biowaste, which is used in composting and digesting facilities (FOEN, 2012). At the regulatory level, the Technical Ordinance on Waste prohibits landfilling of combustible waste and obliges the authorities to ensure a maximum of source separation. Information campaigns over many years have brought the population to a broad awareness and understanding of the importance of source separation. As complementary measures, most cities and municipalities have introduced “pay-per-bag” fees within the last 20 years, a system based on the polluter-pays principle. At the beginning of the “pay-per-bag” practice, the measure was not always well accepted. Experience from Switzerland shows that, within a few months, the population gets used to it and adopts waste-reducing habits.

4.3.2 Driving forces in South Korea

The regulations listed below, enforced by the Korean Government, are the key drivers for the source separation of food waste in Korea. They not only lead to the decline of food waste entering the landfills but also reduced food waste generation, and assisted effective management of food waste in Korea.

- Ban of food waste into the landfill: In 2005, a ban on the entry of biodegradable food waste into the sanitary landfills was introduced in order to encourage recovery of renewable materials.
- Promotion of source separation of food waste: In 2005, use of pre-paid authorized plastic bags introduced, or special bins for the collection and disposal of the source separated food waste.
- Food waste volume based fee system (VBFS): In 2012, the VBFS was introduced, i.e., food waste disposal fee is paid depending on the volume of food waste generated.
- Ban of food waste leachate to oceans: In 2013, a prohibition on food waste leachate (generated during the treatment/recycling of food waste) dumped in oceans was introduced.
- Regulation on diminution of moisture content of food waste: In 2005, a regulation concerning the obligation of the producers of large quantities of food waste, was adopted to reduce the moisture content of the food waste by 25%. This is achieved by drying or by heating prior to further treatment.

4.3.3 Hong Kong

In Hong Kong, the “Policy Framework for the Management of Municipal Solid Waste in Hong Kong (2005-2014)” was adopted in 2005 by the Environmental Protection Department (EPD). The declared aim was to recover 26% of domestic waste by 2012. The Programme on Source Separation of Domestic Waste was launched across the territory in 2005 to encourage more people to separate their waste for recycling. The rationale behind the programme is the simple fact that Hong Kong is running out of space for landfilling, and thus drastic measures for waste prevention/reduction and recycling are needed. In the above context, source separation of domestic waste is considered essential to ensure the quality necessary for recycling. Along with a territory-wide information campaign and a flexible, step by step implementation process, a “Guidebook on source separation of waste in residential buildings” was published to help households separate their domestic waste. More information is available from: Hong Kong Waste Reduction https://www.wastereduction.gov.hk/en/household/source_intro.htm.

5. Economics of source separation

Although source separation and separated waste collection is historically perceived as an element that increases the costs of waste treatment, this is only true if source separation is seen separate from the overall management of municipal waste. Source separation adds costs to the waste collection process, but reduces the amount of residual waste and the costs of its management (Favoino, 2006), and should therefore be integrated and optimized, together with the measures for waste minimization and recycling, within the overall system of municipal waste management.

5.1 Qualitative cost analysis, based on Swedish experience

The qualitative cost analysis below is based on the Swedish experience, and concerns the additional costs and the current costs for the management of the separate food waste collection system. Most costs, such as sorting equipment, bins and information, are financed by the municipality through waste fees. Reconstruction of waste chambers, construction of recycling sheds or waste bin shelters are normally financed by the owner of multi-dwelling units, housing cooperatives or associations. The latter are therefore not included in the compilation of items for the municipality's additional costs, as listed below.

A. Additional costs when introducing a system for source separation

- Vehicles adapted for source separation.
- Bins for food waste (for use inside and outside)
  (Includes costs for delivery, packaging and assembly of containers)
    - Sorting equipment (bags and bag holders)
    - Staff (e.g. quality assurance staff, drivers, training, etc.)
- Information activities
- Reloading points

B. Additional costs after introduction of source separation

- On-going information and feed-back
- Collection
- Additional costs for collecting two different waste streams
    - It is cheaper for apartment buildings (using shared bins) than for detached houses
- Staff (e.g. quality assurance staff, drivers, training, etc.)
- Treatment, including transportation to treatment plant
    - Sometimes cheaper, sometimes more expensive than for e.g. incineration
- Bins/liners/bags (used by the residents for collection of source separated food waste)
- Quality assurance work
    - Regular monitoring of the performance of the scheme, in terms of quality of the separated fraction, preferably in cooperation with property owners and residents.

An incentive-based system is applied in Sweden. Source separation is voluntary for households. The municipality encourages and supports the most environmentally friendly waste management option by charging a higher waste management fee for households who choose not to source separate their food waste.

5.2 Cost efficiency through integration of source separation into overall MSW management

Long-time experience from the source separation of organic fractions in Italian and Catalonian (Spain) municipalities demonstrate that the total costs per unit of waste decreases with the increasing amount of waste collected. Existing literature (e.g. Favoino, 2002) indicates that the costs of separate collection by waste management companies and municipalities are comparable with the traditional mixed waste collection, at last when the collection of the source separated digestible/organic fraction is integrated into the overall waste management system. Integration of waste management processes is shown schematically in Figure 28. The author highlights the importance of evaluating and optimising collection schemes according to their local suitability and of implementing effective waste prevention/reduction policies. He emphasises that traditional cost analyses focus on cost per unit (kg or tonne) of a single waste stream separately collected. In municipalities where the organic fraction is collected separately, the amount of residual waste to be collected is lower. Separated fractions and residual waste can therefore be collected in alternate weeks resulting in the same overall number of collection journeys. The corresponding lower tonnage of residual waste results in lower costs for its management, off-setting the additional costs for the source separation of the digestible/organic fraction.

Integration of separate collection of source separated waste into waste management systems results in the need to redesign the whole municipal waste collection system. This means that removal of the digestible/organic fraction of for example household waste should reduce the volume of waste sufficiently to allow residual waste to be collected less often. In Italy and Catalonia (Spain), the collection of residual waste was reduced this way from 4 to 6 times a week up to 2 or 3 (Favoino and Ricci, 2006). Other countries have taken similar approaches. For example in the UK, the collections of residual waste have been reduced from weekly to fortnightly in many areas where a weekly food waste collection and comprehensive dry recycling service are provided to residents. The cost of the waste collection (and the number of collection rounds) will increase only if source separation of household waste is implemented as an "add-on" service, on top of the existing MSW collection, and without any modifications of the other waste collection schemes. On the other hand, if source separation is integrated within the overall MSW management, so that collection frequencies, vehicles, containers, and logistics are reviewed and optimised across all the other municipal waste streams, the overall costs of MSW management and the collection frequencies will be comparable with the mixed waste collection (Favoino and Ricci, 2006).

Although the cost efficiency of schemes with intensive collection of food waste and lower frequency for residual waste is highly relevant in warm climates, where there are normally very high frequencies of MSW collection, the author indicates that such schemes could be applied with good results in Central and Northern Europe as well (Favoino, 2003). The author summarises the key principles of a cost efficient source separation of digestible household waste as:

- Designing user-friendly collection schemes
- Keeping food waste collection separate from yard waste (requires lower frequency)
- Hand-picking made possible, to reduce pick-up times and costs (houses with gardens).
- Replace expensive packer trucks by cheaper vehicles for transportation of food waste
- Reduce or even eliminate washing rounds by using buckets and watertight bags
  (Increases captures and makes the system more user-friendly)
- Reduce collection frequency of residual waste accordingly

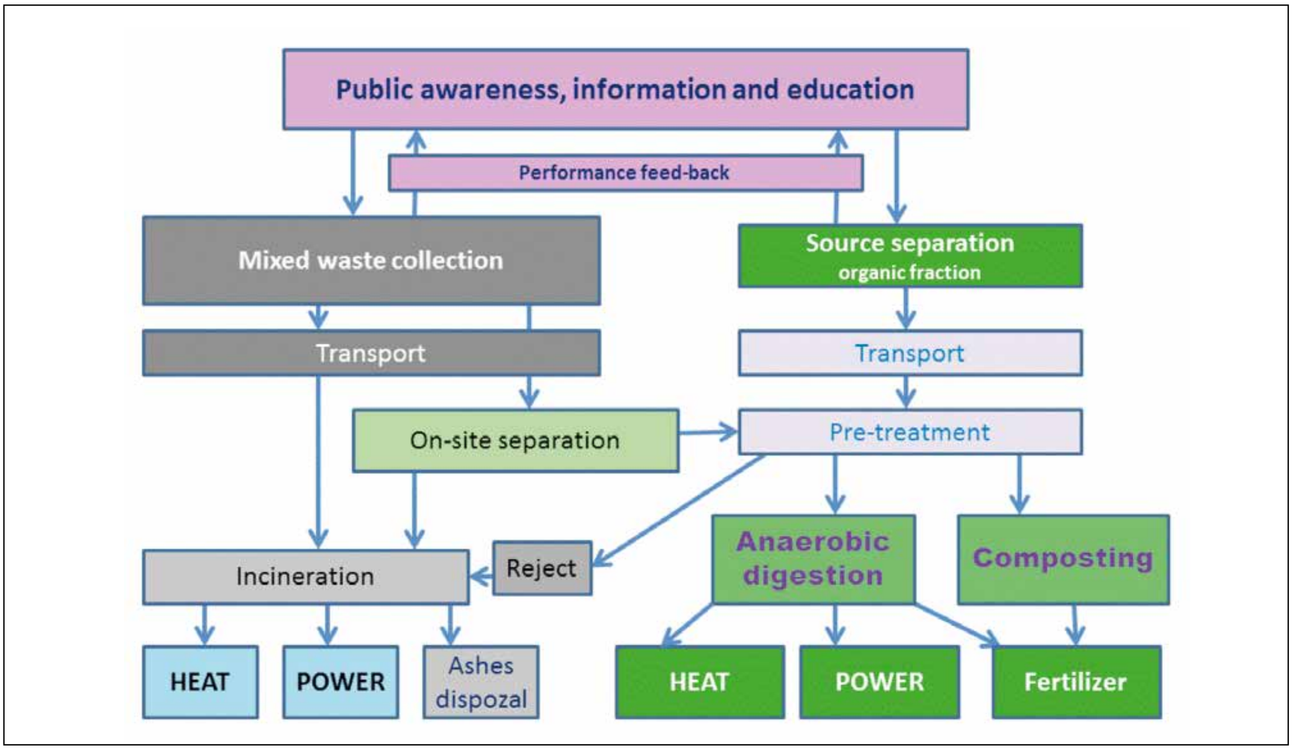


Figure 28: Flow diagram of MSW management with energy recovery

6. Successful source separation schemes

Three successful schemes are summarised below. Additional information in the form of an assessment of source separated waste schemes, including life cycle assessment, and case studies have been carried out by the VALORGAS European project (VALORGAS, 2012a, b, c & d).

6.1 Source separation of food waste in Umeå, Sweden

Location of case study

- Umeå is a municipality situated in the north-eastern coastal part of Sweden. The municipality has a population of about 120,000 citizens and covers an area of 2,300 km^2.
- The town of Umeå has about 15,000 detached houses, 39,000 households in apartment buildings, approximately 4,600 weekend residences and 260 food businesses.

Overview of the waste collection process

- Umeå Vatten och Avfall (UMEVA) is a company owned by the municipality of Umeå which is responsible for the municipal waste management. In 1997, UMEVA already contemplated implementation of various types of systems for separate collection of food waste. After a decision to use separate bins for food waste collection, a full scale trial in an area comprising 1,000 apartments was carried out in the year 2000. The decision to introduce separate collection of food waste was taken in 2006 and was implemented as a four years project, starting in 2007.
- The collection of waste in the municipality is now performed by the contractors Ragn-Sells and Allmiljö AB.
- A system with separate bins is applied to detached houses, apartment buildings and businesses which are similar to households, such as nursery schools and offices.
- The results from waste composition analyses, performed late in 2010, showed that households in apartment buildings source separated an average of 1.2 kg of food waste per week and detached houses 3.8 kg per week.
- The system is voluntary and includes an environmental tariff based on weight. This means that an environmental fee is charged to those who choose not to separate their food waste. Households who source separate have their fee decreased according to actual weight of their separately collected food waste. Businesses that serve more than 1,500 food portions per week are not offered collection of food waste in bins. However, they are required to install a waste disposal unit with a tank. The landlord or the business owner is responsible for this investment. Today there is only one waste disposal unit with tank in the municipality, but according to the municipality's work plan there will be 20 to 30 such units by 2016.
- 68 % of the detached houses source-separate their food waste, either in separate bins (56 per cent) or by home composting (12 %). The objective is a participation rate of 80 per cent. For encouragement, the associated environmental fee has been adjusted. In apartment buildings, 65 % of the households have the possibility to source-separate food waste.
- By the end of 2010, 27 % of the food waste from the households in the municipality was biologically treated (the estimate does not include food waste from businesses).
- The introduction of source separation of food waste was carried out at a relatively low pace (1,200 – 12,000 new households per semester over four years).

Waste collection

- Residents in detached houses are offered food waste collection every second week at the kerbside. Residents in apartment buildings and businesses are offered food waste collection 1-2 times per week. Residual waste is collected in separate bins and recyclables are taken to recycling centres.
- Paper bags (Figure 29) and ventilated bins (140 l) are used for source separation in kitchen - this is included in the subscription. Businesses are also offered this equipment. Biodegradable plastic bags have also been used for trial in some businesses, but purchase of bags and kitchen caddy is charged at own cost. Bags are distributed to detached houses once a year. Owners of apartment buildings have the possibility to order the bags they need, and the delivery is made monthly by UMEVA or by a contractor.

Figure 29: Using paper bags for separate collection of food waste (Source: UMEVA)

Figure 30: Side-loading vehicles for waste collection (Source: UMEVA)

- Back-loading and side-loading vehicles (Figure 30) with two compartments are mostly commonly used, but also collection vehicles with one compartment are used on some routes. No special adaptations of the vehicles have been made. However, maintenance of lid closure mechanisms and seals is looked after more carefully now, compared to when collecting combustible waste.

Communication:

- Information on the implementation of source separation of food waste was given through the municipal website (Figure 31), in printed form (Figure 32) and through information meetings for owners of apartment buildings and housing cooperatives.
- The non-profit housing associations and the landlords functioned as information channels from the municipality to the households, and during the introduction phase they visited residents to disseminate information. UMEVA arranges annual meetings with associations to discuss the type of information that should be prepared for distribution to the residents. Similar information meetings were held directly with tenants, but these were not as successful.

Figure 31: Multilingual information concerning the waste materials collected in brown bins (digestible) and green bins (non-digestible). Source: www.umeva.se

BRUNT KÄRL	BROWN BIN	CONTENEDOR MARRÓN	WEELKA MIDABKA BUNIGA LEH	وعاء بُنّي
Matrester	Leftover food	Residuos de comida	Harayga cuntada	بقايا الطعام
Grönsaker och frukt	Vegetables and fruit	Verduras y fruta	Khudaarta iyo miraha	خضار وفاكهة
Kaffe, te och deras filter och påsar	Coffee, tea including filters and tea bags	Café, té y sus filtros y bolsas	Qaxwo, shaah iyo waxyaalaha la socdo	قهوة، شاي وأكياسهم وفلاترهم
Ris, mjöl, pasta	Rice, flour, pasta	Arroz, harina, pasta	Bariis, bur, baasto	رز، طحين، معكرونات
Äggskal	Egg shells	Cáscaras de huevos	Qolofta ukunta	قشر البيض
Skaldjur	Shellfish	Mariscos	Xayawaan-badeedka an laf dhabarta lahayn	بحريات
Mindre ben från kött, fisk och fågel	Smaller bones from meat, fish and poultry	Huesos pequeños de carne, pescado y aves	Lafaha yaryar ee hilibka, kalluunka iyo digaagga	عضم صغير من اللحم، والسمك، والطيور
Blommor (men inte jord!)	Flowers (but not soil!)	Flores (¡pero no tierra!)	Ubax/dhirta (carrada ka reeban!)	ورود ونباتات (بدون التراب)

GRÖNT KÄRL	GREEN BIN	CONTENEDOR VERDE	WEELKA MIDABKA CAGAARAN LEH	وعاء أخضر
Tobak	Tobacco	Tabaco	Tubaakada	تبغ
Tuggummi	Chewing gum	Chicles	Lubaanta	علكة
Plast	Plastic	Plástico	Blaastikada	بلاستيك
Folie	Foil	Papel aluminio	Blaastikada qafiifan	ورق التغطية
Kattsand	Cat litter	Arena de gatos	Carrada yaanyuurta	تراب القطط
Blöjor	Nappies	Pañales	Xifaayada	حفاضات
Textil	Textile	Textiles	Dharka	أقمشة
Grillkol och aska	Barbecue charcoal and ash	Carbón de barbacoa y cenizas	Dhuxul iyo dambas	فحم الشوي والرماد

Figure 32: Food waste collection and recycling – information brochure (Source: www.umeva.se)

Contamination:

- The vehicle drivers inspect the quality of the food waste by checking the bins when emptying them. Any incorrect sorting is reported and targeted information is sent to the appropriate person. Since high purity level of the food waste is one of the municipality's highest ranked objectives, waste composition analysis and scheduled quality inspections are performed on a routine basis. Feedback on quality is provided to housing associations and landlords through leaflets, posters and the municipality's website.
- Results from a waste composition analysis performed in the autumn of 2010 showed that food waste from apartment buildings and detached houses had an average non-food content of 1.2 %. Some samples from detached houses had only 1 %.

AD of the source separated digestible fraction (if applicable)

- The AD treatment of source separated food waste is currently carried out in the biogas plant in Boden (a town situated about 300 km north of Umeå). The biogas produced is upgraded to vehicle fuel and primarily used for buses (Figure 33).

Figure 33: Food waste transformed into biogas is used as vehicle fuel in Sweden (Source: www.umeva.se)

Other information

- The long-term objectives of the municipality regarding separate food waste collection are:
  - 50 % of the food waste from households and industries shall be biologically treated by 2020.
  - 98 % purity of the collected food waste (maximum 2% non-food content)
  - 80 % participation rate for detached houses and 64 % for apartment buildings.
  - 30 % of the industries in the municipality should have a system for source separation of food waste by 2016.
- During the introduction of collection of food waste, UMEVA was required to make sure that all waste premises of apartment buildings fulfilled the requirements for the working environment before the system was taken into operation.
- The transition to source separation of food waste was undertaken with a new contractor for the collection of food waste. To achieve a reasonable waste collection price, this is something UMEVA recommends other contracting organizations.
- The introduction was carried out as new project, with a project manager and, on average, three full-time employees. Hiring additional personnel is recommended when implementing a new system. The costs for the additional personnel corresponded to 44 % of the transition costs. The additional cost during the introduction was around 242 SEK per household. Subsequently, annual costs increased by 46 SEK per household to finance more staff for managing the daily operation of the food waste collection system, the slightly increased collection costs and the purchase of paper bags.
- There are still 7,000 households in the countryside that do not participate in source separation of food waste. However, they will be offered source separation of food waste in 2013. The system with separate collection from businesses has only just started. UMEVA is not willing to compromise the work environment, and therefore the decision has been made to install waste disposal units with tanks in large-scale kitchens. This also means that the full implementation will take a longer time to accomplish.
- Critical success factors
  - Suitable waste premises and equipment adapted to the food waste quantities
  - Clear national environmental objectives as driving force
  - Voluntary system for participants
  - Coordinating the introduction of food waste collection with the procurement of collection contracts to ensure affordable prices
  - Thorough introduction schemes and initial slow pace of implementation
  - Information to apartment buildings provided in due time
  - Sufficient human resources for the implementation
  - Investment in municipal activities first (e.g. separate food waste collection systems in schools), to set good examples for private waste producers (e.g. restaurants)
  - Well thought-out and laid-out information
  - Good cooperation with landlords and housing associations
  - Door-to-door campaigns in apartment buildings
  - Preparation of the whole organisation for the conversion to source separation of food waste
  - Learning from municipalities which have already introduced the system for source separated food waste
  - Quality inspections and waste composition analysis performed on a routine basis
  - Results of quality controls fed back to landlords and housing associations
  - Regular inspections to build trust in the system
  - Advocating alternative/adjusted systems such as the installation of a waste disposal unit with tank, instead of bins, for big businesses.

Figure 34: The town of Umeå, situated on the Eastern coast of Sweden (Source: Google Maps)

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6.2 Source separation of food waste in Oxford City Council, UK

Location of case study

- Oxford is a city located in central southern England and is the county town of Oxfordshire. It has a population of approximately 150,000 and covers an area of 46 km^2.
- Oxford's urban areas are densely populated. However, 52% of the city is open space. It has a diverse economic base. Its industries include motor manufacturing, education, publishing and a large number of information technology and science-based businesses.

Overview of waste collections

- Oxford city council has offered residents a weekly kerbside food waste recycling collection since 2010. In addition, a year-long food waste collection trial for businesses in Oxford was rolled out in February 2012.
- The food waste is collected by a dedicated food waste vehicle (Figure 35) and transported directly to the Agrivert Cassington Anaerobic Digestion facility.
- A dedicated weekly green waste collection is also provided for residents. Green waste is collected at kerbside and taken to an in-vessel composting plant in Ardley and operated by Agrivert, which produces compost that is sold in bulk from sites in Oxfordshire and Hertfordshire.
- 17.59% of the total household waste was sent for composting or anaerobic digestion from April 2011 to March 2012 (Lets recycle, 2011).

Waste sources

- Food waste is collected from residents as well as from colleges, pubs and conference centres which have a dedicated food waste collection as part of the commercial food waste collection trial.

Waste collection

- Oxford City Council offers its residents a weekly collection of the following streams from the kerbside:
    - Residual waste
    - Dry Recycling
    - Food waste (including meat)
- However, large blocks of flats are not provided with a food waste collection.
- A fixed cost for waste management services is incorporated into Council Tax bills for each property, which is the case throughout the UK. There is no "pay as you throw" component in the system.
- Residents are supplied with a:
    - 7 litre food caddy for use in the kitchen (Figure 36); and
    - 22 litre food-waste bin with lockable lid (Figure 36) to store food waste ready for outside kerbside collection.
- A small number of biodegradable liners (Figure 37) are provided free of charge to residents, but they are able to purchase additional liners or alternatively line their caddies with newspapers if required.
- The dedicated collection vehicle shown in Figure 35, takes the collected material directly to the Cassington AD facility.

Figure 35: Oxford City Council food waste collection vehicle

Figure 36: Food waste caddies of 7 litres and 22 litres

Figure 37: Biodegradable kitchen caddy liner

Figure 38: Food Waste Recycling Leaflet

Communication

- A ‘Food Waste Recycling’ leaflet was distributed to residents on roll out of the scheme. This is shown in Figure 38.
- A dedicated Food Waste Recycling webpage has also been established by the Council to inform and educate residents:
  http://www.oxford.gov.uk/PageRender/decER/Foodwasterecycling.htm

Quality control

- To monitor the quality of food waste presented for collection, field officers/wardens conduct visual spot checks on a regular basis. If contaminants such as plastics, glass, soil, cooking oil or timber are identified, food waste bins are ‘carded’ or given tickets explaining why their food waste was not collected. Re-offending residents get a visit from a warden. The visit is designed to provide information and advice regarding food waste collection to the resident.

Cassington Anaerobic Digestion Plant

- The source separated food waste is used as feedstock for biogas production at the Cassington AD facility.
- The £9 million Agrivert plant (Figure 39) was developed as a joint venture with skip hire firm M&M Skip Hire (Oxford Renewable Energy) under a 20-year contract with Oxfordshire County Council to provide food waste treatment for Oxfordshire County Council.
- The facility diverts 40,000 tonnes of food waste from landfill every year, including commercial packaged food products.
- The food waste is processed through a Wacker hammer mill, which rotates at 4000rpm, pulverising the waste through a trommel, leaving the biodegradable plastic bags and other outsize materials contaminants as a reject stream (Figure 40).
- The facility produces about 4.5 million m^3 of methane per year, used to generate 2.1MW of renewable electricity which is supplied to the national grid. The electricity produced is enough to power around 4,200 homes.
- The liquid digestate produced at Cassington is used

Figure 39: Agrivert Cassington Anaerobic Digestion Plant

Figure 40: Food waste processing at Agrivert Plant

as a biofertiliser on local farms, improving crop yield and reducing the need for artificial fertilisers. The quality of digestate meets the requirement of the Anaerobic Digestate Quality Protocol (http://www.wrap.org.uk/content/quality-protocol-anaerobic-digestate) and its associated standard PAS 110 (http://www.wrap.org.uk/content/bsi-pas-100-compost-specification). This means that the digestate produced meets the minimum quality standard and can thus be used without waste regulation controls in many applications in England and Wales.

- The local market demand for the digestate fertiliser outstrips the volume produced; a second AD plant is under construction.

Reference list for the information used in this case study

Agrivert Cassington Anaerobic Digestion Facility http://www.agrivert.co.uk/facilities/cassington-ad-facility

Lets Recycle (2012) Council League Tables 2011/12. Source: www.letsrecycle.com/councils/league-tables-1/2011-12-green-food

Oxford City Council. Food Waste Recycling. Source: www.oxford.gov.uk/PageRender/decER/Food-wasterecycling.htm

Waste and Resource Action Programme (WRAP) (2010) The Quality Protocol for Anaerobic Digestate. http://www.wrap.org.uk/content/quality-protocol-anaerobic-digestate

Waste and Resource Action Programme (WRAP) (2010) BSI PAS 100 - Compost specification http://www.wrap.org.uk/content/bsi-pas-100-compost-specification

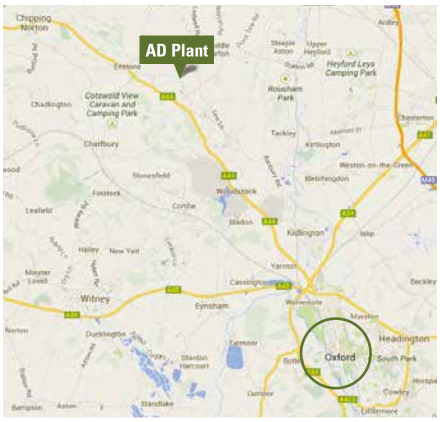

Figure 41: Location of Oxford town and of Cassington AD plant, in central southern England, UK (Source: Google Maps)

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6.3 Source separation of food waste in Daejeon, South Korea

Location of case study

- Daejeon Metropolitan City (DMC) is located in the central southern part of the Korean peninsula and is the fifth largest metropolitan city in South Korea. DMC is densely populated, with about 1,530,000 inhabitants in 2013. The city covers an area of 540 km^2; 52 % of the city is mountainous terrain.
- Daejeon is known as "Science Town" with 75 research institutes and 12 universities, serving as a hub of science and education, transportation, culture and politics.

Overview of the food waste collection process

- Food waste in Korea includes left-over food and waste produced during the processing of food (cutting, trimming) or waste generated due to improper storage, packaging and transportation.
- Food waste is typically characterized by high moisture content (> 80 %), because a typical Korean meal includes a bowl of rice, different kinds of soups along with some side dishes such as kimchi (fermented food), soya sauce, meat, seafood and vegetables. This means that food waste requires special management practices like a daily collection system, as food waste can degrade rapidly, causing odour nuisance and leachate problems. The leachate production rate is usually 0.6-0.8 m^3 per m^3 of food waste during collection and transportation. As this kind of waste is not suitable for landfilling or incineration, it cannot be collected along with other municipal solid waste (MSW).
- The Korean Ministry of Environment (MOE) introduced a regulation for source separation of food waste in 2005, aiming to recover renewable materials. As a consequence, source separated food waste is collected in special bins or pre-paid authorized plastic bags and then disposed at the kerbside for further management. The special bins or pre-paid authorized plastic bags can be bought from supermarkets or from local municipalities. Until 2011, fixed food waste disposal fees were paid monthly, irrespective of

the amount of food waste generated. Since the implementation of the food waste volume based fee system (VBFS) in 2012, food waste fees depend on the volume of food waste generated. This measure aimed to increase recycling and to minimise generation of food waste in Korea. One year after its implementation in 2011 in Daejeon Municipality, the food waste generation had been reduced by 12%.

Waste sources

- Food waste in Korea comes from the three main sources:
  1. Detached houses, row house and small restaurants
  2. Apartment complexes
  3. Large quantity food waste producers (LQP)
     a. Institutes/schools/other organisations that provide meals for over 100 persons per day
     b. Large restaurants, with an area of more than 200 m^2
     c. Large stores and markets
     d. A wholesale market, a cooperative's joint market, and a distribution centre for agricultural and fishery products
     e. Tourist hotels and lodges
- According to the disposal rules, food waste such as radish, Chinese cabbage, pumpkin, and watermelon need to be chopped into small pieces, whereas, sour foods such as kimchi, salted fish, pickled sauce and pepper paste etc. should be pre-washed before discarding into the food waste bin. In addition, source separated food waste cannot be mixed with other MSW. Any foreign materials such as paper, plastic caps and tooth picks have to be removed before disposal. Some of the materials of concern for effective recycling are given in Table 7.

In Korea, 13,537 tonnes/day of food waste was generated in 2011, which accounted for 27% of total municipal solid waste (MSW). DMC generated 509.9 tonnes of food waste in 2011, as shown in Figure 42. Although the amount of food waste is increasing every year, about 96% of the food waste is recycled in Korea (Korea MOE, 2011). In 2012, the introduction of VBFS resulted in 47 tonnes reduction of food waste, which is equal to 11.9% of the total amount of food waste produced.

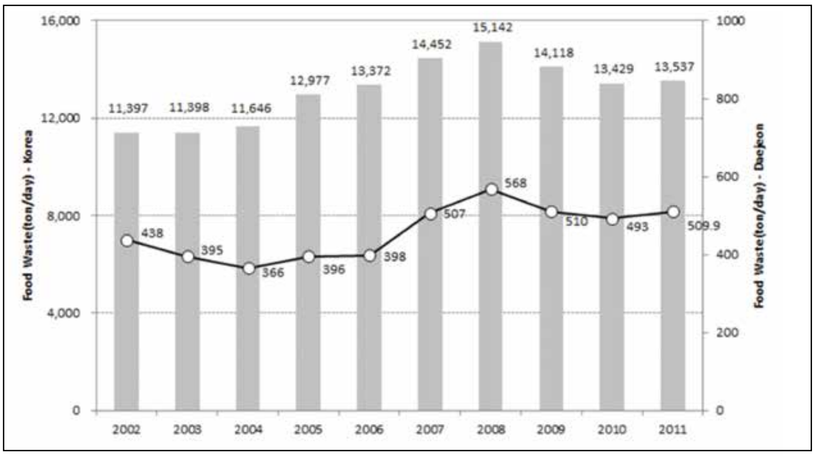

Figure 42: Generation of food waste in Korea and DMC

Table 7: Materials of concern in food waste, to be removed before dispozal

Foreign materials	Plastic, bottle caps, toothpicks, straws, foil, etc.
Vegetables	Parsley, onion and garlic roots, corn-cob, etc.
Fruits	Peach or apricot seeds, walnuts seeds, grape seeds, grapevine, shells of peanut, pineapple water melon, etc.
Fish and shellfish	Fish bones, shells crab, prawns, oyster, clams, animal oils and fats
Meat	Bones, flesh of cow, pig, chicken and hair, etc.
Other	Egg shells, tea and tea bags

Waste collection

1. Kerbside collection for single house, row house and small restaurants.

- Food waste will be contained in either 3, 5 or 20 litre pre-paid authorized plastic caddies or bins. Bins are provided initially to new residents, however, any second and subsequent replacement bins are chargeable.
- Once a bin is filled with food waste, residents hang a pre-paid sticker on the bin, as shown in Figure 43, and deliver it to a kerbside col-

lection point between 18:00 ~ 24:00 hours every day, except Saturday.

- The coloured sticker applicable to different size of bins can be bought from supermarkets and local municipalities. The dedicated collection vehicles operated by the local municipality, take the collected food waste directly to the respective recycling facilities for further treatment during the hours 00:00 ~ 05:00 hours every day except Sunday. Motor-bicycles or tricycles are used to collect food waste bins placed in narrow alleys where the collection vehicle is not able to access.
- Food waste collected using motor-bicycles or tricycles are transferred to a small truck as shown in Figure 44. There is no transfer station to bulk food waste prior to the final facility. The local municipality offers its residents a weekly collection for other municipal solid wastes such as residual wastes and dry recycling streams from the kerbside or residential properties.

Figure 43: Pre-paid sticker and collection vehicle

Figure 44: Food waste collection bicycle and truck

2. Communal collection

- Food waste (trimmings of vegetables, fruit peels, leaves, etc.) is generally filtered through a screen, fitted in the washing sink, and is collected in a small vinyl bag or a small container as shown in Figure 45.
- When a small bag or container is full, residents dispose of it into 120 litre communal bins placed at a central location in the apartment complex between 18:00 - 24:00 hours every day, except Saturday. The complex managers place a pre-paid authorized sticker (red colour) on the filled communal bin.

Figure 46 shows the communal collection system and the 11 tonnes collection truck, used in collection and transportation of food waste. The waste is collected in 120 litre communal bins in the period 00:00 ~ 05:00 hours every day, except Sunday. The collected waste is sent directly to the recycling facilities.

- A red sticker on the communal bin clearly indicates the bin is ready for collection. In order to remove residual materials and to avoid odour nuisance and leachate problems in the vicinity, food waste bins are washed by a washing vehicle, as shown in Figure 47, after the food waste has been transferred to the 11 tonne truck.
- A food waste volume based fee system is favourable for single houses, row houses and small restaurants, as the fee depends on the amount of food waste generated. However, in the case of a communal collec-

Figure 45: Food waste screened in wash sink, vinyl collection bag, and small container

Figure 46: Communal collection system

Figure 47: Washing vehicle for 120 litre communal bins

tion system residents pay on the average volume, irrespective of the actual amount of food waste generated per household. This can be the major disadvantage of VBFS when used for the communal collection system.

3. Private collection

- According to the regulation, producers of large quantities of food waste (LQP) must self-managing food waste. The regulation requires the moisture content of food waste to be reduced to less than 25% by drying and heating. 40% of the waste needs to be converted into compost and animal fodder. LQPs have to use a qualified recycler or organization to recycle their food waste. The mode of collection, classified by waste sources is summarised in Table 8.

Communication

- DMC and the local government are making efforts to promote the appropriate management of food waste along with food waste reduction. Information is disseminated via posters placed on the collection bins, pamphlets in the local newspapers, TV advertisements and social education through NGO's.

All the information on food waste management, as shown in Figure 48, has been published on the web pages of the DMC and of the local government:
http://www.daejeon.go.kr/language/english/living/residence/garbage/index.html
http://www.yuseong.go.kr/html/kr/life/life_08_03_t05.html

Contamination

- Food waste is separated from other materials such as glass, metal, paper, plastics, even bones and hard fruit seeds. Unsorted impurities contained in food waste are further separated in the subsequent process of pre-treatment, which consists of breaking liners and sorting foreign materials before recycling.
- If impurities and contaminants are identified in the collected material, the bins are carded or given a notice explaining why the food waste was not collected, as shown in Figure 49. A leaflet is also given to the respective residents to remind them how to separate correctly the food waste in their household.

AD of the source separated digestible fraction

- DMC currently generates 470 tonnes of food waste per day, of which 100 tonnes are composted and the

Figure 48: Promotion of food waste fee system in DMC

Table 8. Mode of collection classified by waste source

Food waste source	Single house, row house and small restaurants	Apartment complex	Large quality food waste producers
Mode of disposal/collection	Kerbside	Communal	Self-treatment/management and consignment (charge)
Volume of collection bins (l)	3, 5, 20	120	Exclusive bins
Disposal time and day	18:00 – 24:00 Every day except Saturday	18:00 – 24:00 Every day except Saturday	As scheduled
Collection time and day	00:00 – 05:00 Every day except Sunday	00:00 – 05:00 Every day except Sunday	As scheduled
Mode of payment	WBFS Blue sticker	WBFS Red sticker	Self or commission fee
Disposal fee	3 l bin – 6 cents 5l bin – 30 cents; 20l bin – 1.1$	120 l communal bin – 6.5$	Self or commission fee
Collection vehicles	Motor-bicycle. Motor-tricycle and 11 tonne truck	11 tonne truck, washing truck and private car	Private truck
Collection authorities	DMC	DMC and private	Private and commissioner

remaining 370 tonnes are used for feed production. A total capacity of 7000 m³ anaerobic digesters is now under construction for the treatment of food waste. The aim is to replace feed manufacturing by treating 200 tonnes of food waste per day, while the remaining food waste (170 tonnes) will be converted into animal fodder as before.

- The food waste leachate, generated in amounts of 360 tonnes/day, has so far been co-digested with the sewage sludge in wastewater treatment anaerobic digesters. A total capacity of 6,000 m³ anaerobic digesters is now under construction to treat 200 tonnes of exclusively food waste leachate per day.
- Composting of 100 tonnes food waste per day would lead to the generation of 5 tonnes of compost/day. The future implementation of AD would yield approximately 27,600 Nm³ of biogas, which could be used to generate 165 MWh of electricity. The solid fraction obtained from filtration of the digestate will be converted to Refuse Derived Fuel pellets and the liquid will be sent to a sewage sludge plant for further treatment.

Figure 49: Carded bins with contaminated food waste

Reference list for the information used in this case study (available only in Korean)

Enforcement regulations of the Wastes Control Act, Korea (2004)

Generation and management of MSW, Ministry of Environment, Korea (2012)

Environmental Statistics Yearbook, MOE, Korea (2012)

Resource Recycling of MSW in Daejeon, Korea http://www.daejeon.go.kr/life/policy/recycling/recycling2/index.html

Report on food waste volume based fee system (VBFS) in Daejeon, Korea (2012)

Report on construction of anaerobic digesters for source separated food waste in Daejeon, Korea (2012)

Figure 50: Location of Daejeon, in the southern part of the Korean peninsula (Source: Google Maps)

Contact

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7. Final comments

Source separating the digestible household waste fraction helps divert digestible material from landfills or incineration and makes it suitable for AD. This is a step towards more sustainable waste management as it allows recovery and recycling, preserves resources and reduces negative environmental impacts. AD has become a standard technology for the treatment of separately collected digestible MSW in many countries, producing biogas with its multiple uses as renewable fuel, and digestate for use as plant fertiliser and soil conditioner. The quality of the source separated waste material is vitally important, as it is the guarantee that recycling of digestate as fertiliser is safe for the environment and for human and animal health, ensuring viable markets for its application in agriculture, horticulture and forestry.

The key driver for source separation of digestible household wastes is thus diversion of organic wastes from landfills towards more sustainable waste management and treatment options. In many places around the world, corresponding policies and socio-economic frames have been established to support this development. In Europe, the Landfill Directive sets targets for diversion of organic material from landfills. The EU Landfill Directive has inspired many other countries around the world to enforce similar measures. In general, policies and regulations aiming to reduce emissions of greenhouse gases, promote recovery and recycling, improve public health, increase the share of renewable energy, increase job creation (especially in low income countries) are driving change. Further growth of source separation and AD treatment of the digestible waste fraction is dependent on the operation costs of the collection schemes and the existence of markets for the end products. A vital role in a successful collection scheme is communication, feedback and information with respect to all stakeholders, in order to maximise the capture and ensure high quality of the collected material. Public information and awareness about sustainable MSW management and about the potential and the benefits of source separation are vital for successful adoption of a source separation system.

The design of the source separation system must be adapted to the local conditions of the municipality concerned. To determine the most suitable approach for the separate collection of digestible waste from households, the following aspects must be considered:

- *Existing schemes of waste and recycling collection* - How will the new collection integrate with existing communal/ kerbside collections? What infrastructure will need to be provided to residents?
- *Capacity of the existing collection vehicle fleet* - Does the existing fleet have capacity to collect organic waste; are new/additional vehicles required?
- *Existing contractual arrangements* - Will the collection of a new waste stream require a change of existing contract(s), or will a new contract need to be agreed?
- *Proximity of treatment facility* - Is there a treatment facility with available capacity nearby, or will the organic waste require bulking ?
- *Health and safety* - Will adding a collection raise any health and safety concerns such as lifting requirements for staff ?
- *Cost* - What will be the net change in costs for the municipality and how to optimise a collection scheme and integrate it in the overall MSW management in order to increase cost efficiency of the overall management of waste.
- *Market* - Is there a suitable market available for the biogas and digestate produced?

This report has shown that source separation of digestible household waste is a sustainable practice, likely to become standard for future municipal waste management around the world. The economics of source separation of digestible household waste are highly dependent on existing waste management policies and the socio-economic frameworks offered by such policies. There are good reasons for municipalities to introduce source separation of digestible wastes and to create premises for their use as feedstock for AD. Source separation of wastes is essential to meet the necessary standards of quality required by waste recycling. The benefits for the environment and human and animal health are widely recognised, and the costs involved have been shown not to be disproportionate to the benefits.

8. References

AL SEADI AND LUKEHURST (2012). *Quality management of digestate from biogas plants used as fertiliser.* IEA Bioenergy publication. Available from: http://www.iea-biogas.net/_content/publications/publications.php

ANDERZÉN & HELLSTRÖM (2011). *Tools for introduction of a system for collection of source separated food waste: Waste Refinery (WR39) and Swedish Waste Management,* ANDERZÉN, C. AND HELLSTRÖM, H. (in Swedish) (2011) Available from: http://avfallsplan.sorab.se/Upload/documents/Rapporter/Slutrapport_hjalpmedel_insamling_WR39_2011.pdf

ARSOVA L, (2010). *Anaerobic digestion of food waste: current status, problems and an alternative product (MSc thesis).* Available from: http://www.seas.columbia.edu/earth/wtert/sofos/arsova_thesis.pdf

AVFALL SVERIGE (2013). *Swedish Waste Management & SP* Technical Research Institute of Sweden. SPCR 120 Quality Assurance System of digestate

BARTH, J., AMLINGER, F., FAVOINO, E. (2012). *Framework Conditions for Biowaste Management in EU Member States: Development of legal framework on bio-waste management and establishment of Quality Assurance System for Compost and National Organization of Quality Assurance for the Compost.* Available from: http://www3.moew.government.bg/files/file/Waste/Biowaste/Phase_I/120910_MS_survey_FR_v2.0_EN.pdf

BECK (2004). R.W.BECK, *Anaerobic digestion feasibility study;* Iowa Department of Natural Resources, http://www.iowadnr.gov/waste/policy/files/bluestem.pdf

BEYOND COMPOSTING (2013). *The Green Bin Program* [Online]. Available from: http://beyondcomposting.ca/how.asp

BURROWS, D. (2013). *Landfill Bans: Handle With Care.* Waste Management World-web version. Available from: http://www.waste-management-world.com/articles/print/volume-12/issue-1/features/landfill-bans-handle-with-care.html

CLIMENHAGA et al. (2013). Compositional analysis of source segregated food waste streams and implications for residual waste composition and quantity, Climenhaga, M., Riley, K., Vaz, F., Vidal Vidal, D., Arnold, R., Cavinato, C., Paavola, T., Zhang, Y., Heaven, S., Proc. 8th APESB/ISWA conference – waste management for resources sustainability, Lisbon, 16–18 July 2013.

DANISH MINISTRY OF THE ENVIRONMENT (2013). *Danmark uden affald. Ressourcestartegi 2013.* Available from: http://www.mim.dk/Arbejdsomraader/danmarkudenaffald/

DEFRA (2011). *Applying the Waste Hierarchy: evidence summary.* Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69404/pb13529-waste-hierarchy-summary.pdf

ENVIRONMENT AGENCY (2008). *Quality Protocol: Anaerobic digestate* [Online]. Available from: www.environment-agency.gov.uk/static/documents/Business/W524AnaerobicDigestatev4%281%29.pdf

EUROPEAN COMMISSION (1999). *EU Landfill Directive.* Available from: http://ec.europa.eu/environment/waste/landfill_index.htm

EUROPEAN COMMISSION (2000). *Success stories on composting and separate collection,* Directorate General for Environment, ISBN 92-828-9295-6

EUROPEAN COMMISSION (2008). *Directive 2008/98/EC on waste. EU Waste Framework Directive.* Available from:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:312:0003:0030:EN:pdf
http://ec.europa.eu/environment/waste/framework/

EUROPEAN COMMISSION (2009). *EU rules on animal by-products* [Online]. Available from: http://ec.europa.eu/food/food/biosafety/animalbyproducts/index_en.htm

EUROPEAN COMMISSION (2009a). *Directive 2009/28/EC (the Renewable Energy Directive) Promotion of the use energy from renewable sources.* Available from:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=Oj:L:2009:140:0016:0062:en:PDF

EUROPEAN COMMISSION (2010). *Assessment of the management of bio-waste.* Working document: Accompanying the Communication from the Commission On future steps in bio-waste management in the European Union. Available from: http://ec.europa.eu/environment/waste/compost/pdf/sec_biowaste.pdf

EUROPEAN COMMISSION (2010a). *Preparatory study on food waste across EU 27,* Technical Report – 2010 – 054. Available from http://ec.europa.eu/environment/eussd/pdf/bio_foodwaste_report.pdf

EUROPEAN COMMISSION JRC-IPTS (2012). *Technical report for End-of-waste criteria on Biodegradable waste subject to biological treatment.* Third Working Document. August 2012.
Available from: http://susproc.jrc.ec.europa.eu/activities/waste/documents/IPTS_EoW_Biodegradable_waste_3rd_working_document_wo_line_nr.pdf

FAVOINO & RICCI (2002). *Myth and reality about cost of separate collection schemes,* FAVOINO, E. and RICCI, M., Workshop of the EC „biological treatment of biodegradable waste: technical aspects, April 2002, Brussels

FAVOINO, E. et al (2003). Optimisation and cost assessment of schemes for high capture of Biowaste, Waste Management World, 2003.

FAVOINO & RICCI (2006). The economics of different separate collection schemes for biowaste, Favoino, E., Ricci and M., ECN/ORBIT e.V., First Baltic Biowaste Conference 2006, Pres. Nr. 07 “The Economics of Different Separate Collection Schemes for Biowaste”
Available from: http://www.recestonia.ee/ecn/presentations/7%20Enzo%20Favoino.pdf

FOEN (2012). FEDERAL OFFICE FOR THE ENVIRONMENT (2012). *Umwelt-Indikatoren, Siedlingsabfälle.* Available from: http://www.bfs.admin.ch/bfs/portal/de/index/themen/02/06/ind13.indicator.130307.1377.html

FOOD AND AGRICULTURAL ORGANISATION (2011). *Global food losses and food waste.* Available from:
http://www.fao.org/docrep/014/mb060e/mb060e00.pdf

HONG KONG WASTE REDUCTION WEBSITE (2013). *Source separation of domestic waste.* Available from: https://www.wastereduction.gov.hk/en/household/source_intro.htm.

HOORNWEG AND BHADA-TATA (2012). D. Hoornweg and Perinaz Bhada-Tata, *What a waste: A global review of solid waste management,* World Bank, Urban Development Series Knowledge Papers, No.15, March 2012

IEA BIOENERGY TASK 37. *Energy from biogas,* web page: www.iea-biogas.net

IPCC (2001). Climate Change 2001: The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press. Cambridge, UK.

IPCC (2007). Fourth Assessment Report: Climate Change 2007: Working Group III: Mitigation of Climate Change, Waste management, Chapter 10, p599. Available from: http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch10.html
http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter10.pdf

LARDINOIS AND FUREDY (1999). *Source Separation of Household Waste Materials: Analysis of Case Studies from Pakistan, the Philippines, India, Brazil, Argentine and the Netherlands* Urban Waste Series 7, 1999. http://www.yorku.ca/furedy/research.htm

LUKEHURST, C., FROST, P., AL SEADI, T. (2010). *Utilisation of digestate from biogas plants as biofertiliser. IEA Bioenergy publication.* Available from: http://www.iea-biogas.net/technical-brochures.html

MURPHY J.D., POWER N.M (2006). *A technical, economic and environmental comparison of composting and anaerobic digestion of biodegradable municipal waste,* J. Environ. Sci. and Health, Part A: Toxic Hazardous Substances and Environ. Eng., 41(2006) 865-79. Available from: http://www.tandfonline.com/doi/abs/10.1080/10934520600614488?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub%3dpubmed&

READ AND GODLEY (2013), A.Read and A.Godley, *How Green is Mechanical Biological Treatment,* Waste Management World, 2013.

SOLOMON S., QIN D., MANNING M., CHEN Z., MARQUIS M., AVERYT K.B., TIGNOR M., MILLER H. L. (2007). *Climate Change 2007: The Physical Science Basis, Contribution of working group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge, UK, and New York, USA. Cambridge University Press.

UNEP (2010). United Nations Environment Programme, Basel Convention (BC), http://www.basel.int/

VALORGAS (2011). *Compositional analysis of food waste from study sites in geographically distinct regions of Europe.* FP7 VALORGAS Project 241334, Deliverable D2.1. Available from http://www.valorgas.soton.ac.uk/deliverables.htm

VALORGAS (2012a). *Assessment of typical source segregated food waste collection schemes in operation in Europe detailing factors influencing yield, capture rates and efficiency.* FP7 VALORGAS Project 241334, Deliverable 2.2. Available from http://www.valorgas.soton.ac.uk/deliverables.htm

VALORGAS (2012b). *Case study for collection schemes serving the South Shropshire Biowaste Digester.* FP7 VALORGAS Project 241334, Deliverable 2.3. Available from http://www.valorgas.soton.ac.uk/deliverables.htm

VALORGAS (2012c). *Case study for collection schemes serving the Valorsul AD plant.* FP7 VALORGAS Project 241334, Deliverable 2.4. Available from http://www.valorgas.soton.ac.uk/deliverables.htm

VALORGAS (2012d). *Results from LCA and energy footprint modelling for optimisation of collection methods and equipment.* FP7 VALORGAS Project 241334. Deliverable 2.7. Available from http://www.valorgas.soton.ac.uk/deliverables.htm

VERMA S. (2002). *Anaerobic digestion of biodegradable organics in municipal solid wastes.* Masters thesis, Department of Earth & Environmental Engineering, Columbia University. http://www.seas.columbia.edu/earth/vermathesis.pdf

WMW (2013). *Waste Management World.* Available from:
http://www.waste-management-world.com/articles/print/volume-11/issue-5/features/digesting-the-state-of-ad-technologies.html

WORLD BANK (2012). *What a waste: A global review of solid waste management.*
Available from:
http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTURBANDEVELOPMENT/0,,contentMDK:23172887~pagePK:210058~piPK:210062~theSitePK:337178,00.html

WRAP (2003).*Using quality compost to benefit crops.* Available from: http://www.organics-recycling.org.uk/uploads/article1836/QP%20crop%20benefits.pdf

WRAP (2008). *Food waste collection trials – use of liners for kerbside containers and kitchen caddies* [Online]. Available from: http://www.wrap.org.uk/sites/files/wrap/Case_study_-_Use_of_Liners.d95352ec.5882.pdf

WRAP (2009a). *Food waste collection guidance* [Online]. Available from: http://www.wrap.org.uk/sites/files/wrap/food%20waste%20collection%20guidance%20-%20amended%20Mar%202010_1.pdf

WRAP (2009b). *Food waste depackaging equipment* [Online]. Available from: http://www.wrap.org.uk/content/food-waste-depackaging-equipment

WRAP (2009c). *Evaluation of the WRAP separate food waste collection trials* [Online]. Available from: http://www.wrap.org.uk/sites/files/wrap/Evaluation_of_the_WRAP_FW_Collection_Trials_Update_June_2009.pdf

ZAMAN, A. U. (2013). *Identification of waste management development drivers and potential emerging waste treatment technologies,* International Journal of Environmental Science and Technology, 10 (2013) 455-464. Available from: http://link.springer.com/article/10.1007/s13762-013-0187-2

9. Further reading

CHU, T.W., HEAVEN, S., GREDMAIER, L. (2013). *Modelling Fuel Consumption in Kerbside Source Segregated Food Waste.* Collection: Separate Collection and Co-Collection. Proceedings of the International Conference on Solid Waste 2013 - Innovation in Technology and Management, Hong Kong SAR, P.R. China, 5 – 9 May 2013. http://www.valorgas.soton.ac.uk/Pub_docs/Chu%20paper%202013.pdf

DEFRA (2009). *Appendix 4: Analysis of collated studies and updated estimates of national municipal waste composition.* http://randd.defra.gov.uk/Document.aspx?Document=WR0119_8658_FRA.pdf

DEFRA (2011). *Waste data overview.* http://www.defra.gov.uk/statistics/files/20110617-waste-data-overview.pdf

DEFRA(2011b). *Landfill Allowance Trading Scheme.*
http://www.defra.gov.uk/environment/waste/local-authorities/landfill-scheme/

DEFRA (2011c). *Government Review of Waste Policy in England 2011.* http://www.defra.gov.uk/publications/files/pb13540-waste-policy-review110614.pdf

ENVIRONMENT AGENCY UK (2010). *Quality Protocol. Anaerobic Digestate. End of waste criteria for the production and use of quality outputs from anaerobic digestion of source-segregated biodegradable waste.* http://www.environment-agency.gov.uk/business/sectors/142481.aspx

EUROPEAN PARLIAMENT (2009). *Regulation (EC) no 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules concerning animal by-products not intended for human consumption.* http://ec.europa.eu/food/food/biosafety/animalbyproducts/index_en.htm

EUROPEAN COMMISSION (2013): *Success stories on composting and separate collection.* http://ec.europa.eu/environment/waste/publications/pdf/compost_en.pdf

FAVOINO, E. (2002a): *Optimisation and cost-assessment of high-capture sorting schemes for compostable waste,* in Proc. EC Conference “Biological Treatment of Biodegradable Waste: Technical Aspects”. Brussels. April 2002.

FAVOINO, E. RICCI, M. (2004): *Source segregation of biowaste in Italy,* Pon. XIX Encuentro Amantes de la Basura, Oviedo.

FAVOINO, E., RICCI, M. et al (2004): *Optimisation of schemes for source separation of compostable waste considering the locally most suitable technique,* Pon. XIX Encuentro Amantes de la Basura, Oviedo.

HEAVEN, S., CLIMENHAGA, M., RILEY, K., GREDMAIER, L. (2013). *Biowaste as feedstock for 2nd generation.* Report from VALORGAS: Valorisation of food waste to biogas. EC Grant Agreement 241334. http://www.valorgas.soton.ac.uk/Deliverables/111129_VALORGAS_241334_D5-1_Final_version.pdf

HEAVEN, S., CLIMENHAGA, M., RILEY, K., CHU, W.T., GREDMAIER, L. (2013). *Food waste collection systems: Options and modelling of energy and resource use.* Proc. 8th APESB/ISWA conference waste management for resources sustainability, Lisbon, 16-18 July 2013.

IPTS (2011). *Technical report for End-of-Waste criteria on biodegradable waste subject to biological treatment.* Second working Document, 11 October 2011. Available from: http://susproc.jrc.ec.europa.eu/activities/waste/documents/20111012-005713_IPTSEoWBiodegradablewaste2ndworkingdocument.pdf.

MCi (2011). *UK waste press release.* (http://www.mbdltd.co.uk/Press-Release/Waste-Management.htm)

OFT (2011).*Organic Waste Market Survey.* (http://www.oft.gov.uk/shared_oft/market-studies/oft1372.pdf)

OELOFSE S, HH AND NAHMAN A. (2013). *Estimating the magnitude of food waste generated in South Africa Waste* Manag Res 2013 31: 80 Originally published online 9 August 2012
DOI: 10.1177/0734242X12457117
http://wmr.sagepub.com/content/31/1/80

PAS100 (2011). *Specification for composted materials.* http://www.wrap.org.uk/content/bsi-pas-100-compost-specification.

PAS110 (2010). *Specification for whole digestate, separated liquor and separated fibre derived from the anaerobic digestion of source-segregated biodegradable materials* http://www.insource-energy.co.uk/tl_files/insource-energy/PDFs/PAS110.pdf

SIEBERT S. (2012). *Oral presentation at Europe Day 2012, Brussels, Belgium.* http://www.wastematters.eu/uploads/media/ECN_-_Stefanie_Siebert_-_European_Day_May_8_2012.pdf

SOLID WASTE & RECYCLING MAGAZINE - Canada‘s on line magazine on collection, hauling, processing and disposal of solid waste. *Article reporting source separation of organic waste for AD in Toronto.* http://www.solidwastemag.com/news/anaerobic-organics-processing/1002482630/

VALORGAS (2013). *WasteCAT Waste collections assessment tool,* FP7 VALORGAS Project 241334. http://www.bioenergy.soton.ac.uk/WasteCAT_tool.htm

VALORGAS (2012). *Institutional and community food waste generation rates and appropriateness of scale for on-site utilisation for second generation biofuel production by AD.* FP7 VALORGAS Project 241334, Deliverable 2.5. http://www.valorgas.soton.ac.uk/deliverables.htm

VALORGAS (2013). *Output from an energy and carbon footprint model verified against primary data collected as part of the research.* FP7 VALORGAS Project 241334. Deliverable 6.3. http://www.valorgas.soton.ac.uk/deliverables.htm

WRAP (2010). *Waste arisings in the supply of food and drink to households in the UK.* http://www.wrap.org.uk/sites/files/wrap/Waste%20arisings%20in%20the%20supply%20of%20food%20and%20drink%20toUK%20households,%20Nov%202011.pdf

WRAP (2011). *A study of the UK organics recycling industry in 2009.* http://www.wrap.org.uk/sites/files/wrap/Organics%20recycling%20survey%202009.pdf

WRAP (2011b). *New estimates for household food and drink waste in the UK.* http://www.wrap.org.uk/sites/files/wrap/New%20estimates%20for%20household%20food%20and%20drink%20waste%20in%20the%20UK%20FINAL%20v2.pdf

WASTE MANAGEMENT WORLD (2013). *Official magazine of the International solid waste association.* Web article on organic waste in Asia. http://www.waste-management-world.com/articles/print/volume-12/issue-5/features/organic-waste-in-asia-3rs-tackle-climate-change.html

Glossary, terms, abbreviations

AD (Anaerobic digestion): (Synonym: digestion, anaerobic fermentation, biogas process): A microbiological process of decomposition of organic matter in the absence of oxygen, carried out by the concerted action of a wide range of microorganisms.

Biodegradable waste: Waste originating from plant or animal sources. Biodegradable waste is defined in the EU Landfill Directive as waste capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard.

Biogas: A combustible gas, typically containing 50-70% methane and 30 – 50% carbon dioxide produced through anaerobic digestion of organic matter.

Biogas plant: (Synonym: anaerobic digester, anaerobic digestion plant, AD plant, AD and biogas reactor) Technical installation for optimisation of anaerobic digestion process and production of biogas.

Biowaste: There are various definitions. The official definition given by the European Commission is: biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants. It does not include forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste such as natural textiles, paper or processed wood. It also excludes those by-products of food production that never become waste. Source: http://ec.europa.eu/environment/waste/compost/

Bulking: The term "bulking" involves consolidating the contents of several containers of similar waste material into a single container. There is often an economic advantage to bulking wastes prior to transfer to the treatment facility.

Digestate: (Synonym: AD residues, digested biomass, digested slurry): The digested effluent from the AD process. Digestate is the semi-solid or liquid product of anaerobic digestion of biodegradable materials, rich in plants nutrients.

Digestible household waste: The fraction of the organic household waste (biowaste) that is capable of undergoing anaerobic decomposition, such as food waste, green garden waste and other similar wastes.

Digestible wastes, similar to household waste: Digestible wastes, other than household waste, but similar to this because of their nature and composition (e.g. herbaceous waste from landscape trimmings, parks, beaches, and other recreational areas, food waste from commercial and institutional sources)

Disposal: (Follows the definition of the EU Waste Framework Directive (WFD) (2008/98/EC)): any operation which is not recovery, even where the operation has as a secondary consequence the reclamation of substances or energy, for example landfill or incineration without energy recovery. Annex I of the WFD sets out a non-exhaustive list of disposal operations.

EoW: End-of-waste is defined as the point at which a waste product ceases to be classed as a waste from a legislative perspective. For example, in the EU, EoW is the point at which material would cease to be a waste as defined by the Waste Framework Directive

Emissions: Fumes or gases that come out of smoke stacks and tailpipes, escape from inside factories or enter the atmosphere directly from oil well flares, garbage dumps, rotting vegetation and decaying trees and other sources. They include carbon dioxide, methane and nitrous oxide, which all contribute to the global greenhouse effect.

Feedstock: Any material which is fed to a process and converted to another form or product.

Household waste: Household waste is defined using as point of reference the EU landfill directive (1999/31/EC), as "the waste generated by the domestic activity of households and collected by or on the behalf of the municipality". Together with wastes from households, in this category can also be included kitchen waste from food preparation, food waste and commercial food waste from food processing, retail outlets, markets and catering activities, and leafy green, waste trimmings and cuttings from households, gardens and urban parks. Definitions outside the EU may differ, but essentially refer to household waste and the wastes collected with this.

MSW (Municipal solid waste): All types of solid waste generated by a community (households and commercial establishments), usually collected by local government bodies. There are various definitions, of which some examples are given below:

- EoW: Municipal waste is non-sorted, mixed waste from households and commerce, collected together. This waste flow excludes the flows of recyclables collected and kept separately, be it one-material flows or multi-material (co-mingled) flows.
- OECD: Municipal waste is collected and treated by, or for municipalities. It covers waste from households, including bulky waste, similar waste from commerce and trade, office buildings, institutions and small businesses, yard and garden, street sweepings, contents of litter containers, and market cleansing. Waste from municipal sewage networks and treatment, as well as municipal construction and demolition is excluded.
- IPCC: Food waste; garden (yard) and park waste; paper and cardboard; wood; textiles; nappies (disposable diapers); rubber and leather; plastics; metal; glass (and pottery and china); and other (e.g., ash, dirt, dust, soil, electronic waste).

Mt: Million tonnes. 1 tonne = 1000 kg (International System of Units)

Organic waste: Waste which originates from plant or animal sources, which may be broken down by other living organisms.

Organic household waste: Organic waste produced from households.

Recovery: (Follows the definition of the EU Waste Framework Directive (2008/98/EC)): Any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfill a particular function, or waste being prepared to fulfill that function, in the plant or in the wider economy. Annex II of the Directive sets out a non-exhaustive list of recovery operations.

Recycling: (Follows the definition of the EU Waste Framework Directive (2008/98/EC)): Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

Separate collection: (Follows the definition of the EU Waste Framework Directive (2008/98/EC)): The collection where a waste stream is kept separately by type and nature so as to facilitate a specific treatment.

Waste treatment: (Follows the definition of the EU Waste Framework Directive (2008/98/EC)): Recovery or disposal operations, including preparation prior to recovery or disposal of waste.

Task 37 – Energy from Biogas

IEA Bioenergy

IEA Bioenergy aims to accelerate the use of environmentally sustainable and cost competitive bioenergy that will contribute to future low-carbon energy demands. This report is the result of the collaboration between IEA Bioenergy Task 37: Energy from Biogas and IEA Bioenergy Task 36: Integrating energy recovery into solid waste management systems.

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