#### **Annex 1**

**Objective 1: To review of current procedures for managing food waste taking into account best practice in the UK and internationally.**

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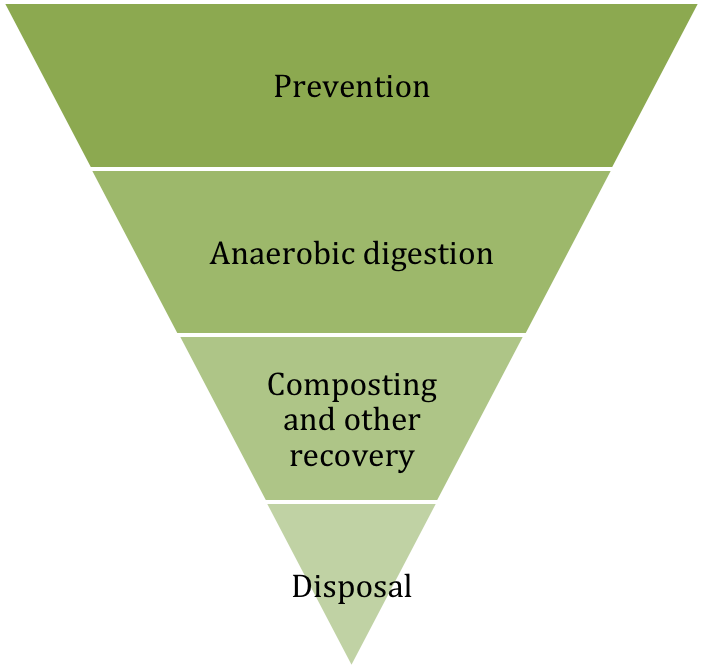
1. Aims and objectives

To compare current methods for the disposal and recycling of food and catering waste in terms of environmental sustainability, impact on global GHG emissions, cost, safety and animal health.

**1.1 Overview of current methods**

A range of management options for food waste is available. The waste hierarchy, as set out in Article 3 of in the revised Waste Framework Directive (Directive 2008/98/EC), ranks waste management options according to what is best for the environment. It gives priority to preventing waste. When waste is created, it gives priority to preparing it for re-use, then recycling, then recovery, and last of all disposal (e.g. landfill)[[1]](#footnote-1). Recycling involves reprocessing the waste into a product for the original or other purposes (not including energy and fuel). Recovery involves waste serving a useful purpose by replacing other materials which would otherwise have been used (or prepared to) to fulfil a particular function (see glossary). In the case of food waste, however, anaerobic digestion (mainly a recovery method due to the generation of biogas) is considered to be environmentally better than composting and other energy recovery options, and therefore it takes priority in the waste hierarchy (Figure 1.1).

**Figure 1.1** Food waste hierarchy (adapted from the Defra Waste Hierarchy Guidance – see note 1).



Includes composting, landspreading, incineration with energy recovery and rendering/biodiesel

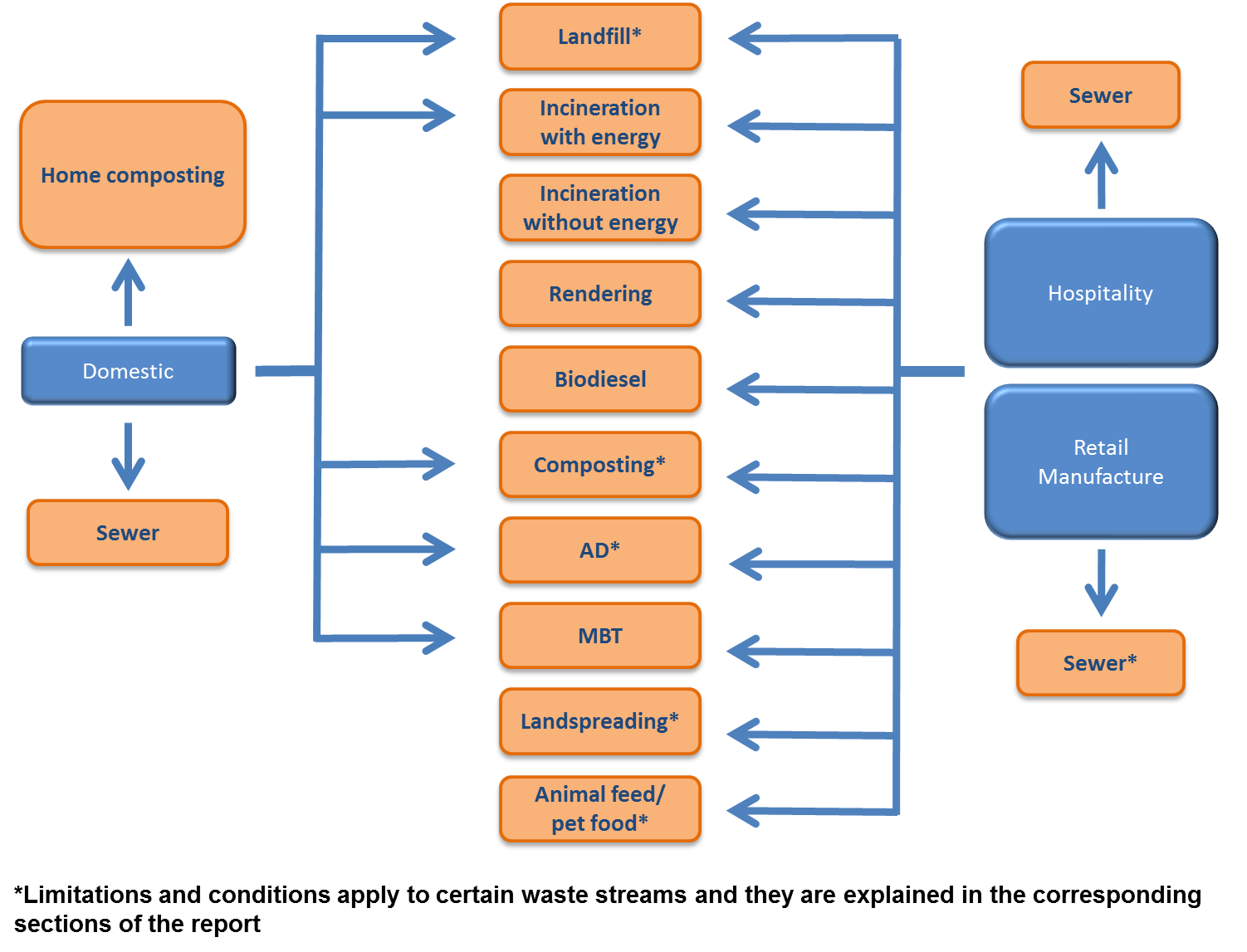
Includes incineration without energy recovery and landfill

The environmental and economic benefits of different treatment methods depend significantly on local conditions such as population density, infrastructure and climate as well as on markets for associated products (energy and composts). In order to assess the sustainability of the different methods a life cycle analysis is required to provide a comprehensive picture of management options for food waste. When considering waste management options it is important to consider the waste collection system jointly with the processing technology, since the collection regime will affect the food waste capture levels and the choice of processing method will be influenced by the composition of the input waste. The Waste and Resources Action Programme (WRAP) published two reports in 2007 (plus an update in 2008) prepared by Eunomia Research and Consulting whereby the economic and environmental costs of different biowaste and food waste disposal/recycling methods were modelled in detail following a life cycle approach and taking into account different collection scenarios (Eunomia 2007a, Eunomia 2007b, Eunomia 2008). According to these reports only around 2% of available food waste was collected separately for composting or anaerobic digestion. Some of the waste was collected by local authorities together with garden waste, but the majority of food waste still went to landfill.

This section of the report provides a brief overview of the main methods currently used in the UK to manage food waste, their costs and their impact on the environment and public and animal health. These include landfilling, incineration, rendering and biodiesel production, biological treatments (anaerobic digestion, composting, mechanical biological treatment (MBT) and land spreading. There is also mention of re-use of food waste in animal feed as a method of waste management, although this option is currently very limited( see Section 1.1) due to the EU Animal By-Products Regulations (ABPR) and its potential is the focus of this research.

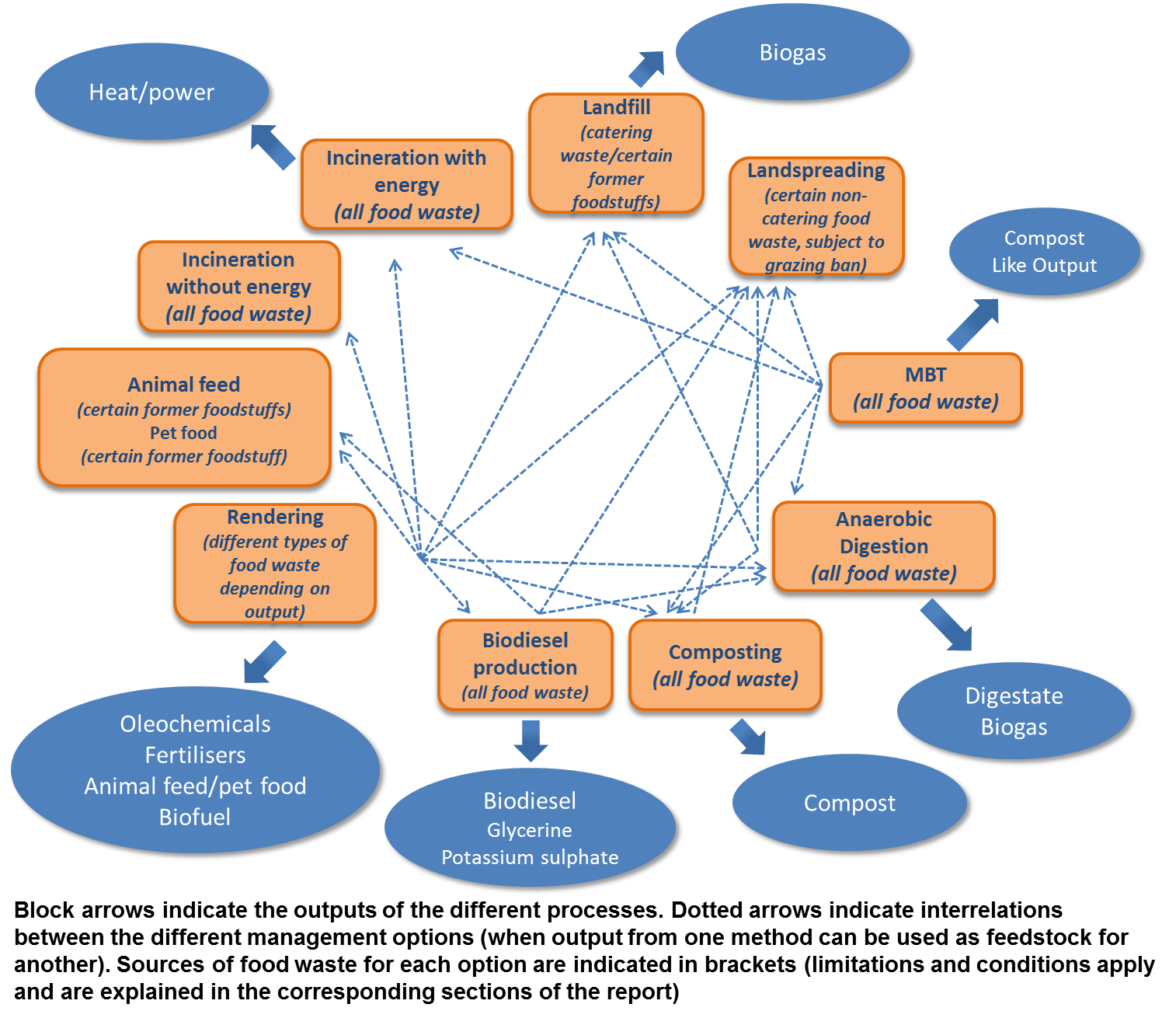
The different food waste streams and current management options are summarised in Figure 1.2. Most methods for treating food waste have a useful output, generating either energy or products that can be used for different purposes. The landfill sector can also generate biogas which is harnessed for energy production.

**Figure 1.2** Current food waste streams and management options.



In some cases, products or co-products of a particular treatment option can be used as feedstock for another method (e.g. digestate from anaerobic digestion can go into composting). The balance between the value of the output and the economic, health and environmental cost of each option will determine the sustainability of each method. The outputs from the different food waste management options and their inter-relationships are summarised in Figure 1.3.

**Figure 1.3** Food waste management options: relationships and outputs.



## 1.2 Landfill

Landfill is a specially engineered area of land where waste is deposited. Landfills need to be constructed and operated in line with the EU Landfill Directive (Directive 1999/31/EC on the landfill of waste). The Directive’s overall aim is “to prevent or reduce as far as possible negative effects on the environment, in particular the pollution of surface water, groundwater, soil and air, and on the global environment, including the greenhouse effect, as well as any resulting risk to human health, from the landfilling of waste, during the whole lifecycle of the landfill.” Following the implementation of the Directive, precautions such as impermeable barriers, methane capturing equipment, etc were required to fulfil the requirement to avoid environmental damage from the generation of methane and effluent[[2]](#footnote-2). Once an individual section of the landfill is full, it is sealed with a permanent cap. The biodegradable part of the waste then decomposes and reduces in volume. Much of the non-biodegradable content of municipal solid waste is stable, and is not released from landfill sites at discernible rates. The gas produced by decomposition of municipal solid waste is commonly used to generate electricity. About a third of the 500 landfill sites taking significant amounts of biodegradable waste have gas controls and many sites extract the gas for energy recovery. Landfill gas accounted almost two-fifths of the bioenergy generation in the UK in 2011[[3]](#footnote-3)

The extent of collection and burning of landfill gas varies from site to site. The leachate is collected and pumped for treatment before discharge or recirculation within the site. Landfill will probably always be needed for the final disposal of unusable residues[[4]](#footnote-4).

The types of food waste that can be sent to landfill are tightly regulated. As the highest risk material, Category 1 ABP material must be destroyed by incineration, or by rendering followed by incineration. These are the only options for material likely to contain TSE agents. Other Category 1 and all Category 2 materials are also permitted to be pressure-rendered, permanently marked and disposed of in an authorised landfill site. International catering waste may be disposed of directly in an authorised landfill site. Category 3 material can also be rendered followed by disposal in an authorised landfill (unlike higher category material this does not have to be pressure rendered). Foodstuffs no longer intended for human consumption (not including raw meat, fish, seafood, raw eggs, untreated milk), and all catering waste can be disposed of to landfill[[5]](#footnote-5).

Although the worst option according to the waste hierarchy, landfill is still the most used disposal method for municipal solid waste (MSW) in the UK and in the EU[[6]](#footnote-6).

1.2.1 Environmental sustainability

Biodegradable waste decomposes in landfills to produce landfill gas and leachate. The landfill gas, if not captured, contributes considerably to the greenhouse effect as it consists mainly of methane. The International Panel on Climate Change (IPCC) and treaties such as the Kyoto Protocol assume methane to be, tonne-for-tonne, 25 times more potent than carbon dioxide at warming the planet. (IPCC, www.ipcc.ch). More recently, Shindell *et al* (2012) used computerized models to show that methane's global warming potential is greater when combined with aerosols — atmospheric particles such as dust, sea salt, sulphates and black carbon. He concluded that the interaction with aerosols could increase methane's relative global warming potential (GWP) to about 33.

The UK landfills a higher proportion of biodegradable waste than most other European countries. It was estimated that at least 40% of the 15 million tonnes of annual food waste arising in the Britain is disposed of to landfill[[7]](#footnote-7). The fact that certain animal by-products (raw meat, fish, seafood), i.e. Category 3 waste from industry, can only be sent to landfill after they have been processed (e.g. rendered) means additional use of energy for this disposal option.

The leachate, if not collected in accordance with the Landfill Directive, can contaminate groundwater and soil. Landfills may also be a source of nuisance for neighbouring areas as they generate bio-aerosols, odours, and visual disturbance. Another negative impact of landfilling is the area of land used, which is larger than for other waste management methods. In the medium to long term it is not considered a sustainable waste management solution and should be considered the last resort for disposal of biodegradable waste. The main negative impacts of landfilling will be reduced, but not eliminated, by adhering to the EU Landfill Directive. The EU landfill target is a reduction by 2020 of biodegradable municipal waste sent to landfill to 35% of that sent in 1995. Defra's definition of municipal waste recently changed and now includes some commercial and industrial waste as well as most of the existing local authority collected waste. The tonnage of the new targets is given below:

|  |  |  |  |
| --- | --- | --- | --- |
| **Landfill Diversion Targets (‘000 tonnes)**[[8]](#footnote-8) | | | |
|  | **2010** | **2013** | **2020** |
| England | 21,773 | 14,515 | 10,161 |
| Scotland | 2,697 | 1,798 | 1,258 |
| Wales | 1,378 | 919 | 643 |
| Northern Ireland | 919 | 612 | 429 |
| UK | 26,766 | 17,844 | 12,491 |
|  |  |  |  |

### 1.2.2 Health impact

Vermin and insects are attracted to the putrescible organic fraction found in MSW. Therefore wherever waste is exposed (e.g. during operation at landfill), infestations are possible. Concerns have been raised over the potential for disease transmission by species associated with waste. Species known to utilise waste, like foxes (*Vulpes vulpes*), badgers (*Meles meles*), rats (*Rattus norvegicus*), rabbits (*Oryctolagus cuniculus*), gulls (*Larus* spp), and insects, in particular the housefly (*Musca domestica)* and blowflies (Lucilia, *Calliphora* spp) (Defra, 2006) are all known potential mechanical vectors of zoonotics and could in theory transmit *Salmonella* and *E.coli* 0157 (VTEC) to humans, however, no cases of this happening have been reported. In order to mitigate the risks from these animals, pest control and litter control is a requirement of a permit to operate a landfill site.

A detailed UK study carried out to investigate whether there is any indication that living close to landfill sites results in an increase in the occurrence of cancer found no relationship. Another important UK study looked at over eight million births in the UK between 1983 and 1999. The study showed that people living within 2 km of an active or disused landfill site in the UK experienced slightly higher rates of several birth defects than people living further away. This suggested a possible link between living near a landfill and birth defects, but it cannot be concluded that the landfill is the cause, as there may be other contributing factors that the epidemiological study could not address fully (confounding factors) (Defra, 2004)[[9]](#footnote-9).

Symptoms such as fatigue, sleepiness and headaches have also been reported in people living near landfill sites. Although these symptoms cannot be assumed to be an effect of toxic chemical action, they may indicate the impact that sites can have on stress and anxiety. It is very difficult to confirm any links between health and landfill sites and the Government funded further research[[10]](#footnote-10) which was recently collated and reviewed by the Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment. (COT). COT recently issued a Second Statement on Landfill Sites(2010)[[11]](#footnote-11).The body of work reviewed by COT confirmed that there is no cause for concern for the health of families with infants or for couples who live in the vicinity of landfill sites and who are considering having a baby. A comprehensive monitoring survey was carried out by the EA as part of the study and comprises the most detailed survey to date of chemicals to be found at the boundaries of landfill sites. Dioxins were found to be at levels comparable to background exposures, below the tolerable daily intake for these compounds, and unlikely to be of concern. However, it was difficult to draw conclusions on arsine and chromium levels.

COT also reviewed a number of studies of ecological design which have investigated the association between adverse health outcomes and landfill sites and concluded that the risk estimates which were derived from these studies are small and it was not possible to discriminate effects due to confounders and bias from those which might be causally associated with the hazard under investigation. They concluded that there would be little value in undertaking further studies of this type.

### 1.2.3 Animal health risks

Relatively small amounts of meat in domestic food wastes is discarded uncooked (Gale, 2002) and it is likely to be of reasonably low risk. There are also restrictions on the disposal of food waste of commercial origin under the animal by-products regulations.[[12]](#footnote-12). However, all catering waste can be deposited at landfill sites under the control of the environmental waste legislation and domestic regulations. Utilisation of sites is restricted under the current regulations so that farm animals will not have direct access to these sites. Wild species known to have access to landfill sites and utilise waste include foxes, badgers, rats, rabbits, gulls and insects (Defra, 2006). All are known mechanical vectors of zoonotic diseases but there are few reports of damaging outbreaks in animal species, resulting from infections at landfill sites. This may be due in part to the precautions for pest control required by the EU Landfill Directive (see above).

Information on the survival of animal pathogens in landfill sites has largely come from studies on disposal of infected animal carcasses after disease outbreaks, e.g. foot and mouth disease in the UK (Scudamore *et al*, 2002) and bird flu (Graiver *et al*, 2009). Studies on bird flu did find virus survival after up to 600 days, but this involved a high titre of virus in the original waste. Obviously containment and management of landfill sites is important to minimise the risk of impacts on animal health, and indications are that if well managed the risk is low. For example, Jacobsen *et al* (2009) investigated the risk of prions from animal waste moving through soils into groundwater and found this was no problem provided the right soil types were used for burial areas.

### 1.2.4 Cost

Landfilling is usually considered the cheapest option. However, the EU Landfill Directive establishes that the environmental costs of landfilling and future costs of landfill closure and aftercare be internalised in the gate fees. This has increased the cost of landfilling as well as raising awareness of the “real” long-term costs of landfills. Equally, revenues from energy recovery and products can at least partly offset the costs of other management options, making them economically more desirable than landfilling is this is done without energy recovery (CEC, 2008). Food waste is subject to the standard rate of landfill tax, currently £64 per tonne, but rising to £72 per tonne from April 2013[[13]](#footnote-13). The UK budget 2010 announced that the standard rate of landfill tax would increase by £8 per tonne each year from 1 April 2011 until at least 2014. There will be a floor under the standard rate, so that the rate will not fall below £80 per tonne from 2014-15 to 2019-20[[14]](#footnote-14). WRAP reports the median landfill gate fee for non-hazardous material (inclusive of the standard rate of landfill tax) for 2012 was £85 per tonne (http://www.wrap.org.uk/content/wrap-annual-gate-fees-report).  Haulage costs need to be added to the gate fees but these are probably similar on average whatever method for disposal is used.

## 1.3 Incineration

Incineration involves the burning of typically unprepared (raw or residual) waste. This gives a large reduction in both volume and weight of the waste. To allow the combustion to take place a sufficient quantity of oxygen is required to fully oxidise the fuel. Incineration plant combustion temperatures are in excess of 850oC and the waste is mostly converted into carbon dioxide and water, and any non-combustible materials (e.g. metals, glass, stones) remain as a solid, known as Incinerator Bottom Ash (IBA), that always contains a small amount of residual carbon[[15]](#footnote-15). Acid gases, particulates, dioxins and heavy metals may potentially be released to the atmosphere and need to be removed. Air pollution control (APC) residues are currently collected and landfilled in the UK where they undergo *in situ* solidification, although the future acceptability of this option is uncertain because the EU waste acceptance criteria (WAC) introduce strict limits on leaching that are difficult to achieve (Amutha Rani *et al,* 2008). Local authorities issue permits for facilities under the Environmental Permitting regime (Defra, 2012a). On the basis of historical monitoring over the last 12 years and in the context of the Groundwater Risk Assessment which forms the basis of the PPC Permit, the disposal of APC residues has no adverse impact on the environment or human health.

All animal by-product food waste can be processed by incineration. Incineration of waste in the UK has traditionally been viewed as a management option, with the main purpose being the destruction of waste. However, more recently energy from waste (EfW) or incineration refers to the burning of waste at high temperatures to reduce its volume and to produce heat and/or electricity. For food waste the high moisture content can be an issue as incineration generally requires a moisture content of less than 30% (food waste is generally 75% water). However, the technology is robust enough to process heterogeneous waste and as such can be used for mixed food and packaging waste. Despite the fact that incineration is a very well established technology, its use in the UK is limited. Around 10% of the UK municipal solid waste was incinerated with energy recovery in 2011 (Bennet, 2011) (Environment Agency briefing note: Energy from waste – Key facts 2006).

In 2011 in the UK, 2% of municipal waste was incinerated on land (including energy recovery)[[16]](#footnote-16) By contrast in many parts of Europe waste incineration is widely used[[17]](#footnote-17).

### 1.3.1 Environmental sustainability

The recovery of energy generated from the incineration of waste has in the past not been seen as important in the UK and much of the energy generated was vented to the atmosphere rather than being recovered and used. The picture has now changed and all municipal waste incinerators in the UK recover energy from waste in the form of electricity and/or heat generation. The normal efficiency of energy from waste plants producing electricity in the UK is about 25%. In order to achieve higher efficiencies (e.g. 60% is the minimum recommended by the Sustainable Development Commission of the Scottish Government for new plants), it is likely that the heat produced by the process would also need to be used, i.e. they would need to be combined heat and power (CHP) facilities, with the waste heat also being used, for example, for hot water or space heating (Bennet, 2011). The benefit of operating as a CHP facility is that any electricity generated from the organic fraction of the waste qualifies for Renewable Obligation Certificates if the facility is classified as good quality CHP. These certificates have a financial value and essentially allow the electricity generated to be sold at a significantly higher price[[18]](#footnote-18).

The overall environmental performance of incineration of MSW, including organic material, depends on many factors, especially fuel quality, energy efficiency of installations and source of replaced energy. The Waste Incineration Directive (WID) imposes very high standards on emissions to air, soil, surface and ground water in order to minimise the impact of emissions on the environment and human health[[19]](#footnote-19). Incinerator emissions have reduced substantially over the past two decades. Most emissions are less than 10% of the level 20 years ago (Defra, 2007).

A recent study on landfill and incineration in Ireland (O'Donovan & Collins, 2011) analysed the Net Social Benefit (NSB) of incineration relative to the status quo of landfilling MSW. An incinerator scenario with a capacity greater or equal to 200,000 tonnes per annum, both electricity and heat recovery capacity and one that exceeds the minimum requirements of the EU’s Waste Incineration Directive on air emission standards delivered the highest NSB of the alternative incinerator scenarios examined. The benefits of incineration were found to be driven mainly by environmental savings in the form of energy and resource recovery. It was found in the analysis that incineration does not provide a net benefit against landfill if its scale and energy recovery capacity are insufficient.

### 1.3.2 Health impact

Incinerator emissions are potentially a major source of fine particulates, of toxic metals and of more than 200 organic chemicals, including known carcinogens, mutagens, and hormone disrupters. A report by the British Society for Ecological Medicine (2008) details large studies which have shown higher rates of adult and childhood cancer and also birth defects around municipal waste incinerators and concludes that the results are consistent with the associations being causal. The air pollutants involved include oxides of nitrogen (NOx), particulate matter (PM) and oxides of sulphur (SOx).

The Defra leaflet (What are the causes of air Pollution?) details the sources of air pollution and their potential health effects as follows:

* Particulate Matter (PM-PM10 and PM2.5) -Both short-term and long-term exposure to ambient levels of PM are consistently associated with respiratory and cardiovascular illness and mortality as well as other ill-health effects.
* Oxides of nitrogen (NOX) -NO2 is associated with adverse effects on human health. At high levels NO2 causes inflammation of the airways. Long term exposure may affect lung function and respiratory symptoms.
* Sulphur dioxide (SO2)- Causes constriction of the airways of the lung. This effect is particularly likely to occur in people suffering from asthma and chronic lung disease.

However, there is a wide variation in the types of incinerators that have been studied in some of the reports on human health risks. Different types of technologies are used for MSW incineration. Typical technologies include (i) grate incinerators, (ii) rotary kilns, (iii) controlled air incinerators, and (iv) fluidised bed incinerators. Among these technologies, grate incinerators are used most extensively (Tzimas,*et al*,JRC report).

Among the substances emitted as a result of incineration, NOX and dioxins/furans are among the most difficult substances to be control, since their emissions cannot be easily mitigated without the use of complex technologies that add substantial cost and reduce plant efficiency. The main technologies that can be used to limit NOX emissions are Selective Catalytic Reduction (SCR) and Selective Non Catalytic Reduction (SNCR).

In Europe, most MSW incineration is carried out in a burning moving bed on a mass burn grate. Current efficient waste management strategies are also aimed at reducing the amount of waste from MSW incinerator plants by processing ash from new plants to approach the target of zero net waste material output and reducing the pollutants in flue gases by end-of-pipe treatment (Yang et al, 2003).

Directive (2000/76/EC) “on the incineration of waste”, that regulates the operation of waste incinerators and co-incinerators limits the emissions of specific substances. The Directive is implemented by the Waste Incineration Regulations (S.I. 2002 No. 2980), and applies to the majority of installations. The Environment Agency issues pemits and provides guidance on how to comply with the Directive requirements.(How to comply with your environmental permit -Additional guidance for: The Incineration of Waste (EPR 5.01).

The current generation of waste incinerators result in much lower levels of exposure to pollutants. No evidence has been found for a link between the incidence of cancers, respiratory diseases and birth defects and the current generation of incinerators. In some cases, apparently significant effects of exposure to emissions from incinerators on the rate of cancer have been observed. These are often in relation to incinerators close to other sources of potentially hazardous emissions, which makes it much harder to pin down the source of any effect. Socio-economic confounding factors can also play a role. In 2008, the Government’s expert advisory Committee on the Carcinogenicity of Chemicals in Food, Consumer Products and the Environment (COC) reviewed seven new studies on cancer incidence near municipal solid waste incinerators which had been published since 2000, some of them also reviewed in the 2008 British Society for Ecological Medicine report mentioned above, and concluded that all of them had studied the older generation of incinerators and most of them had failed to factor in confounding factors such as other sources of emissions or socio-economic factors (HPA, 2009). They concluded that “*any potential risk of cancer due to residency (for periods in excess of ten years) near to municipal solid waste incinerators was exceedingly low and probably not measurable by the most modern techniques.”*

Whether or not the scientific data suggest that there is low risk to human health, public perceptions will play a part. Convincing the public that incineration is safe will remain a challenge.

### 1.3.3 Animal health risks

The very high temperatures achieved at these plants, i.e. in excess of 850oC, are much higher than those required to eliminate bacteria and, under the ABP rules, maintaining this temperature for 2 seconds is expected to reduce the risk from prions. Garcia (2005) reported that a heat treatment at 65oC for 20 min was sufficient to ensure microbiological quality of feed samples. For viruses treatment at 70oC for 1 hour was reported to be sufficient by Salström *et al* (2008) and was used in the development of the EU standard for the treatment of animal by-products in EC Regulation 1774/2002, now replaced by Regulation (EC) 142/2011. Fichet *et.al*. (2004) and Sakudo *et al* (2011) reported heating to 134oC for 18min to be sufficient to remove prions (if any are present in the food waste), so the animal health risks from ash from this source will be extremely low.

### 1.3.4 Cost

Incineration requires high investment and high operational costs. As an example, the Waste Technology Data Centre[[20]](#footnote-20) estimates a capital cost of £25m for a facility with an annual capacity of 50,000 tonnes per annum, £35m for 136,000 tpa and £51m for 265,000 tpa. Examples exist where costs of building incinerators have soared above their original estimates (e.g. waste-burning incinerator near Hedon has increased to £144m). O'Donovan and Collins (2011) estimated the capital and operational costs of incineration in Ireland over a period of 20 years. This included building, operation, remediation and aftercare based on a capacity of 200,000 tpa and using 2008 prices. The calculated median figures per tonne of waste were €600.13 for capital cost and €696.12 for operational costs.

On the other hand, incineration can offer good economies of scale and does not require changes to existing MSW collection schemes for landfilling, while bringing in revenues from energy recovery, especially when the efficiency is maximised by using waste in high efficiency cogeneration units for the production of both electricity and heat. The cost of incineration of mixed waste has been estimated to be £80/tonne, although quoted costs in the literature vary enormously depending on factors such as the cost model used or the type of facility (Eunomia, 2007). WRAP Gate Fees report (2012) found gate fees for incineration higher than landfill presumably because of the higher running and capital investment costs incurred. Environment agency permit fees for incinerators can be up to £2500. Overcapacity in the UK may lead to economic difficulty for incineration plants in the future (Mathieu, 2011).

## 1.4 Rendering and biodiesel production

The rendering process is generally applied to those parts of meat animals that are not intended for human consumption, such as by-products generated at abattoirs. It involves crushing and grinding, followed by heat treatment to reduce the moisture content and kill micro-organisms. The melted fat (tallow) is separated from the solid (protein) by centrifuging and pressing the material. The solid fraction is then ground into a powder, such as meat and bone meal, MBM (when the input is Category 1 or Category 2 ABP material) or processed animal protein, PAP (when the input material is Category 3 ABP). The products of rendering are used both as resources in their own right (oleochemicals, fertilisers, animal feed/pet food, food) and as substitutes for fossil fuels (as biofuels themselves, e.g. oils and tallows, and in the production of biodiesel).

In the EU the incorporation of processed animal protein (PAP) in any farmed animal feed is not permitted. Some tallow from Category 3 material, depending on its grade or quality, is used in animal feeds, but by far the majority is used for industrial purposes. The fat and animal protein derived from poultry by-products and feathers (which are processed in dedicated plants or lines) are used extensively in pet food.

Rendered fats and oils can be used to produce biodiesel. Where biodiesel is produced partially or completely from animal by-products, the plant must be approved under the ABP regulations. Wastes that are suitable for production of quality biodiesel are classified under the following European Waste Catalogue (EWC) codes (although not all wastes classified under these codes may be suitable for processing)[[21]](#footnote-21):

- 20.01.25: waste cooking oil originating in restaurants, catering facilities and kitchens (municipal wastes - household waste and similar commercial, industrial and institutional wastes - including separately collected fractions: edible oil and fat).

- 02.02.99: rendered animal fat and waste cooking oil (wastes from the preparation and processing of animal carcasses, meat, fish and other foods of animal and vegetable origin other than from the sources listed at 20.01.25: wastes not otherwise specified).

Waste vegetable oil (WVO) is often used as starting material for biodiesel production. When the oil comes from a catering facility its direct use in the manufacture of biodiesel is not controlled by the ABP regulations. Therefore, biodiesel plants using only catering WVO do not require approval under the regulations (NB under review in the EU). All products from non-approved biodiesel plants are considered to be untreated catering waste, and must therefore be disposed-of as if they were catering waste. In particular, glycerine produced in non-approved biodiesel plants cannot be used for feeding to livestock. Where operators of approved plants are using catering WVO to produce biodiesel, the WVO must be subject to processing (rendering) in an approved processing plant prior to entering the biodiesel plant, this would include approval as End of Waste biodiesel[[22]](#footnote-22). The co-products (glycerine and potassium sulphate) can be placed on the market, but operators should note that the glycerine cannot be used for feeding to livestock because the regulations permit only rendered fats obtained from certain Category 3 materials to be used for feed purposes.

As in the case of catering WVO, where the WVO originates from food factories that fry vegetables only (e.g. crisps, chips) it is not controlled by the regulations and does not have to be processed in an ABP approved plant. In this case, the oil and glycerine derived from it can be used for feeding to livestock. When WVO originates in food factories that “flash fry” meat and fish, it is controlled by the regulations. If used for biodiesel manufacture, it must be processed (rendered) in an ABP approved processing plant prior to entering the approved biodiesel plant, in the same way as any other unprocessed ABP starting material. Provided that the operator can demonstrate that no muscle fibres remain in the glycerine co-product, it can be used for feeding to livestock[[23]](#footnote-23).

Used cooking oil is collected and cleaned for re-use by a network of companies across the UK, which are all members of ACORN (the Affiliated Cooking Oil Reclaimers Nationwide). The oil is collected by individual companies, cleaned and sent for further refining (SAC, 2005). Approximately 100,000 tonnes/year of waste vegetable oil are currently collected in the UK, of which 80,000 tonnes/year come from the catering industry. Around 75,000 tonnes of the catering WVO are used for biodiesel production, the remainder going to oleochemical production and incineration/CHP. A further 20,000 tonnes/year of WVO are collected from food factories/food production and are recycled by the animal feed industry. Total WVO arisings could be as much as 200,000 tonnes a year[[24]](#footnote-24),[[25]](#footnote-25).

### 1.4.1 Environmental sustainability

Rendering potentially has a major role to play in a sustainable food chain and economy. The process itself leads to the safe recovery of animal by-products, thus avoiding the disposal of a substantial quantity of waste. In the UK, there is a kilogram of inedible meat by-product that must be disposed of for every kilogram of meat that is consumed. In 2004, Woodgate and van der Veen reported that approximately 17 million tonnes of slaughter by-products were produced by the meat industry every year in the EU. Disposing of these volumes of animal by-products in landfill, for example, would have a significant impact on available landfill space.

However, rendering also has the potential for producing negative impacts on environmental quality. The handling and processing of organic raw materials produce undesirable biodegradable by-products that can have significant impacts on water and air quality[[26]](#footnote-26). The main environmental impact of rendering is odour. Defra’s guidance on Integrated pollution control[[27]](#footnote-27) recommends to control odours by preventing, minimising and capture and treatment, in that order. 90% of odours can be removed using cold water washing with further emission reductions achieved using afterburners, scrubbers or biofilters (Kalbasi-Ashtari et al., 2008). With regards to effluents generated at rendering plants, the release of suspended solids, oils and greases must be controlled to prevent the release of material with high biological and chemical oxygen demand into watercourses (Gwyther et al., 2012). The risk of pollution can be reduced by the efficient filtering, use and reuse of wastewater or by more intensive wastewater treatment on or off-site at sewage treatment works (DEFRA, 2008c). The rendering industry operates under strict environmental regulations and modern rendering facilities have sophisticated treatment processes and control equipment for maintaining acceptable water and air emissions.

The products of rendering are used both as resources in their own right and as substitutes for fossil fuels. Both of these outlets reduce the reliance on virgin materials, hence reducing land use and avoiding potential environmental degradation and habitat loss. Tallow has a high fat content and when burnt for energy production, a considerable amount of energy may be recovered which would otherwise be lost, thus reducing the net environmental footprint of the process (Woodgate & van der Veen, 2004). As with incineration, rendering has a high energy demand but if tallow is recovered for subsequent energy production then the net GHG emissions are likely to be low. According to the Renewable Fuels Agency, in 2008, 12% of the tallow produced in the UK was used for biodiesel production and 49% as heating oil[[28]](#footnote-28).

The use of biofuels in place of fossil fuels is seen as a way of reducing emissions of CO2. The SAC report (SAC, 2005) indicates that on combustion, most emissions from biodiesel are reduced compared to mineral diesel. Sulphur in particular is reduced. An exception is NOx emissions, but this can be improved by engine timing adjustments. The energy balance (output/input ratios) of biodiesel production varies according to the range of by-products included in the energy output and the scenarios applied in production, but it is favourable for most situations.

The current Renewable Transport Fuels Obligation was introduced in 2008 and places an obligation on owners of liquid fossil fuel intended for road transport use to ensure that either a certain amount of biofuel is supplied or that a substitute amount of money is paid. Only those organisations that supply more than 450,000 litres of fossil fuel in a given year are obligated by the Order. The amount of biofuel that must be supplied increases annually until April 2013 when it will reach 5% of total road transport fuel supplied by volume. These measures intend to reduce the use of fossil fuel for transport in favour of biofuels. The use of food waste such as waste cooking oil represents a more sustainable source of biofuel than crops grown specifically for biofuel production, although it only represents a small proportion of the fuel demand. In the UK, 250 million litres of waste cooking oil could be sourced from commercial outlets[[29]](#footnote-29) but this would make up considerably less than 1% of fuel demand in the UK. Additionally, biodiesel production from waste cooking oil offers a solution to the increasing problem of oil wastes from households and industrial sources.

The European Standards Organisation, CEN, finalised EN 14214 – the standard for biodiesel – in 2003. This standard was derived from the characteristics of biodiesel produced exclusively from virgin rape oil and came into force in the UK as BS EN 14214:2003[[30]](#footnote-30). In the case of biodiesel intended for use as a heating fuel the standard to be met is BS EN 14213. Moreover, a quality protocol has been produced by WRAP and the Environmental Agency that sets out standards for the production and use of quality biodiesel and for the protection of human health and the environment[[31]](#footnote-31). The environmental risks associated with the use of waste-derived biodiesel are low. The Environment Agency has assigned low risk status to many of the activities involved in the storage and treatment of waste derived biodiesel[[32]](#footnote-32).

### 

### 1.4.2 Health impact

The value of the rendering process as a mechanism to control risks from microbial pathogens as well as other hazards was validated in a UK Department of Health (2001) study. Risks of human exposure to biological hazards were found to be negligible when fallen stock and by-products were processed by rendering, incineration, or funeral pyre. However, incineration and pyres were reported to cause moderate to high exposure to chemical hazards associated with burning. Only materials that had been rendered yielded negligible exposure to both biological and chemical hazards. This study found that the only agent that required incineration of the solid products after rendering was the BSE prion.

No information has been found regarding health impact of food waste rendering operations. As mentioned earlier, rendering facilities are subjected to strict regulations and modern technology enables efficient pollution controls.

Regarding biodiesel, the Biodiesel Quality Protocol aims to protect human health and the environment (including soil) by setting standards for the production and use of quality biodiesel as automotive or heating fuel and describing acceptable good practice for its use.

### 1.4.3 Animal health risks

Rendering plants can take all categories of animal by-products, but they must be approved in accordance with Article 24 of Regulation (EC) 1069/2009 and they must comply with all the established requirements regarding separation of different categories of animal by-products, processing methods, hygiene, waste water treatment, etc. Rendered food waste (Category 3 material under the ABPR) can be used in the production of animal feed, though TSE related restrictions on the feeding of processed animal protein severely restrict this.

The rendering process is an effective method for the destruction of pathogenic viruses, bacteria, and other microorganisms. The EU regulation EC 142/2011 sets out different processing methods for animal by-products, stipulating the conditions required in order to ensure elimination of bacteria, viruses and many other microorganisms, and production of an aseptic protein product that is free of potential biohazards and environmental threats. Troutt et al. (2001) sampled unprocessed animal by-products at 17 different US rendering facilities in each of two seasons. *Clostridium perfringens, Listeria* species, and *Salmonella* species were found in more than 70 percent of the samples taken before processing. All samples taken after heat processing were negative for these and other pathogens. These data suggest that rendering is an effective tool for use in controlling pathogenic bacteria, enabling the safe recycling or disposal of animal by-products and production of safe, biosecure finished products[[33]](#footnote-33).

As mentioned earlier, it is known that prions are not destroyed through rendering. However, biodiesel production from rendered animal by-products had been suggested to destroy infectivity from TSEs (Seidel et al. 2006). Bruederle et al. (2008) investigated the survival of scrapie prions after production of biodiesel from meat and bone meal (MBM) through a modified form of alkaline methanolysis. They showed that the solid MBM residue after biodiesel production was still capable of inducing scrapie symptoms upon injection into hamster brains, although infectivity was reduced. Prions are unlikely to be present in food waste as they should not have entered the food chain.

Regarding biodiesel production, adherence to the Quality Protocol and the standards for biodiesel helps to minimise any potential risks for animal health. As described above, the use of the glycerine co-produced with biodiesel as animal feed is under the ABP regulations as is the disposal of waste products.

### 1.4.4 Cost

The SAC report (SAC 2005) provides an economical evaluation of different scales of operation for biodiesel production. They conclude that the full utilisation of plant capacity and the costs of feedstock are the key factors affecting production costs. They report a production cost of £0.0413/litre of biodiesel produced from seeds in a facility of 60,000 tonnes capacity. The use of food waste as feedstock for biodiesel represents a much cheaper alternative than specifically grown crops, with production costs coming closer to those of petroleum diesel[[34]](#footnote-34). Kemp (2006) reported that oil feedstock cost is the major cost of biodiesel production, accounting over 70 % of the total costs. Hence, if the waste vegetable oil is used as biodiesel feedstock, the economics of biodiesel can be significantly improved. Moreover, the use of waste cooking oil also reduces the waste treatment costs. Some biodiesel plants in Europe use WVO in combination with other oils to reduce overall costs. However, the availability of these waste materials is still a limiting factor.

## 1.5 Biological treatment

Biological treatment of waste includes composting and anaerobic digestion. These processes are generally used as recycling or recovery methods to produce valuable products such as compost, digestate and biogas. Sometimes biological treatments are used as pre-treatment methods prior to landfilling or incineration.

Composting is a commonly used biological treatment option for MSW, mainly using mechanically turned open windrows, which is the cheapest system. Nationally, about one to two per cent of municipal waste is composted, amounting to an estimated 1.5 million tonnes of product. Most UK facilities are designed for operation with the material typically collected from collection schemes targeting food and garden waste. The EU ABPR [(EC) 1069/2009](http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:300:0001:01:EN:HTML) does not allow composting of catering waste in open windrows, except for household waste. Other types of food waste therefore must be composted in enclosed systems (in-vessel composting (IVC) or covered windrow) or digested anaerobically. Local authorities in the UK are implementing a range of schemes to increase the collection of food waste. Within England just under 50% of local authorities collect food waste in some form or another. Of those collecting food waste there is a 60:40 split between those collecting food waste separately and those collecting food and garden waste together. All 22 local authorities in Wales currently collect food waste. The Welsh Government's (WG) preferred option for food waste is prevention, then reuse, followed by anaerobic digestion (AD). Scotland is actively enhancing its collection system at present, although its geographical problems mean that some areas are further behind. The waste collection systems used by the different local authorities have a significant influence on the cost of biological treatments. Whether food waste is collected separately or together with garden waste will influence the choice of treatment.

### 1.5.1 Composting

Organic materials make up a significant part of household waste and most organic materials - including garden green waste, cardboard, fruits, vegetables and wood waste - can be composted. Composting is a microbiological process by which naturally occurring microorganisms degrade organic material in the presence of oxygen. The biological activity during the process releases heat, increasing the temperature of the compost heap up to 60-70oC, which is needed to kill pathogens and weed seeds. In vessel composting (IVC) ensures that composting is subject to accurate temperature control and monitoring. The basic EU standard is 70oC/60 minutes/12mm particle size although the EU ABPR (EC) 1069/2009 do allow for alternative standards subject to demonstration of satisfactory pathogen destruction. Also Member States may introduce their own national standards where catering waste is the only animal by-product being composted and the UK has done so. Category 3 material can be used directly in approved composting plants. Under the UK standards two composting ‘barriers’ or processing standards must be met when catering waste includes meat. Table 3.1 shows the different processing option combinations that may be used to meet ABPR processing standards[[35]](#footnote-35). Open-air windrows or 18 days storage is used as a second barrier after IVC to achieve stabilisation of the compost product[[36]](#footnote-36).

Defra guidance allows for some artificial heat (such as steam) to be used to help achieve time/temperature requirements. Regulation 16 of the domestic ABPR 2005 introduced an exemption to the composting requirements only for situations where the catering waste is generated, composted and then used all on the same premises and similar arrangements continue to apply following repeal of those regulations under the revised EU ABPR (EC) 1069/2009 [[37]](#footnote-37).

**Table 1.1.** Composting treatment systems and parameters for catering waste.

|  |  |  |  |
| --- | --- | --- | --- |
| ***System*** | ***Composting in a closed reactor*** | ***Composting in a closed reactor*** | ***Composting in housed windrows*** |
| **Maximum particle size** | 40cm | 6cm | 40cm |
| **Minimum temperature** | 60°C | 70°C | 60°C |
| **Minimum time spent at the minimum temperature** | 2 days | 1 hour | 8 days (during which the windrow shall be turned at least 3 times at no less than 2 days intervals) |

##### *1.5.1.1 Environmental sustainability*

Compost is valued for its organic matter content, and is typically used as a soil improver to enhance the chemical, physical and biological properties of soil. Compost also provides slow release nutrients, containing nitrogen, phosphorus and potassium which complement traditional fertilisers and help to gradually build natural soil fertility( WRAP, ref: 47ORG).The use of compost as a soil improver offers agronomic benefits such as improvement of soil structure (Lakhdar et al. 2009), moisture infiltration, water-holding capacity (Nguyen et al 2012), soil microorganisms and supply with nutrients (on average, compost from kitchen waste contains about 1% nitrogen, 0.7% phosphate and 6.5% potassium). In particular the recycling of phosphorous can reduce the need to import mineral fertilizer while replacement of peat reduces damage to wetland eco-systems. Increased water retention capacity improves workability of soils, thereby reducing energy consumption when ploughing them. Better water retention (soil organic matter can absorb up to 20 times its weight in water) can help to counteract the desertification of European soils and prevent flooding. Finally, the use of compost contributes to counteracting the steady loss of soil organic matter across temperate regions (CEC,2008).

However, composting facilities have the potential to cause environmental pollution and harm to human health and to produce poor quality compost if they use poor quality feed stock or are not operated correctly. The Environment Agency have expressed concerns about the unacceptable impacts caused by composting sites if they are poorly managed and operated. In particular, they can:

• give rise to nuisance odours

• produce immature compost (which is likely to be malodorous), contaminated

or otherwise poor quality compost

• catch fire

• expose people nearby to high concentrations of potentially harmful bioaerosols

The Environment Agency sets specific standards for composting waste in open and closed systems (Environment Agency Standard rules SR2011No1, revised 2012). These standards set rules for limiting noise, odour and other nuisances.

Environmental impacts of composting also include emissions of greenhouse gas, ammonia and volatile organic compounds. The agricultural benefits of compost use are evident but there is debate about their proper quantification (e.g. by comparison to other sources of soil improvers), while the main risk is soil pollution from poor quality compost (Green Paper on the management of bio-waste in the European Union SEC(2008) 2936). Biowaste (organic waste) becomes easily contaminated during mixed waste collection, therefore the use of compost on soil could potentially lead to accumulation of hazardous substances in soil and plants. Typical contaminants of compost include heavy metals and impurities (e.g. broken glass), but there is also a potential risk of contamination by persistent organic substances such as polychlorinated dibenzo*-p-*dioxins/furans (PCDD/F), polychlorinated biphenyls (PCB) or polychlorinated hydrocarbons (PAHs). Proper control of input material coupled with the monitoring of compost quality is crucial. This approach limits the risk and reduces the cost of compliance testing by allowing less extensive monitoring of production and use of compost (CEC, 2008). In the UK, BSI PAS100 (Publicly Available Specification) specifies requirements for the process of composting, the selection of input materials, the minimum quality of composted materials and the storage, labelling and traceability of compost products. It specifies requirements for a Quality Management System (QMS) for the production of composts to ensure they are consistently fit for their intended uses. It also requires Hazard Analysis and Critical Control Point (HACCP) assessment, which the composter takes into account when developing, implementing and reviewing the QMS[[38]](#footnote-38). The implementation of this quality standard should ensure the freedom of the compost from physical impurities, damaging chemicals and weed seeds, and ensure traceability.

Life cycle assessments have been carried out on home composting in Denmark where it performed better than or as good as incineration and landfilling in several of the potential impact categories (Andersen et al, 2012). One exception was the global warming category, in which incineration performed better due to the substitution of heat and electricity based on fossil fuels.

##### *1.5.1.2 Health impact*

The health effects of compostingfacilities are likely to be dependent on the type of facility (open windrow or in-vessel system). There are few epidemiological studies of populations living near composting facilities, although some reports have considered the health effects. Some of these studies show that living near composting plants could increase the rate of conditions like bronchitis, coughing and eye irritation (Herr et al. 2003). However, no links with increased rates of asthma have been found (Browne et al. 2001). Another study looked at whether there was a cancer risk due to exposure to substances released by composting sites, concluding that no additional risk of cancer was found[[39]](#footnote-39). Nevertheless, research into emissions and potential health effects of composting has been limited so far and more investigation would help to better understand the risks. There are also a range of risks to workers in the plants, which need to be addressed by employers, including exposure to organic dusts, bioaerosols and microorganisms (Domingo & Nadal, 2009).

The use of compost in agricultural land could potentially have associated risks due, for example, to contamination of the waste with pesticides, pharmaceuticals or other non-permitted substances,. However, compliance with quality assurance systems such as the PAS 100 and the Compost Quality Protocol (WRAP) will minimise those risks.

##### *1.5.1.3 Animal health risks*

Under the EU ABPR (EC) 1069/2009 composting can be used for treatment of Category 3 waste, including catering waste. Uncooked meat may potentially contain non-indigenous animal pathogens such as foot-and-mouth disease virus, African swine fever virus and classical swine fever virus, and to ensure the safety of the compost the conditions in the composting process must be carefully controlled. The net pathogen destruction by the composting process is determined largely by the degree of bypass, and to accommodate the possibility of large joints or even whole carcases being discarded uncooked to catering waste, a time/temperature condition of 60oC for two days is recommended (Gale, 2002). A risk assessment carried out by WRAP in 2003 concluded that most pathogens are inactivated by the composting process , although resistant organisms such as *C. perfringens*, *C. botulinum* and the cysts and eggs of protozoan and helminth parasites may survive (WRAP, 2003). As a safeguard against this the regulations specify particle size reduction before composting (see Table 3.1) and as an added safeguard, the EU ABPR (EC) 1069/2009 prohibits the use of land for grazing or cropping for feedingstuffs following the application of compost unless grazing restrictions have been observed. In the UK the grazing ban is 8 weeks for pigs and 3 weeks for all other farmed animals, which is longer than that suggested by Gale (2002).

Domestic wastes are likely to contain a lower amount of uncooked meat so will be lower risk than commercial catering wastes. For catering waste containing meat the composting process must achieve any two of the processing standards listed in Table 3.1. Where meat has been excluded, only one of the processing standards must be met followed by a minimum 18-day storage period. When treating material to 70°C for 1 hour, there is a greater risk of failing to meet the temperatures required in all of the material. Treating to 60°C for 2 days lessens the risk of failure to meet temperatures, but also reduces the capacity of the in-vessel unit (Guide to Selecting an In-Vessel Composting System 2005 – Clean Merseyside).

##### *1.5.1.4 Cost*

The capital costs for in-vessel composting vary, depending on the type of facility and installations. To offset these capital costs and running costs, gate fees are charged by site operators, WRAP Gate Fees 2012 (Table 1.3) states median fees of £44 for mixed food and garden waste and £49 for food waste only. This income is critical for the businesses running these premises as a critical review by Farrell & Jones (2009) reported that the composting product can be of very low value in itself and difficult to market.

### 1.5.2 Anaerobic digestion (AD)

Anaerobic digestion is a process where putrescible biomass is degraded by microorganisms in the absence of oxygen, during which biogas is collected. The process also produces a nutrient-rich digestate. Biomass is put inside sealed tanks (either in parallel within a single digestion vessel, or in a series of separate vessels) in which physical parameters (temperature, retention time and pH) are controlled to maintain conditions conducive to microbial activity. Biogas comprises a mix of methane and carbon dioxide that can be used as a source of clean renewable energy. The material left over at the end of the digestion process is rich in nitrogen, phosphate and potassium and is an excellent replacement for mineral fertilisers. This material is known as biofertiliser or anaerobic digestate. Anaerobic digestion can also be used as a pre-treatment method before waste disposal.

Almost any kind of organic material can be digested anaerobically, with the exception of woody materials, which contain lignin, a substance that cannot be degraded by anaerobic microorganisms. Regarding animal by-products, anaerobic digestion and composting plants can only treat Category 3 animal by-products, Category 2 animal by-products if they have been pressure rendered, and certain specified Category 2 materials such as manure, digestive tract content, milk and milk products.

A standard environmental permit from the Environment Agency is required by most UK anaerobic digestion plant operations. Larger sites processing more than 100 tonnes of waste a day will require a bespoke permit, while digesters with a net thermal capacity below 0.4MW are exempt from requiring an environmental permit Authorisation under the ABPR is also required for the processing of low-risk (category 3) ABPs and catering waste which contains meat or which comes from a premises handling meat [[40]](#footnote-40). Table 3.2 shows the different processing options that may be used to meet ABPR processing standards[[41]](#footnote-41). Plants treating catering waste under national standards, as well as meeting the time/temperature treatment requirement, must also utilise at least one additional barrier (pasteurisation). The requirement for additional barriers is a national standard, and does not apply to systems complying with the EU standard (which has a far smaller maximum particle size, precluding the need for a second stage). Biogas plants must either (a) treat only meat-excluded catering waste; or (b) following treatment, store the material for a minimum of 18 days. Storage may include anaerobic digestion.

**Table 1.2.** National standards for biogas systems for treatment of catering waste.

|  |  |  |
| --- | --- | --- |
| ***System*** | ***Biogas in a closed reactor*** | ***Biogas in a closed reactor*** |
| **Maximum particle size** | 5cm | 6cm |
| **Minimum temperature** | 57°C | 70°C |
| **Minimum time spent at the minimum temperature** | 5 hours | 1 hour |

The UK has some 95 operational plants (http://www.biogas-info.co.uk/index.php/ad-map.html) currently, excluding those in the water industry. The WRAP report (2010) reported an increase in the number of AD sites and attributed this in part to increased recycling of food waste. Nevertheless, the government recognised the unrealised potential of AD in this country and the Defra Anaerobic Digestion Strategy and Action Plan[[42]](#footnote-42) published in 2011 aims to bring about an increase in energy from waste through anaerobic digestion.

##### *1.5.2.1 Environmental sustainability*

AD has the advantage over composting of generating energy, which reduces emissions of climate change gases by offsetting emissions from fossil fuelled power stations. It therefore can give net carbon savings. If just 5.5 million tonnes of food waste was treated by AD, between 477 and 761 GWh of electricity could be generated each year, enough to meet the needs of up to 164,000 households (Hogg *et al*, 2007). Compared to composting, treating the same amount of food waste with AD would save between 0.22 and 0.35 million tonnes of CO2 equivalent, assuming the displaced source is gas-fired electricity generation (ERM, 2006). But at the moment only a small proportion of food waste is treated using AD.

Using the digestate as a soil improver also brings environmental benefits through storing some carbon in the soil and displacing the use of mineral fertiliser, which requires significant energy input to be produced (FOE, 2007 AD ; Arthurson,2009).

Emissions from processing and utilising the digestate need to be considered. Most of the emissions in the treatment options for digestates arise from nitrogen decomposition into N2O, NH3 and NO3− and carbon compounds into CH4 (Rehl & Muller (2011). These emissions can be reduced by filter, air tight storage cover or special application technologies. However, it is important to take a holistic consideration of all impact categories: the reduction of one emission, e.g. reduction of NH3 emissions during treatment, might lead to higher emissions during later parts of the life cycle of the digestate. Pezzolla et al (2012) reported that the application of AD digestate led to an increase grass yields and in CO2 emissions from soils especially after the 2nd application (74.1 kgCO2-C ha–1 day–1) compared with the control soil (36.4 kg CO2-C ha–1 day–1).

Leakage in containment of biogas can result in the release of strong and unpleasant odours. These can cause public concern and stress to the general public even if there is no proven risk to human health and they can also be difficult to monitor scientifically (Ranzato et al, 2012). However, as AD is conducted in closed reactors the emissions to the air are significantly lower and easier to control than from open air composting.

The efficiency of biogas production in AD using food waste as a feedstock can be compromised, for example, trace nutrients are often absent from food wastes, particularly selenium and to a lesser extent nickel and molybdenum. Volatile fatty acids are produced from feedstocks with a relatively high proportion of carbon (sugars and carbohydrates) to nitrogen and this feedstock will acidify quickly, meaning digester pH can drop - this is balanced by providing protein rich feedstocks high in ammonia, which are a source of alkalinity, which in turns balances/buffers the pH. Balancing the digester can be achieved by adding other wastes to the food waste (e.g. Zhang et al, 2012). If everything is balanced in the digester then the biogas yield will be maximised and a PAS110 compliant digestate will be produced.

Due to the energy recovery potential from biogas coupled with the soil improvement potential of digestate (especially when treating separately collected biowaste) AD often represents the environmentally and economically most beneficial treatment technique after prevention/re-use (CEC 2008). However, methodologies for life cycle analysis are complex and studies are often not readily comparable (Bernard & La Cour Jansen, 2012).

##### *1.5.2.2 Health impact*

Like most treatment processes, there will be some emissions from AD. Air emissions are low due to the enclosed nature of the process, though combustion of the biogas will produce some nitrogen oxides. However, emissions from AD-CHP are generally lower than other forms of waste disposal.

The health risk from the solid and liquid residue from the AD plant should be low as long as source-separated waste is being used (i.e. no chemical contaminants are entering the system from other waste). The quality and safety parameters for anaerobic digestate are specified by the BSI PAS 110 (for example, ABP regulations require samples to be tested for human and animal pathogen indicator species) and the Anaerobic Digestion Quality Protocol. These, together with the national and EU ABPR processing standards aim to ensure the safety of these products to be spread on the land.

##### *1.5.2.3 Animal health risks*

Raw food waste is likely to prove attractive to animals if stored in an inappropriate manner so procedures should be put in place to ensure that access to the waste is denied. The main hazards in the waste are likely to be from the typical bacteria and viruses found in food, for example *Escherichia coli,* *Salmonella* spp., *Campylobacter* spp, etc (see Annex 6) although surveys have not been carried out to confirm this.

Most information on the animal health risks from AD processes comes from evidence on processing sludge and sewage wastes, for example, Popat *et al* (2010) carried out a study on the kinetics of inactivation of the roundworm (*Ascaris suum*) and vaccine strain poliovirus type 1 (PVS-1), selected as indicators for helminth ova and enteric viruses respectively, during AD at temperatures ranging from 51 to 56oC (thermophilic digestion). Inactivation of both indicator organisms was fast, with greater than two log reductions achieved within 2 h for *A. suum* and three log reductions for PVS-1. Bendixen (1994) reviewed the procedures for the removal of pathogens during AD at lower temperatures and recommended the use of faecal streptococci as indicators to check the function of the plants and the reduction of pathogens.

Different AD designs can use a range of temperature regimes. Broadly, anaerobic digesters are either mesophilic (typically operating at 33-38°C, but sometimes at temperature below 30°C) or thermophilic (typically 49-57°C, but sometimes up to 70°C). Mesophilic reactors are the norm for AD in the UK. The survival of *Escherichia coli* and *Salmonella* spp. through MAD has been examined extensively, for example, Horan *et al*. (2004) measured inactivation of *E. coli* in both the primary and secondary stages of MAD using a laboratory digester system operated under compliant conditions and fed with raw sludge. They observed a 1.66 log removal for *E. coli* and 2.23 for *S.* Senftenbergduring the primary stage*.* There have been reports that some of the endospore forming bacteria, particularly the obligate anaerobes may survive and possibly even grow in AD (Watcharasukarn *et al*. 2009). A comprehensive picture of proliferation of certain Clostridium species in AD reactors is not available at the moment, however, an initial study suggested that no proliferation of human pathogenic Clostridia occurs under mesophilic or thermophilic conditions assessed in lab scale reactors (Dohrmann *et al*. 2011).

Category 3 animal by-products must be treated in accordance with the EU Regulation. Pasteurisation is a requirement when ABP or catering waste are used as feedstock. The EU standard treatment is pasteurisation at 70°C for at least 1 hour with a maximum feedstock particle size of 12mm. This is to ensure pathogen elimination. However, Bagge et al (2005) reported that although Salmonella and other pathogenic bacteria were reduced, spore forming bacteria were not and there was a potential for regrowth in storage afterwards. A Defra- funded project carried out by AHVLA (project SE4401, 2011) identified a list of thermo-resistant viruses which might be present in ABP Cat 3 waste- the project concluded that parvovirus (particularly bovine and porcine) were particularly resilient and supported the EC 208/2006 regulations for its use as an indicator species for viral inactivation for ABP.

Generally speaking, where AD plants are treating animal by-products, including food waste, they will need an approval from the Animal Health Veterinary Laboratory Agency (AHVLA) under Animal By-Products legislation. High-risk material such as dead/fallen stock cannot be used in AD. Permissible AD plant treatment and hygiene standards are set out in the Implementing Regulation (EC) 142/2011. There are certain limited exceptions where AD plants treating animal by-products, including food waste, will not need to have an approval from AHVLA. These include AD plants treating food waste on the premises of origin, and there is a small list of animal by-products that can be used in AD without needing an AHVLA approval, including manure, milk and milk products and colostrum. Land treated with digestate derived from AD plants using animal by-products will be subject to the grazing ban. Spreading digestate on agricultural land or non-agricultural land to confer benefit requires an exemption or an environmental permit. The Environment Agency is responsible for determining applications for environmental permits for these types of recovery operations and for the registration of permit exemptions. The Environment Agency is also responsible for ensuring compliance with the conditions of environmental permits, including by means of appropriate periodic inspections. Livestock must not be allowed access to the land during the ban period and cropping for feedstuffs is not allowed.

##### *1.5.2.4 Cost*

Investment costs of an anaerobic digestion plant will vary depending on factors such as the type of technology, emission reduction techniques used and input material requirements. Generally, for food waste feedstock pre-treatment technology is required to remove packaging and homogenise the feedstock before it is added to the digester. Because of this, capital and operating costs tend to be higher than those plants where feedstock requires lower levels of treatment, but income can be generated through charging a gate fee for waste coming in. The current median gate fee for AD published by WRAP is £41 per tonne (Table 3.3). This figure indicates that AD is becoming cost-competitive with landfill and other methods of waste management such as in-vessel composting. However, a big obstacle for the development of AD plants is the difficulty of securing feedstock contracts. Some companies are reported to be offering free collection to some waste producers as a means of getting feedstock into a facility (Eunomia 2011).

Digestate has almost zero value at present and WRAP (2012) recently carried out a study identify digestate enhancement technologies and techniques in an attempt to identify technologies are available to create a range of novel digestate products such as concentrated or balanced fertilisers, which have the potential to be marketed as “products”. These need further development before they can be used in earnest in the UK.

A number of case studies are provided on the Biogas website (http://www.biogas-info.co.uk/index.php/ad-case-studies.html) illustrating the returns expected. There are also a range of incentives available to AD plants (http://www.biogas-info.co.uk/index.php/incentives-qa.html). Since April 2010, Feed-in Tariffs (FITs) have provided a guaranteed price for a fixed period to small-scale electricity producers. This is intended to encourage the provision of small-scale low carbon electricity. Only AD facilities of less than 5MW completed after 15 July 2009 are eligible for FITs. The Renewables Obligation (RO) is the main support scheme for large-scale (>5MW) renewable electricity projects in the UK. A Renewables Obligation Certificate ( ROC) is a green certificate issued to an accredited generator for eligible renewable electricity generated within the UK and supplied to customers within the UK by a licensed electricity supplier.

Anaerobic digestion is among the technologies that receive additional support in the form of multiple ROCs. An anaerobic digester will receive 2 ROCs/ MWh until April 2015, this will then fall in line with DECC estimations of costs to 1.9 ROCs/MWh in 2015/16 and 1.8 ROCs/MWh in 2016/17.

Most AD plants turn their biogas into electricity but the introduction of the Renewable Heat Incentive, which provides support for both direct heat use and the injection of biomethane to the grid has changed the market (Defra report 2012). In addition, the Renewable Transport Fuel Obligation recently increased the available support for waste derived fuels. The launch of the Anaerobic Digestion Loan Fund in July 2011 has provided £10m funded by Defra and administered by WRAP, to support the development of 300,000 tonnes of new capacity to deal with food waste through AD.

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### 1.5.3 Mechanical Biological Treatment (MBT)

Mechanical Biological Treatment is a generic term for a combination of mechanical separation techniques and biological treatments (aerobic and/or anaerobic) and is primarily used to deal with municipal solid waste and reduce the environmental impact of disposing of it in landfill[[43]](#footnote-43). A common element of many MBT plants is the sorting process. Sorting the waste allows to separate different materials which are suitable for different end uses. Potential end uses include material recycling, biological treatment, energy recovery and landfill. A variety of different techniques can be employed, and most MBT facilities use a series of several different techniques in combination to achieve specific end use requirements for different materials. The mechanical step often has a dual role breaking down the material into smaller parts (e.g. by shredding) and removing some recyclable material. During the biological stage, the biodegradable material in the waste is composted or digested. If anaerobic digestion is used, the biogas produced can be used as a source of energy for the plant.

Different types of output can be obtained from MBT, such as combustible fraction (often used as fuel to produce electricity), recyclables (e.g. metals) and compost-like output (CLO, the organic material resulting from the biological treatment). MBT can only be used for the treatment of catering waste and not other animal by-products, and the CLO cannot be spread to land if livestock can gain access.

MBT has mainly been used in Italy, Germany, Austria, Switzerland and the Netherlands, with other countries such as the UK growing fast. In November 2011 WRAP reported that an estimated 0.4 million tonnes of organic waste were treated by MBT in 2009 in the nine plants identified as operational in the UK (WRAP, 2011a).

##### *1.5.3.1 Environmental sustainability*

Mechanical-biological treatment encompasses a range of technologies and combinations of them. Therefore, the environmental impact would be dependent upon the specific method utilised. A report by Eunomia described a detailed analysis of the climate impacts of different residual waste technologies. It found that an MBT process that extracts both the metals and plastics prior to landfilling is one of the best options for dealing with residual waste in terms of climate change, with emission levels around 255-312 kg CO2 equivalents. This meant a lower impact than either MBT processes producing RDF for incineration or incineration of waste without MBT (Eunomia, 2008).

##### *1.5.3.2 Health impact*

Depending on the nature of an individual facility, the health effects of MBT facilities might be expected to be comparable to those of in-vessel composting facilities**.** The production of CLO is relatively new and only small amounts are produced at the moment. Currently, CLO are landfilled, used as a landfill cover or spread on previously developed land to improve it, although the latter is only permitted for CLO derived from catering waste if livestock cannot access the land. The risks associated with applying increasing amounts of CLO to land are not well understood. However, there are concerns that CLO might pose a risk to the environment or human health when spread on land; especially where that land might be brought into future use in food production. This is because of the potential for contaminants to have an impact on soil, water or the food chain (Environmental Agency, Position statement[[44]](#footnote-44)). Trials on mixed waste derived materials have reported large amounts of physical contaminants (e.g. glass) and levels of potentially toxic elements above limits for the British Standards Institute (BSI) Publicly Available Specification (PAS) 100: for composted materials, in particular for zinc, lead, cadmium and mercury[[45]](#footnote-45).

##### *1.5.3.3 Animal health risks*

In MBT facilities organic wastes will be treated using aerobic or anaerobic digestion processes with similar risk impacts to those explained in Sections above.

##### *1.5.3.4 Cost*

The capital costs for MBT are variable, depending on the type of facilities, but compared with incineration, for example, MBT facilities are cheaper to build and operate (FOE, 2008. Mechanical-Biological Treatment Briefing).Nevertheless, MBT plants involve large capital investments and are sensitive to markets and outlets for the products generated through the different processes. Regarding revenue for the facilities from gate fees, current median figures are £79 per tonne (WRAP\_GateFees2012.pdf; Table 3.3).

**Table 1.3.** Summary information on gate fees (£/tonne) (extracted from WRAP\_GateFees2012: http://www.wrap.org.uk/content/wrap-annual-gate-fees-report).

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment** | **Type of facility** | **Median** | **Range** |
| **Composting** | In-vessel\* (mixed food and garden waste)  In-vessel\* (food waste) | £44  £49 | £28-£60  £31-£60 |
| **Anaerobic Digestion** |  | £41 | £35-£60 |
| **Landfill** | Gate fee plus landfill tax | £76 | £68-£111 |
| **Incineration** | Post-2000 facilities | £82 | £44-£101 |
| **MBT** |  | £79 | £65-£84 |

## 1.6 Land spreading

The recycling of organic materials to agricultural land has played a valuable role in agriculture for thousands of years. Organic materials can provide many benefits, including adding valuable nutrients, improving soil structure and water holding capacity, beneficially altering the pH of the soil and increasing organic content. Moreover, this practice can reduce the requirement for chemical fertilisers.

Land spreading is considered a method of waste recovery in the waste hierarchy. Liquid wastes and sludges (e.g. from on‐site effluent plant, fat traps, etc) are often applied to agricultural land. Food waste of animal origin, catering waste (including food wastes and cooking oils from kitchens, catering facilities and restaurants) or food wastes that may have been in contact with meat, bones or other animal by-products are not allowed to be spread on land on which animals may graze. Certain foodstuff waste such as milk and milk-based products may be applied directly to land without processing, provided there is no risk of transmitting a disease and the grazing ban is respected. Shells from shellfish and eggshells may also be applied to land in accordance with national rules (ABPR Guidance, 2011)[[46]](#footnote-46).

A survey conducted by Oakdene Hollins Ltd. for the Food and Drink Federation and Defra in 2008[[47]](#footnote-47) revealed that land spreading was the most popular management route for food waste within the food and drink industry.

### 1.6.1 Environmental sustainability

There are potential environmental risks associated with land spreading food waste. Poor management, such as the spreading of these materials at inappropriate times, or in excessive quantities can lead to undesirable environmental impacts such as soil contamination, deterioration of structure, oxygen depletion due to the high biological oxygen demand (BOD) of food waste, odour and visual nuisance and leaching of nutrients to rivers and groundwater. However, there are mechanisms in place to control these risks. To be able to spread food waste on land, an exemption from environmental permitting (England and Wales) or waste management licensing (Northern Ireland and Scotland) must be obtained. It is necessary to demonstrate that there is no danger to human health or the environment and that the land spreading provides agricultural or ecological benefit[[48]](#footnote-48).

### 1.6.2 Health impact

Food waste spread on land has the potential to increase the risk of pathogens spreading disease in humans. However, regulations are in place to control this and other risks. As mentioned earlier, the range of food waste materials that may be spread directly on land is very restricted and subject to rules. For example, in the case of eggshells, the spread to land without previous heat treatment is only allowed under certain rules aimed at minimising the risk of pathogens such as *Salmonella* spp. (ABPR guidance 2011).

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### 1.6.3 Animal health risks

Food wastes, as other organic materials, are applied as organic fertilisers or soil improvers and as such the grazing ban applies. The grazing ban prohibits direct access by livestock to land and cropping for feedstuffs to which organic fertilisers and soil improvers have been applied, and is 8 weeks for pigs and at least 3 weeks for all other livestock[[49]](#footnote-49). This is principally to ensure the inactivation of pathogens that might be present, such as classical swine fever virus.

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### 1.6.4 Cost

Land spreading does not involve large capital investment and therefore represents an economical way of recovering value from organic wastes.

## 1.7 Animal feed and pet food production

Certain types of food waste can be recycled into animal feed or pet food. According to Regulation (EC) 142/2011[[50]](#footnote-50), Category 3 material (with a few exceptions) can be used for the production of pet food. Certain rendered Category 3 material can also be used in the production of certain animal feedingstuffs, though TSE related restrictions on the feeding of processed animal protein severely restrict this (ABPR guidance 2011). Hydrolysed proteins from non ruminants or from ruminant hides and skins, non ruminant gelatine, egg products, milk products and colostrum are allowed for ruminants and fishmeal is allowed as a milk replacer for unweaned ruminants. All of these are allowed for non-ruminants in addition to fishmeal, blood products from non ruminants and di and tricalcium phosphate of animal origin. Blood meal from non-ruminants is permitted for fish. In England, Authorisation 10 allows Category 3 material to be fed to pet animals under certain conditions. This includes the use of household food waste for feeding own pets only. The definition of a pet animal given within the EU ABPR is 'any animal belonging to species normally nourished and kept, but not consumed, by humans for purposes other than farming.

Some former foodstuffs may be recycled for feeding farm animals, although this practice is banned for all catering waste, even from vegetarian kitchens. Due to the rising costs of wheat based animal feeds, re-processing un-sold bread products and wheat-based products has seen a dramatic increase in the last 5 years (IGD 2012). Unlike catering waste, waste from supermarkets and other retailers is amenable to arrangements to keep eligible material separated from other materials containing or in contact with animal by-products. Bread/cereal waste products, for example, are relatively easy to process ready for feeding to animals. Some farmers will take these products from local manufacturers/retailers and feed them direct to their livestock[[51]](#footnote-51). Alternatively, they can be incorporated into a compound feed. A typical process would involve de-packaging, loading onto a conveyer and screening to filter out any potential undesirable elements (e.g. residual packaging) Once free of contamination the product would be shredded and heated for up to 4 hours to kill any pathogens. The wheat-based product will then been added to a tailor made high protein product and pelletised before being supplied as animal feed.

De-packaging former foodstuffs for re-processing into animal feed is a challenging issue. The mechanical processes utilised remove most of the packaging, however, small amounts can remain in the material that can only be dealt with through visual inspection and manual removal. Annex III of Regulation (EC) No. 767/2009 on the marketing and use of feed classes ‘packaging from the use of products from the agri-food industry, and parts thereof’ as being prohibited for animal nutrition purposes. This prohibition has been interpreted as being a ban on the presence of residues of food packaging material in animal feed, as well as the use of the packaging material *per se*. However, the Netherlands and German authorities have undertaken their own risk assessments and both now tolerate the presence of packaging up to a level of 0.15%. European Union Member States generally agree that a zero tolerance for these traces is neither practical, nor proportionate to the risk. The UK Food Standards Agency has agreed with stakeholders (feed producers, UK enforcement officials, feed assurance inspectors and the food industry) that, in the absence of any guidance from the European Union, the UK would adopt a tolerance of 0.15% in line with Germany and the Netherlands. However, this stance would be subject to revision once advice from EFSA is available. The operation and enforcement of the *de facto* tolerance will be reviewed by the Food Standards Agency (60th Meeting of the Advisory Committee on Animal Feedingstuffs, 2013).

Data concerning costs, environmental and health impact of the different options for animal feed and pet food production are variable depending on methods, type of material, etc and they are currently insufficient. This work aims to assess the economic and environmental sustainability of the potential use of food waste in animal feed as well as the human and animal health risks that might arise from such practice. Annex III describes some of the methods that are currently used in the UK for animal feed production from permitted food waste material as well as some of the methods used in other countries where catering waste is permitted for animal feed production.

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