LIFE Project Number

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LIFE PROJECT NAME or Acronym

LIFE-F4F (Food for Feed)

Action:	B7. Completing, Incorporating and Evaluating the F4F Process as Part of the EU's Wastes Strategy and other Union Policies
Partner:	Harokopio University of Athens (HUA)
Deliverable:	B7.1. The role of F4F in the wastes management strategy and how it should be implemented as part of zero waste scheme

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Table of Contents

1 SUMMARY

Surplus food stock occurs for a variety of reasons such as trial runs, over-ordering and out of date stock, overcooking, packaging defects or the wrong size or weight of goods produced. A proportion of the finished product cannot be placed on the market for human consumption and is unsuitable for charity food banks. It is often ended up in landfill.

Present European and national legislation permits the utilisation of food waste as feed for furry animals and pets after undergoing an extremely demanding management procedure, which involves essentially sterilising them (Chapter 3, 2011 R0142, 23-02-2015). The rigor of this process, though it may not lead to the destruction of the protein that is implicated in encephalopathy (the great fear that overshadows any discussion of utilising animal by-products of any form), dramatically increases the cost and environmental footprint of the process, thereby reducing any benefit. At the same time, at the household level, the practice of utilising food residues in the feeding of domestic productive (and non-productive) animals, such as pigs and birds, continues to exist without any restrictions or limitations. On the other hand, food waste residues from the hospitality and foodservice industry (HFS), which apply extremely stringent HACCP rules (both for incoming raw materials and for their management), may not have the same outcome.

It has been officially launched at European Union (EU) level[1], but also in other developed countries, such as the USA[2], a debate on redefining the potential use of food waste as a feed and indeed, with more than one starting point. One is ethical and economical, and the amount of food waste dumped in the EU each year is estimated at 88 million tonnes, which is estimated at 143 billion euros. The other concerns the environmental footprint of the waste and the food production process, and in particular the process of producing animal protein. Lastly, the EU's (and not only) policy regarding the Circular Economy, the Road Map to Resource Efficient Europe, the Farm to Fork Strategy and the Framework Waste Directive cannot ignore the fact that the food cycle does not seem to close.

Former foodstuffs should be regarded as a resource, not a waste product. Diversion of food waste from disposal is becoming an increasing priority for governments of the Member States, which are promoting recycling and the development of markets for valuable products.

Many of these former foodstuffs, including bread, biscuits, breakfast cereal, crisps and confectionery have a high nutritional value - being a source of high-quality fats, sugar, and carbohydrates.

After checking their feed safety, traceability and therefore suitability, they can be converted into high-quality ingredients for use in animal feed, avoiding waste from food that is outside of specification for human consumption.

[1] EU Platform on Food Losses and Food Waste. Available at: https://ec.europa.eu/food/safety/food_waste/eu_actions/eu-platform_en
[2] Sustainable Management of Food - Reduce Wasted Food by Feeding Animals. Available at: https://www.epa.gov/sustainable-management-food/reduce-wasted-food-feeding-animals

2 INTRODUCTION

Animal feed plays an important part in the food chain and has implications for the composition and quality of the livestock products (milk, meat, and eggs) consumed by people.

Surplus food stock occurs for a variety of reasons such as trial runs, over-ordering and out of date stock, overcooking, packaging defects or the wrong size or weight of goods produced. A proportion of the finished product cannot be placed on the market for human consumption and is unsuitable for charity food banks. It is often destined for landfill.

Many businesses are unaware of how significantly waste impacts their bottom line. With so many other issues to manage within a busy food production site or supermarket chain, getting this surplus food disposed of as waste may seem like the simplest choice, but results in a cost being levied to the business and environmental damage from landfill.

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Many of these former foodstuffs, including bread, biscuits, breakfast cereal, crisps and confectionery have high nutritional value - being a source of high-quality fats, sugar, and carbohydrates. After checking their feed safety, traceability and therefore suitability, they can be converted into high-quality ingredients for use in animal feed, avoiding waste from food that is outside of specification for human consumption.

Anything designated for feed use will ultimately be re-entering the food chain, so strict adherence to regulations is essential. When former foodstuffs are used to produce animal feed, certain legal obligations are placed on the factory of production. By law, the factory is deemed a 'Feed Business Operator' and must be compliant under the Feed Hygiene Regulation (EU) 183/2005.

Global economic and population growth is generating ever-greater amounts of waste. By 2050, global solid waste generation is expected to increase by 70%[3]. Inefficient and unsustainable production and consumption patterns are creating waste challenges in all countries, particularly in the developing ones[4]. Municipalities in low-income countries spend an average 20% of their budgets on waste management, while over 90% of waste is still openly dumped or burned. Financing solid waste management systems is a significant challenge. In high-income countries, operating costs for integrated waste management generally exceed $100 per tonne. Lower-income countries spend around $35 per tonne and sometimes more, but they have much more difficulty in recovering costs[5].

The EU is an important player in the global waste market. In 2016, the EU exported an estimated 40 million tonnes[6] of waste to non-EU countries – around 20% of the global export of waste. At the same time, approximately 13 million tonnes of waste were imported into the EU. A growing attention is being paid to emerging waste streams due to new technologies such as solar panels, batteries, turbines, etc. Cooperation with industrialised countries can be reinforced to prevent landfilling and reduce the lifecycle impact of new green technologies.

Waste management plays an important role in the circular economy. For many countries, particularly developing countries, this is the first problem that needs to be addressed to start the transition. Reducing the amount of waste generated, including through product design, product reuse and repair, favouring

[3] The World Bank (2018), What a Waste 2.0. A Global Snapshot of Solid Waste Management to 2050.

[4] UNEP (2019), Global Environmental Outlook (GEO-6). Summary for Policymakers, p. 16.

[5] The World Bank (2018), What a Waste 2.0. A Global Snapshot of Solid Waste Management to 2050.

[6] Eurostat data on export of all waste streams, except mineral waste, based on customs information and available data from Member States.

recycling (including through separate collection) and turning waste where possible into a resource will demand investment in waste prevention and reuse, collection, and recycling infrastructures. This also to ensure as much as possible that waste treatment does not result in negative environmental and health impacts and that the recycled materials are safe and of high quality. Many of the EU's partner countries, in particular developing countries, lack the capacity, frameworks, and systems to achieve this. Working with these countries to help them improve their waste prevention and management policies, standards and practices would contribute to address these challenges, in line with EU approaches.

3 THE RELATIONSHIP BETWEEN FOOD WASTE AND ANIMAL FEED

3.1 DEFINITIONS

The most cited definitions of food waste and food loss come from various documents published by the United Nations (UN) Food and Agriculture Organization (FAO).

- Food loss: "Refers to a decrease in mass (dry matter) or nutritional value (quality) of food that was originally intended for human consumption. These losses are mainly caused by inefficiencies in the food supply chains, such as poor infrastructure and logistics, lack of technology, insufficient skills, knowledge and management capacity of supply chain actors, and lack of access to markets. In addition, natural disasters play a role." (Food Wastage Footprint, 2013)
- Food waste: "Refers to food appropriate for human consumption being discarded, whether or not after it is kept beyond its expiry date or left to spoil. Often this is because food has spoiled but it can be for other reasons such as oversupply due to markets, or individual consumer shopping/eating habits." (Food Wastage Footprint, 2013)
- Food wastage: "Refers to any food lost by deterioration or waste. Thus, the term "wastage" encompasses both food loss and food waste." (Food Wastage Footprint, 2013)

Also, in Directive 2008/98/EC,

Waste means any substance or object which the holder discards or intends or is required to discard (EU)**.** and

Food waste means all food as defined in Article 2 of Regulation (EC) No 178/2002 of the European Parliament and of the Council that has become waste.

Food (or foodstuff) is defined as any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be ingested by humans (Regulation (EC) No 178/2002).

Food includes drink, chewing gum and any substance, including water, intentionally incorporated into the food during its manufacture, preparation, or treatment. It includes water after the point of compliance as defined in Article 6 of Directive 98/83/EC and without prejudice to the requirements of Directives 80/778/EEC and 98/83/EC.

Some of the peripheral definitions that are also used to further define waste include:

- Food residues/food by-products: "a production residue that is not a waste," where a production residue is defined as "a material that is not deliberately produced in a production process but may or may not be a waste." (European Commission, 2007[7])
- Avoidable Food Waste: "Food and drink thrown away that was, at some point prior to disposal, edible (e.g., slice of bread, apples, meat)." (Quested and Johnson, 2009[8])

[7] Communication from the Commission to the Council and the European Parliament on the Interpretative Communication on Waste and By-products. Commission of the European Communities, COM/2007/059 final, Brussels, Belgium, 2007. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52007DC0059.
[8] Quested, T.; Johnson, H. Household food and drink waste in the UK: final report. Wastes & Resources Action Programme (WRAP), 2009.

- Possibly Avoidable: "Food and drink that some people eat and others do not (e.g. bread crusts), or that can be eaten when a food is prepared in one way but not in another (e.g. potato skins)." (Quested and Johnson, 2009)
- Unavoidable Food Waste: "Waste arising from food or drink preparation that is not, and has not been, edible under normal circumstances (e.g., meat bones, eggshells, pineapple skin, tea bags)." (Quested and Johnson, 2009)
- Former Foodstuffs: "means foodstuffs, other than catering reflux, which were manufactured for human consumption in full compliance with the EU food law but which are no longer intended for human consumption for practical or logistical reasons or due to problems of manufacturing or packaging defects or other defects and which do not present any health risks when used as feed." (Catalogue of Feed, 2013[9])

Most of the literature sources agree with the FAO definition of food waste, however, some reports and government regulations incorporate both edible and non-edible food losses. For example, BSR (2014) surveyed US food manufacturers, grocery retailers, and wholesalers about their waste streams and reported results for both edible and inedible food waste. Bond et al. (2013),[10] reported for the United Kingdom, including also both avoidable and unavoidable food losses. One advantage to this method is that it allows the country to properly account for all the "waste" material being generated. If management capacity, i.e., recycling and recovery plants, was solely set based on edible waste then the recovery infrastructure will be overcapacity from its inception. The inedible addition contributes roughly 10% to the total waste that must be managed in the UK (Downing et al., 2015)[11]. On the other hand, by identifying by-products as waste, materials with economic value may more likely be treated through waste management rather than as a secondary value stream.

In this report the EU definition of food waste is used.

3.2 THE FOOD WASTE CHALLENGE

While food loss is a global issue, the problem scale and waste sources vary according to regional customs, season, and economic development status. For example, in Japan, there is a significant problem with table waste because it is a part of the culture to have large, plentiful meals with only the freshest ingredients. Much of this food ends up going to waste (Parry et al., 2015)[12]. According to Girotto et al. (2015)[13] at the global level, 32% of edible food produced is wasted. This equates to 61 million tons per year in the United States, 6.24 million tons per year in Korea, 92.4 million tons per year in China, 21 million tons per year in Japan, and 90 million tons per year in the European Union (Girotto et al., 2015). Developing and developed nations have different issues driving food loss; in the developed world, 40% of waste is generated at the retail and consumer stages whereas developing nations lose 40% of food in post-harvest (Girotto et al., 2015). For developing nations, some of the causes for food loss include improper storage, handling, and refrigeration, whereas developed nations

[9] Commission Regulation (EU) No 68/2013 of 16 January 2013 on the Catalogue of feed materials (Text with EEA relevance). OJ L 29, 30.1.2013,p. 1-64; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R0068.
[10] Bond, M.; Meacham T.; Bhunnoo R.; Benton T.G. (2013). Food waste within global food systems, Global Food Security Programme, A Global Food Security report. Swindon, UK, 2013.
[11] Downing, E.; Priestley, S.; Carr, W. (2015). House of Commons Library. Food Waste; Briefing Paper Number CBP07045, 2 September 2015.
[12] Parry, A., P. Bleazard and K. Okawa (2015), "Preventing Food Waste: Case Studies of Japan and the United Kingdom", OECD Food, Agriculture and Fisheries Papers, No. 76, OECD Publishing. http://dx.doi.org/10.1718/5js4w29cf0f7-en
[13] Girotto, F.; Alibardi, L.; Cossu, R. Food waste generation and industrial uses: a review. Waste Management. 2015, 45, 32-41; doi: 10.1016/j.wasman.2015.06.008.

face losses due to overconsumption and high expectations of quality (Lipinski et al., 2013)[14]. The disparity in food loss by product stage between developed and developing nations is represented below, in Figure 1 (Lipinski et al., 2013). North America and Oceania have similar waste generation characteristics to both Industrialised Asia and Europe. The main difference with Industrialised Asia is that the second largest waste source comes from handling and storage and North America and Oceania has the highest consumption losses at 61% (Lipinski et al., 2013).

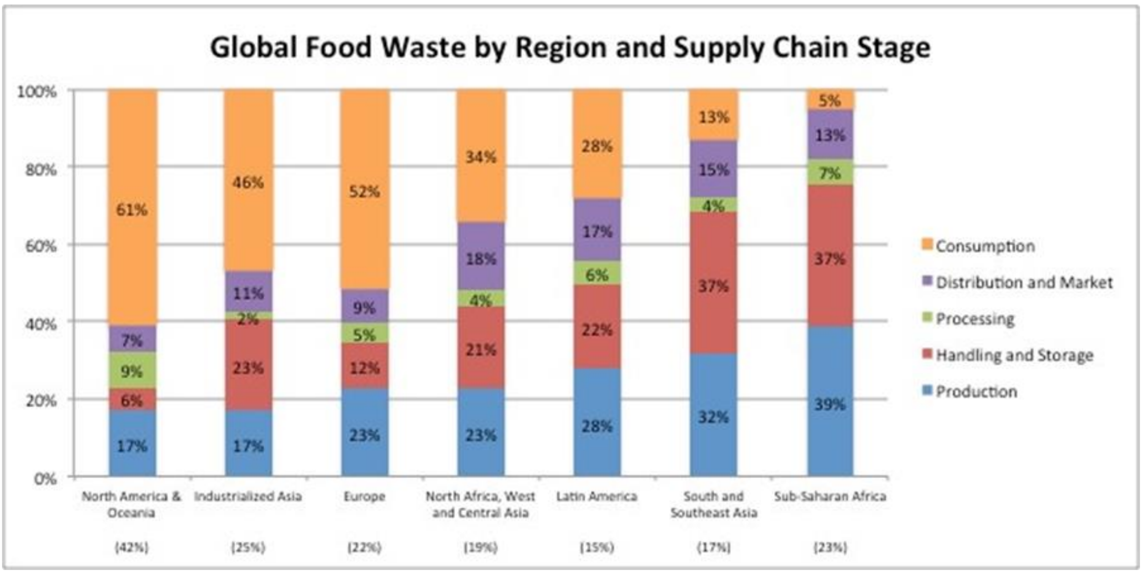


Figure 1. Global food waste by region and supply chain stage, (Lipinski et al., 2013)

The implications of waste occurring at later stages in the food chain for developed nations are that recovery options for the losses become more limited and costly. Steinfeld et al. (2006)[15] noted "Food waste from marketing and retailing are much less recycled as feed… because their content and quality vary greatly and their geographical spread increases collection costs. The safety of food wastes is also questionable." Packaging, volume, quality, and consistency play roles in the ability to recover foods for certain types of recycling. Griffin et al. (2009)[16] quantified recovery by each stage of the food chain using data from a roughly 100,000-person community in Upstate New York. The waste data included both edible and inedible components of food. As shown in **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**, recovery was significantly higher at the production and processing stages than at the distribution or consumption levels. According to the authors' study, all the food waste at the production stage was assumed to have gone to composting and processing waste was recovered primarily through donation and animal feed (Griffin et al., 2009).

Table 1. Community Food Waste Audit (adapted from Griffin et al., 2009)

Stage	Generation	Recovery	Recovery (%)	% Generation of Total
Production/ Agricultural Waste	4,108,287	3,911,274	95.2%	20.13%
Processing Food Waste (Bakeries, wineries, etc.)	258,415	229,661	88.9%	1.27%

[14] Lipinski, B.; Hanson, C.; Lomax, J.; Kitinoja, L.; Waite, R.; Searchinger, T. Reducing food loss and waste; World Resources Institute Working Paper, 2013.
[15] Steinfeld, H.; Gerber, P.; Wassenaar, T.; Castel, V.; Rosales, M.; Haan, C. D. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations: Rome, Italy, 2006.
[16] Griffin, M.; Sobal, J.; Lyson, T. A. An analysis of a community food waste stream. Agriculture and Human Values. 2009, 26(1-2), 67-81; doi: 10.1007/s10460-008-9178-1

Distribution/Retail (Restaurants and supermarkets)	3,750,340	679,360	18.1%	18.38%
Consumption (Households and institutions)	12,292,845	893,400	7.3%	60.23%
Total	20,409,887	5,713,695	28.0%	100.00%

* Includes edible and inedible portions.

The economic impact of global food loss was estimated in 2007 to be roughly $750 billion (Papargyropoulou et al., 2014[17]). The FAO, in "Food Wastage Footprint Full-cost Accounting" (2014)[18], calculated the cost to be close to $2.6 trillion. In the FAO's analysis, the authors included losses such as value of lost subsidies, water scarcity, and health damages. The largest contributing factors were the value of products lost and wasted ($936 billion), the risk of conflict ($396 billion), the livelihood loss ($333 billion), and thew greenhouse gas emissions ($305 billion).

In the United States alone, the cost of food loss has been reported to be between $165 billion and $198 billion and accounts for roughly 13 million metric tonnes per year of $CO_{2\text{-eq}}$ GHG emissions (Venkat, 2012[19]; Papargyropoulou et al., 2014; Bond et al., 2013). From an environmental point of view, food waste generates emissions at each stage of the supply chain where material is lost from the resources used to produce the food as well as the methane gas released as it decomposes in a landfill. One tonne of food waste equates to six tonnes of $CO_{2\text{-eq}}$ when decomposed in a landfill and most of the degradation occurs before 100 days (Beyond Waste, 2010). According to the EPA Waste Reduction Model (WARM)[20], the net landfill emissions for food waste is 0.78 metric tonnes $CO_{2\text{-eq.}}$ per metric tonne of food waste. Additionally, Cuéllar and Webber (2010)[21] estimated the embodied energy of wasted food in the United States based on energy invested to produce the lost resource. In 2007, they estimated the embodied energy to be 2030 ± 160 trillion BTU, equivalent to 550,000 to 650,000 GWh, sufficient to power between 50 and 60 million homes for one year (Cuéllar and Webber, 2010). A 2005 report by the FAO quantified the relative global greenhouse gas impact of food waste as compared to what nations emit on a yearly basis. Food wastage, with just over 3 Gt $CO_{2\text{-eq}}$, produces more than eight of the top ten GHG emitting countries, after China and the United States, both of which are around 7 Gt $CO_{2\text{-eq}}$ (Global Initiative, 2014[22]). The next largest emitters are the Russian Federation and India at roughly 2 Gt $CO_{2\text{-eq}}$ a piece (Global Initiative, 2014).

Many nations are attempting to mitigate food waste and its damages through various programmes and regulations. The recovery methodology and success rate vary significantly by country. For example, in 2006 Korea recycled 94.6% of its food waste (Kim et al., 2011[23]), whereas as of 2010, the United States

[17] Papargyropoulou, E.; Lozano, R.; Steinberger, J. K.; Wright, N.; bin Ujang, Z. (2014). The food waste hierarchy as a framework for the management of food surplus and food waste. Journal of Cleaner Production, 76, 106-115; doi: 10.1016/j.jclepro.2014.04.020.
[18] Food Wastage Footprint Full-Cost Accounting: Final Report; Food and Agriculture Organization of the United Nations, 2014.
Food Wastage Footprint: Impacts on Natural Resources: Summary Report; Food and Agriculture Organization of the United Nations (FAO), 2013
[19] Venkat, K. (2012). The climate change and economic impacts of food waste in the United States. International Journal on Food System Dynamics, 2(4), 431-446.
[20] Environmental Protection Agency, Food Waste, 2015, http://www3.epa.gov/epawaste/conserve/warm/pdfs/Food_Waste.pdf
[21] Cuéllar, A. & Webber, M. (2010). Wasted Food, Wasted Energy: The Embedded Energy in Food Waste in the United States. Environmental Science & Technology. 44. 6464-9. DOI: 10.1021/es100310d.
[22] Global Initiative on Food Loss and Waste Reduction; Food and Agricultural Organization of the United Nations, 2014.
[23] Kim, M. H.; Song, Y. E.; Song, H. B.; Kim, J. W.; Hwang, S. J. (2011). Evaluation of food waste disposal options by LCC analysis from the perspective of global warming: Jungnang case, South Korea. Waste management, 31(9), 2112-2120; doi: 10.1016/j.wasman.2011.04.019.

only reported recovering 2.8% of its 34.8 million tonnes of food waste (Solid Waste, 2011[24]). It is important to note that how countries define food waste also impacts the resulting recovery rate figures. As stated before, while the United States includes only *edible food* waste in its calculation, many of this country's counterparts include both edible and inedible waste.

Although, strategies for encouraging, enforcing, and engaging stakeholders in food waste recovery differ by nation, many agree in the general management hierarchy. Table 2 shows the food waste hierarchies for select European countries and the United States (Eriksson et al., 2015). Also, the South Korean waste management hierarchy, beyond just food waste, is presented in Table 2; the section of reduction includes reuse of materials including animal feed (Seo, 2013). Interestingly, the South Korean strategy incorporates several different landfill scenarios. The only listed country that has a differing set of priorities is Japan. This country has given top diversion priority to fertiliser and animal feed due to targets to reduce national dependence on imports.

Table 2. Food waste diversion hierarchies from select countries.

EU[25]	**UK[26]**	**USA[27]**	**The Netherlands[28]**	**Sweden[29]**	**South Korea[30]**
Prevention	Reduce	Source reduction	Prevention	Donation	Waste reduction
Re-use and preparation for re-use	Feed people in need	Feed hungry people	Use for human food		Recycling
			Conversion to human food		
Recycle	Feed livestock	Feed animals	Use as animal feed	Animal Feed	
Recovery	Composting and 100% renewable energy	Industrial use	Raw materials for industry	Biogas	Anaerobic digestion
			Processing to make fertiliser for co-fermentation	Composting	Composting
			Processing to make fertiliser through composting		Waste to Energy
			Use for sustainable energy		Modern landfill recovering and using CH_4
		Composting	Burn as waste	Incineration	Modern landfill recovering and flaring CH_4
					Landfills that do not capture CH_4
Disposal	Disposal	Disposal	Dumping	Landfill	Unsanitary landfills and open burning

[24] Solid Waste and Emergency Response. Municipal Solid Waste Generation, Recycling and Disposal in the United States: Facts and Figures 2010; 2011.

[25] Eriksson, M.; Strid, I.; Hansson, P. A. 2015). Carbon footprint of food waste management options in the waste hierarchy–a Swedish case study. Journal of Cleaner Production. 93, 115-125; doi: 10.1016/j.jclepro.2015.01.026.

[26] Eriksson, *op. cit.*

[27] Eriksson, *op. cit.*

[28] Eriksson, *op. cit.*

[29] Eriksson, *op. cit.*

[30] Seo, Yoonjung (2103). Current MSW Management and Waste-to-Energy Status in the Republic of Korea. M.S. Thesis, Columbia University, New York, NY.

4 EU POLICY FOR FOOD WASTE

4.1 FOOD WASTE TO ANIMAL FEED POLICY IN THE EU

The animal by-products including processed products are being excluded from the scope of the Directive 2008/98/EC to the extent that they are covered by other Community legislation (i.e., Regulation (EC) No 1774/2002), except those which are destined for incineration, landfilling or use in a biogas or composting plant.

The use of food wastes is permitted only where it can be demonstrated that there is no risk of contamination with meat, fish, or other animal products. This requires either that a facility handle no animal products, or they establish separate handling streams for animal and non-animal products, along with Hazard Analysis and Critical Control Point (HACCP) procedures.

However, a large proportion of food waste that could be legally recycled under the current legislation already exists, as provisioned by the Commission Regulation No. 1017/2017 in the catalogue of feed materials. More specifically, the Regulation includes former foodstuffs (Figure 2, source 1), defined as food products manufactured for human consumption in full compliance with the EU food law but which are no longer intended for human consumption for practical or logistical reasons. The second type of source is fruit and vegetable surplus, which is composed of surplus derived from the industrial processing of raw fruit and vegetables, such as fruit pulp.

Figure 2 outlines the main results regarding the applicability of the F4F process. Concerning the legal framework on food waste and feed production currently in force, the analysis has proven not to be fully suitable for implementation in the EU due to two main drawbacks: The nature of the raw material used as input for the food waste transformation process (catering waste) and, secondly, the destination of the final product.

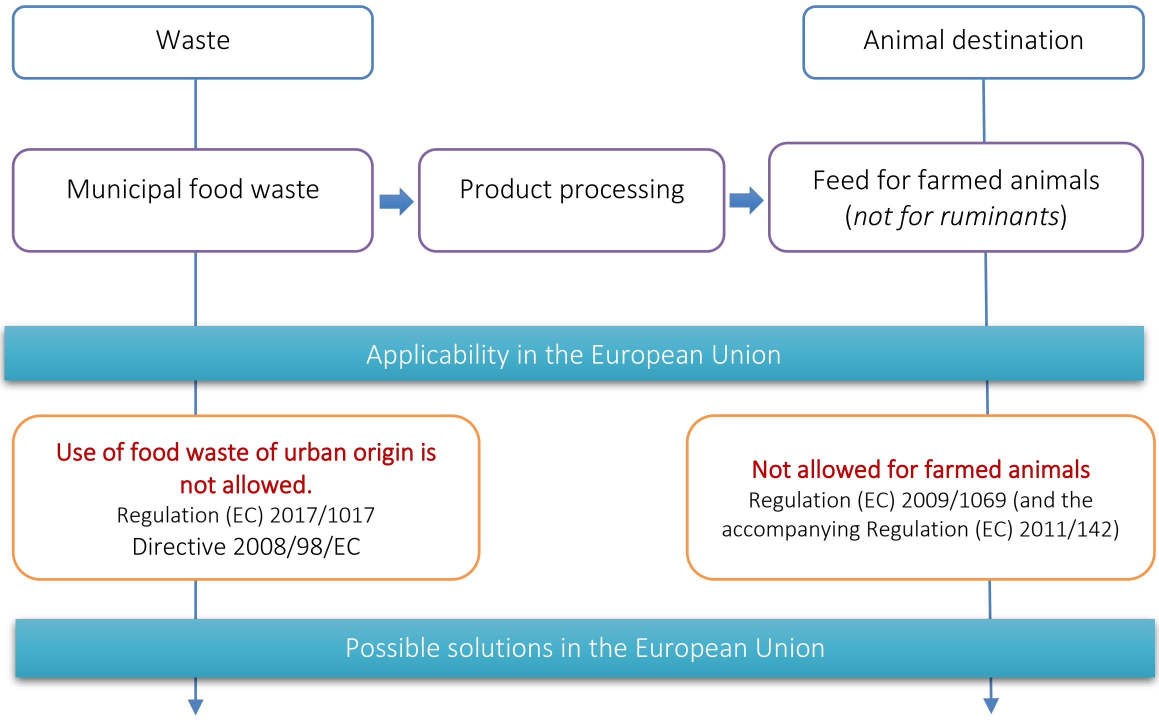
Markedly, sources 1 and 2 (former food and fruit and vegetable surplus) can be used for farmed animals since the absence of animal proteins makes them suitable for transformation into livestock feed within the EU safety requirements. Furthermore, all the sources listed in Figure 2 can be used for the production of pet food including catering residues, under specific conditions. Protein is the most expensive macronutrient in ecological and economic terms, and therefore the one requiring the most attention for sustainability[31]. The animal protein content significantly determines the environmental impact of dog and cat food recipes, and there is an increasing demand for culturally acceptable products for pet owners, while still being nutritious and palatable to the pets[32]. Eco-alert owners of pets- wish to balance their pets' dietary needs with the protection of the planet. Thus, the development of controlled measures for collecting, transporting, and storing raw materials is the principal condition for the safe use of the raw materials identified as livestock feed or pet food.

The third type of food surplus identified is catering residues, defined by Regulation (EU) 2017/1017 as all waste food containing material of animal origin originating in restaurants, catering facilities and kitchens, including central kitchens and household kitchens. The food material comprised in this category can be considered as one of the most interesting sources for animal feed production and derives from three main origins: Sludge due to kitchen procedures, the food surplus generated by unconsumed

[31] McCusker, S.; Buff, P.R.; Yu, Z.; Fascetti, A.J. Amino acid content of selected plant, algae and insect species: A search for alternative protein sources for use in pet foods. J. Nutr. Sci. 2014, 3, p39.
[32] Carter, R.A.; Bauer, J.E.; Kersey, J.H.; Buff, P.R. Awareness and evaluation of natural pet food products in the United States. J. Am. Vet. Med. Assoc. 2014, 245, 1241–1248.
Swanson, K.S.; Carter, R.A.; Yount, T.P.; Aretz, J.; Buff, P.R. Nutritional sustainability of pet foods. Adv. Nutr. 2013, 4, 141–150.

food portions (which can also be redistributed for human consumption) and plate leftovers, under specific safety conditions determined by HACCP procedures.

Source 4, namely the fish and meat surplus, is composed of animal products or by-products with or without treatment, such as fresh, frozen, and dried food products.



Former food	Reg. (EC) 2017/1017	Farmed animals, aquarium fish and pets
1. Fruit and vegetable surplus	Reg. (EC) 2017/1017	Farmed animals, aquarium fish and pets
2. Fish and meat surplus	Reg. (EC) 2017/1017 Reg. (EC) 2009/1069 (and the accompanying Regulation (EC)2011/142)	Aquarium fish, pets, and fur animals
3. Catering residues	Reg. (EC) 2017/1017, Part C (list of feed materials, number 9.9.1 Reg. (EC) 2009/1069 (and the accompanying Regulation (EC) 2011/142)	Aquarium fish, pets, and fur animals

Figure 2. Applicability analysis of food residues transformation to animal feed for the EU.

The second critical point relates to the destination of the product, namely the type of animals that can be fed with the product originating from the food waste treatment. Regulation (EU) 1069/2009 specifies the health rules regarding animal by-products and derived products not intended for human consumption. However, it does not permit the feeding of farmed animals with processed animal proteins. This measure derives from past crises related to outbreaks of foot-and-mouth disease, the spread of transmissible spongiform encephalopathies such as bovine spongiform encephalopathy (BSE), and the occurrence of dioxins in feedstuff.

The processed municipal food waste is not allowed in the EU following Directive 2008/98/EC which considers food and kitchen waste from households, restaurants, caterers, and retail premises as biological waste for incineration, landfilling, or use in a composting, anaerobic digestion plant.

Even when the final product analysed can show its compliance with safety requirements and a good nutritional profile, the European approach, which does not permit municipal waste to be used as raw material for the food chain, can be considered as the best solution for public health protection.

The fact that the F4F process uses food scraps as raw material implies that the costs related to food waste disposal and treatment are expected to be significantly lower. The secondary food product could also partially replace the traditional raw materials needed for feed and consequently provide a potential land/water saving for crop cultivation. In addition, the reduced competition among food/feed/energy crop use could reduce the environmental impact of animal feed production.

The F4F system would seem to have a positive socio-economic impact and to successfully contribute to the improvement in the global sustainability of the agri-food system, in accordance with the objectives of the circular economy.

The analysis also highlights the wide margin of improvements for food waste prevention within the current EU framework, without necessarily changing regulations on food waste management. However, the basis for the implementation of the proposed strategies consists in the development of controlled systems that would guarantee that the food surplus is collected and managed in compliance with the most stringent safety requirements.

Relevant EU Legislation

1. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance). OJ L 312, 22.11.2008, p. 3–30, as amended by,
2. Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste (Text with EEA relevance). OJ L 150, 14.6.2018, p. 109–140.
3. **Regulation (EC) No 1069/2009** of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation). OJ L 300, 14.11.2009, p. 1–33
4. **Commission Regulation (EU) No 142/2011** of 25 February 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council **Directive 97/78/EC** as regards certain samples and items exempt from veterinary checks at the border under that Directive (Text with EEA relevance). OJ L 54, 26.2.2011, p. 1–254.
5. **Commission Regulation (EU) 2017/1017** of 15 June 2017 amending Regulation (EU) No 68/2013 on the Catalogue of feed materials (Text with EEA relevance). OJ L 159, 21.6.2017, p. 48–119.
6. **Regulation (EC) 2017/625** of the European Parliament and of the Council of 15 March 2017 on official controls and other official activities performed to ensure the application of food and feed law, rules on animal health and welfare, plant health and plant protection products, amending Regulations (EC) No 999/2001, (EC) No 396/2005, (EC) No 1069/2009, (EC) No 1107/2009, (EU) No 1151/2012, (EU) No 652/2014, (EU) 2016/429 and (EU) 2016/2031 of the European Parliament and of the Council, Council Regulations (EC) No 1/2005 and (EC) No 1099/2009 and Council Directives 98/58/EC, 1999/74/EC, 2007/43/EC, 2008/119/EC and 2008/120/EC, and repealing Regulations (EC) No 854/2004 and (EC) No 882/2004 of the European Parliament and of the Council, Council Directives 89/608/EEC, 89/662/EEC, 90/425/EEC, 91/496/EEC, 96/23/EC, 96/93/EC and 97/78/EC and Council Decision 92/438/EEC (Official Controls Regulation) (Text with EEA relevance). OJ L 095 7.4.2017, p.1.

7. Commission Delegated Regulation (EU) 2019/625 of 4 March 2019 supplementing Regulation (EU) 2017/625 of the European Parliament and of the Council with regard to requirements for the entry into the Union of consignments of certain animals and goods intended for human consumption (Text with EEA relevance.). OJ L 131, 17.5.2019, p. 18-30.

5 MANAGEMENT OPTIONS FOR FOOD WASTE

A range of management options for food waste is available. The waste hierarchy, as set out in the Waste Framework Directive, ranks waste management options according to what is best for the environment. It gives priority to preventing waste. When waste is created, the hierarchy gives priority to preparing it for re-use, then recycling, then recovery, and last of all, disposal (e.g., landfill). In the case of food waste, however, anaerobic digestion (mainly a recycling method due to the generation of biogas) is environmentally better than composting and other energy recovery options, and therefore it takes priority in the waste hierarchy over composting and other recovery, but not prevention (**Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**). For former foodstuffs destinated in feed for food producing animals, former foodstuff processors manage to retain food losses in the food chain.

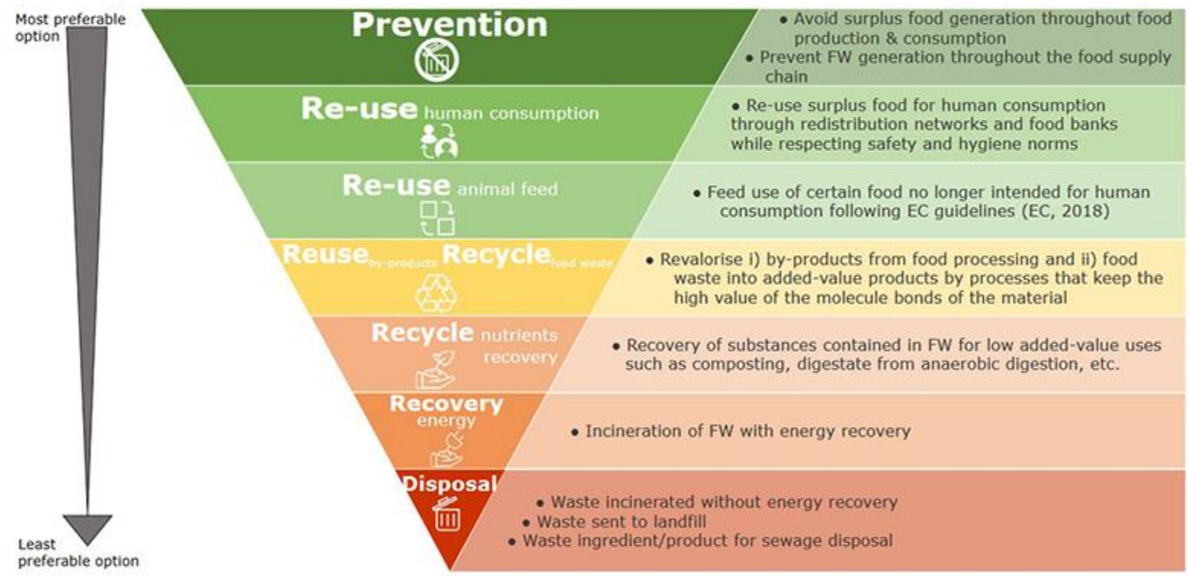


Figure 3. Hierarchy for prioritisation of food surplus, by-products, and food waste (FW) prevention strategies. Adapted from Teigiserova et al. (2020), Papargyropoulou et al. (2014) and UNEP (2014)[33]

As it can be seen in the "hierarchy for prioritisation of food surplus, by-products, and food waste (FW)" [34], the forwarding of food to animal feed, once it can no longer be redistributed to people, is part of food waste reuse. Another point that comes forward from the hierarchy is the fact that valorising former foodstuffs into animal feed is by no means a form of waste treatment, as is the case for energy generation by anaerobic digestion and compost applications.

By offering food producers a consistent and sustainable outlet for their food losses as well as a non-land using alternative to grains for compound feed manufacturers, former foodstuff processors are a of former foodstuffs processed into animal feed in the EU would have to be replaced by for example wheat production, an approximate 350.000 hectares would be needed. Effectively, the use of former foodstuffs in animal feed enables the release of those hectares of grain production into primary food production.

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, compost, and animal feed). To assess the sustainability of the different methods a life

[33] Some food waste treatment processes can be associated with more than one category. For example, anaerobic digestion produces fertiliser (digestate) and energy (biogas) and can be considered as both 'Recovery of nutrients' and 'Recovery of energy'.

[34] Source: Brief on food waste in the European Union. European Commission Joint Research Centre, 2020 Brief on food waste in the European Union. Available at: https://ec.europa.eu/jrc/sites/default/files/kcb-food_waste_brief_print_hq.pdf. Accessed 12 November 2021.

cycle analysis is required to provide a comprehensive picture of management options for food waste. Life cycle analyses have been carried out for some of these processes. Takata *et al* (2012) reported that in Japan composting facilities showed a relatively low environmental impact and a high economic efficiency, whereas animal feed facilities had a wide distribution of the total GHG emissions, depending on both the energy usage during the drying process due to the water content of the food waste and the number of recycled products. In comparison with incineration, most of the food recycling facilities in Japan showed low GHG emissions and acceptable economic effectiveness. Kim & Kim (2010) compared feed manufacturing and composting in Korea, where they reported that 200 kg of CO_2-eq could be produced from dry feeding process, 61 kg of CO_2-eq from wet feeding process, 123 kg of CO_2-eq from composting process, and 1,010 kg of CO_2-eq from landfilling, making the wet feeding process the best in terms of environmental impact.

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. In 2019, only around 2% of available food waste were collected separately for composting in Greece. The landfills in Greece contain a higher proportion of biodegradable waste than most other European countries. It was estimated that at least 92% of the 1.8 million tonnes of annual food waste arising in Britain is disposed of to landfill.

A brief overview of the main methods currently used in the EU and Greece 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 and animal feed production, although use for the latter is currently very limited due to the restrictions in the EU Animal By-Products Regulations (ABPReg)

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). 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 considering 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 most of the food waste still went to landfill.

This section of the report provides a brief overview of the main methods currently used in the EU (and internationally) 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 treatment (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 due to the EU Animal By-Products Regulations (ABPR) and its potential is the focus of this report.

The different food waste streams and current management options are summarised in Figure 4. 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.

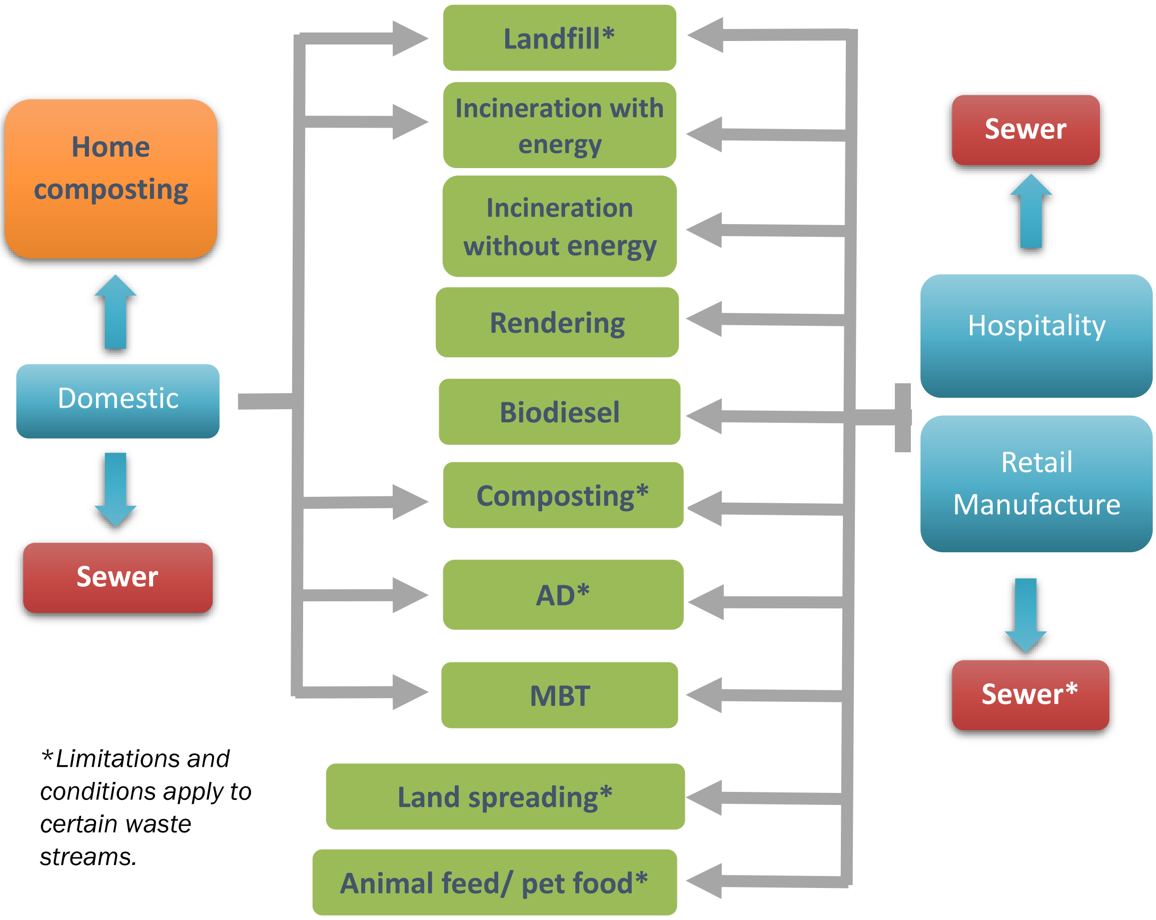


Figure 4. Food waste streams and current management options.

The different food waste sources and current management options are summarised in Figure 5**.** Most methods for treating food waste, except for incineration without energy recovery, have a useful output, generating either energy or products that can be used for different purposes. In some cases, products or co-products of a particular treatment option can be used as feedstock for another method (e.g., rendered products can be used for energy recovery by incineration). 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. For example, in the UK (but also around EU), AD and biofuels are subject to incentives from the government for example the Anaerobic Digestion Loan Fund, the Feed in Tariffs and the recently introduced Renewable Heat Incentive whereas the use of landfill is being discouraged by the landfill tax – with increases maintained towards a floor of £88.95 (about €100) per tonne in 2018/19. The value of products such as biogas also offset the costs.

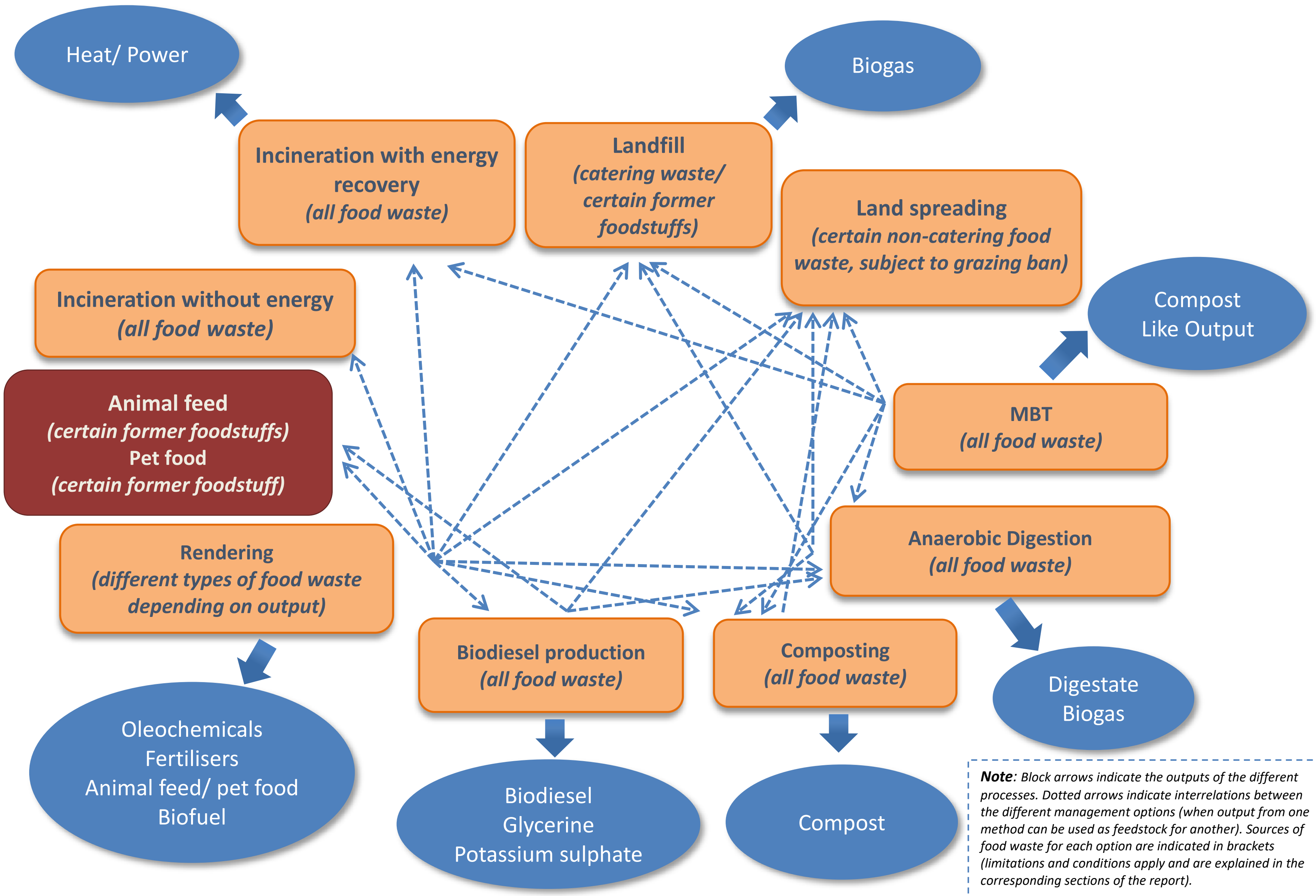


Figure 5. Food waste management options: relationships and outputs.

Following the BSE and FMD outbreaks in the UK there is great sensitivity about the safety of animal feed. Methods that include incineration or a rendering process provide a high degree of security, in that they will eliminate most pathogens likely to be found in the food waste (incineration is required to fully eliminate the risk of BSE prion). Although there have been some reports of incineration facilities affecting human health in the nearby area none of these have been statistically proven, so they are considered safe.

Landfill is currently accepted to be a safe method for disposal of food waste, provided it is managed effectively. Biological methods for the disposal of waste containing ABPs, e.g., composting and AD are controlled under ABP regulations and quality standards. The processes are known to substantially reduce non-sporulating pathogens (*E. coli* and *Salmonella*). Compost and digestate are applied to agricultural fields but subject to grazing bans to protect animal health. Direct spreading of food waste to land is only allowed for certain low risk food wastes such as waste milk and are subject to the grazing ban.

The use of food waste as an animal feed requires that processes used are effective in eliminating any pathogens present as it is consumed directly by the animal and will therefore enter the human food chain.

The outputs from the different food waste management options and their inter-relationships are summarised in Figure 5. This figure illustrates the complexity of the interactions involved between processes, where some of the current processes exchange streams, for example, some waste from the AD process will be ultimately sent to landfill and waste from rendering may go to AD, landfill or incineration.

Data concerning costs, environmental and health impact of the different options for animal feed and pet food production are not currently available. 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.

5.1 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. 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. 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.

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.

Although the worst option according to the waste hierarchy, landfill is still the most used disposal method for municipal solid waste (MSW) in Greece.

5.2 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 an adequate quantity of oxygen is required to fully oxidise the fuel. Incineration plant combustion temperatures are more than 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[35]. Acid gases, particulates, dioxins, and heavy metals may potentially be released to the atmosphere and need to be removed.

All animal by-product food waste can be processed by incineration. Incineration of waste in the EU 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. Even though incineration is a very well-established technology, its use in Greece is almost no existent. By contrast in many parts of Europe waste incineration is widely used[36].

5.3 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)[37]:

[35] http://archive.defra.gov.uk/environment/waste/residual/newtech/documents/incineration.pdf
[36] http://www.ifr.ac.uk/waste/energy_recovery.htm#biomass
[37] http://www.environment-agency.gov.uk/static/documents/Business/Biodiesel_QP_NIEA_GEHO0311BTPC-E-E.pdf

- 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. All products from non-approved biodiesel plants are untreated catering waste and must therefore be disposed-of as if they were catering waste. Particularly, 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[38]. 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[39].

Used cooking oil is collected and cleaned for re-use by a network of private companies across Greece. The oil is collected by individual companies, cleaned, and sent for further refining. Approximately 4,000 tonnes/year of waste vegetable oil are currently collected in Greece, of which 2,000 tonnes/year come from the catering industry. All of the collected catering WVO are used for biodiesel production, Total WVO arisings could be as much as 40,000 tonnes a year[40,41].

5.4 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. Regulation (EC) 1069/2009 (ABPReg) does not allow composting of catering waste in open windrows,

[38] http://www.environment-agency.gov.uk/business/sectors/32599.aspx
[39] http://animalhealth.defra.gov.uk/managing-disease/animalbyproducts/biodiesel.htm - 2
[40] WRAP 2007, Waste vegetable oil technical report
[41] WRAP 2008 Financial impact assessment for biodiesel

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 Greece are implementing a range of schemes to increase the collection of food waste. Within Greece less than 50% of local authorities collect food waste in some form or another. Almost all of those collecting food waste are collecting food waste separately. 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.

5.4.1 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 Reg. (EC) 1069/2009 ABP 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.

Category 3 material can be used directly in approved composting plants. Under the EU standards two composting "barriers" or processing standards must be met when catering waste includes meat. **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**Table 3 shows the different processing option combinations that may be used to meet Reg.ABP processing standards[42]. Open-air windrows or 18 days storage is used as a second barrier after IVC to achieve. An exemption to the composting requirements exists only for situations where the catering waste is generated, composted, and then used all on the same premises under the EU Reg. (EC) 1069/2009 ABP[43].

Table 3. 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	40 cm	6 cm	40 cm
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)

5.4.2 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

[42] http://archive.defra.gov.uk/foodfarm/byproducts/documents/authorisations.pdf
[43] http://archive.defra.gov.uk/foodfarm/byproducts/documents/compost_guidance.pdf

known as biofertilizer 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.

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.

5.4.3 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. 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 no 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. An estimated 0.4 million tonnes of organic waste were treated by MBT in 2019 in the four plants identified as operational in Greece (ESDA, 2020).

5.5 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. In the UK, shells from shellfish and eggshells may also be applied to land in accordance with national rules[44]. However, land spreading is not practiced in Greece.

5.6 FOOD WASTE TO FEED GROWTH

Currently, much of the global feed produced comes from cereals or grains. This began in the United States in the 1940s when corn was introduced to livestock diets in larger portions than previously. Around this time, researchers demonstrated that concentrated feeds, such as corn, were a cost-effective means, over grass fed, to mature livestock in less time (Corah, 2008). According to Capper and Bauman (2013), "Over the past century, the US dairy industry has shifted from extensive production systems based entirely on forage to intensive systems with diets still founded on forage but formulated with feed components to optimize rumen fermentation and meet the dairy cow's nutrient requirements."

Despite the increases in efficiency from concentrated feeds, a reliance on specialty blends of these ingredients can leave the livestock industry vulnerable to the fluctuations of commodity feed pricing. Historically, cereal or grain prices were on a steady decline, which was one of the reasons that made them so attractive around the world (Steinfeld et al., 2006). For example, in Japan, the use of food waste and food by-products as feed was declining recently due to how inexpensive concentrated feed had become. Currently, however, feed pricing has been more volatile, which represents a significant risk for farmers; for example, between roughly 2007 and 2009, soybean prices climbed from around $150 per metric ton to over $250 per metric ton and back down again to $150 (Gardebroek et al., 2014). In the European Union, in 2012, animal feed was close to 50% the cost of pig production and roughly 15% for cattle (FEFAC Congress, 2013).

Conventional animal feed processing has a few inherent challenges, i.e., volatile crop pricing and GHG emissions from fertilizer use. However, these benefits are not necessarily the main driver for diverting food waste to feeding animals. The primary focus should be on keeping food waste out of landfills and utilizing it as a resource. Animal feed is one of many value-added outlets, along with feeding people, composting, anaerobic digestion, and thermochemical conversion, that should be evaluated on a case-by-case basis depending on the characteristics of a given food waste stream.

Food waste diversion and feeding animals are two processes that historically have been paired together, providing a more effective outlet for food waste, garbage, and food by-products as input to animal feed production. This pairing is also positioned highly on most food waste recovery hierarchies across the globe. However, current data does not suggest that a significant amount of food waste is being recovered and diverted to feed. As will be discussed in subsequent Chapters, most feed diversion is from the by-products of food production, not from waste. Feed safety laws and disease incidences have also discouraged the continual growth in this area.

There has been a long history of feeding food products to livestock both in the United States as well as around the world. According to Westendorf (2000), "Garbage and food waste have been used as livestock feed for centuries." In the recent past, however, several health outbreaks have led to regulatory changes and market shrinkage. The major health concerns from feed contamination with swine include foot-and-mouth disease (FMD), African swine fever (ASF), hog cholera, and vesicular exanthema of swine (VES); these diseases are spread from swine consumption of "partially-cooked infected tissues" (Westendorf, 2000). In

[44] http://archive.defra.gov.uk/foodfarm/byproducts/documents/abp-guidance-110703.pdf

recent history within the United States, there have been nine cases of FMD between 1870 and 1930; across the outbreaks, 300,000 swine, cattle, goats, and sheep were slaughtered to stop the spread of disease (Westendorf, 2000). A case of VES occurred in California between 1935 and 1944 in which 430,000 swine were slaughtered (Westendorf, 2000). The most recent incidences of hog cholera have been more recent than some of the aforementioned diseases. The United States was not free of the disease until 1978 (Westendorf, 2000).

The more recent disease outbreak impacting global regulation for animal feed was Bovine Spongiform Encephalopathy (BSE), also known as "mad cow disease," which had the first reported cases in the UK in 1986 (Jin et al., 2004). United Kingdom had slaughtered roughly 4.4 million cattle as a safety measure and had spent roughly $7.4 billion (Brown, 2000). United States introduced a Mammalian Protein-Ruminant Feed Ban in 1997; Canada introduced a similar measure in the same year (Jin et al., 2004). Despite the introduction of safety measures around the world, there are still a few reported cases of BSE each year, even as 2015; Canada, Norway, and Slovenia each self-reported one infection. The United Kingdom reported two cases in 2015.

Despite the health outbreaks caused by improper handling of certain feeds, specific countries are actively promoting increased use of FFP. One reason is that countries such as Japan and Korea want to decrease their dependence on imported feed for their livestock. According to Ha et al. (1996), before 1996, South Korea was importing roughly 15 million metric tons of animal feed from Southeast Asia and the United States. One of the purposes of their study was to evaluate the incorporation of food by-products into feed to lower the rate of imports. In Japan, Sugiura et al. (2009b) highlighted the importance of their feed independence. As of 2007, roughly 75% of their total digestive nutrition for feeds was imported. Forages included hay, ensiled grass, corn, rice, and rice straw. The compound feed ingredients included grains such as corn, rice, sorghum, rice bran, soybean oil residue, beet pulp, beer residue, and bean curd residue.

Although the diversion of food waste to feed still has a lot of room to grow, there is already significant research and industry around incorporating co- and by-product foods into livestock feed. According to a food waste survey conducted in 2013 (BSR, 2014), 81% of all food products and by-products generated by U.S. food processors were diverted to animal feed. The amount diverted to animal feed decreased drastically at each new stage in the supply chain. This study included both edible and inedible food products.

Certain types of food waste can be recycled into animal feed or pet food. According to Regulation (EC) 142/2011[45], Category 3 material (with a few exceptions) can be used to produce 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.

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

[45] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:054:0001:0254:EN:PDF

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[46]. 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 be 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.

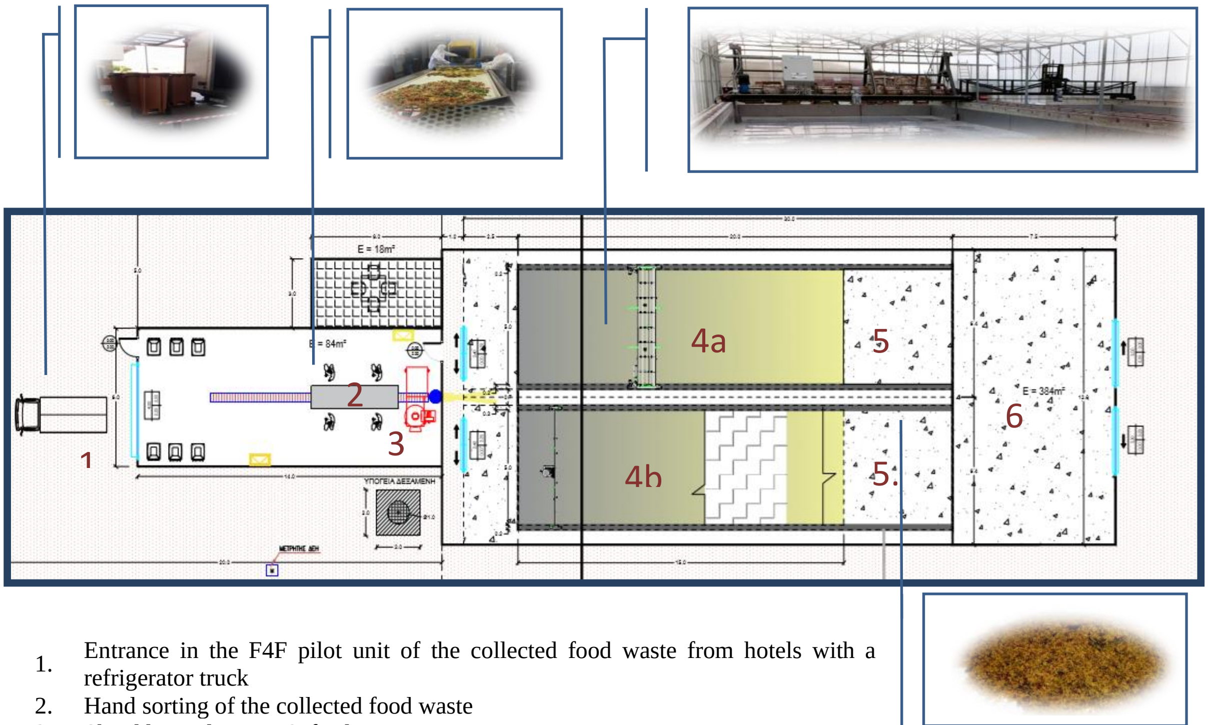
Data concerning costs, environmental and health impact of the different options for animal feed and pet food production are variable depending on methods, type of material, etc and they are currently insufficient. This work aims to assess the economic and environmental sustainability of the potential 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.

5.7 THE F4F PRODUCTION PROCESS

The F4F pilot unit consists of a prefabricated building (14m x 6m) where food waste pre-treatment takes place and a solar drying unit (30m x 12.8m). A series of air-conditions and air extraction and recirculation units (for health and safety issues) have been installed into the prefabricated building.

The solar drying unit is essentially a greenhouse, covered by polycarbonate, windows are covered with insects' net and there is a concrete floor for pest control. Roof based fans are used to extract moisture from the sun drying hall, connected with the operation of the turners. It consists of two drying halls, covered by stainless steel. Each drying hall (20m long and 5m wide, with 0.80m high reinforced concrete side walls), is covered with an extensive network of pipelines connected with solar thermal collectors and a heat pump in order hot water to accelerate the drying rate. On the top of the pipelines, a high-quality stainless still cover is covering the drying hall surface, where the food waste is in contact with. Each corridor floor has a different type of drying turner (a horizontal and a vertical turner are being used). The turners are a prototype system custom-made for the process. They have several motors and sensors for a variety of moves: a) moving in the drying hall corridor using wheels rolling on the sidewalls, in various speeds and both directions, b) increasing and decreasing the height of the turner's drum, c) turning the drum both directions and in various and control speeds, e) estimating its position from the ends of the corridor at all times, and f) including a series of safety operation mechanisms (e.g., emergency stop).

[46] http://www.igd.com



1. Entrance in the F4F pilot unit of the collected food waste from hotels with a refrigerator truck
2. Hand sorting of the collected food waste
3. Shredder, pulveriser & feeding pump
4. 4a. Solar drying tank with a horizontal drying turner
   4b. Solar drying tank with a vertical drying turner
5. Free space for emptying the drying cells after the completion of the drying process. The final product is placed in big bags.
6. Temporary storage of the final product

Figure 5-6. The F4F production process

Food residues is collected on-site in specific inox containers and transported with a refrigerator truck that keeps the waste residues separate from the general environment, accordingly, keeping odours to a minimum, minimising the attraction of insects, rodents, and other vectors, and also to reduce the contamination of the food residues during transport. The plant treats about 150 tonnes of food waste in each operational period (1.0- 1.5 t daily) of source-separated food waste from hospitality units (mainly from 5-star hotels) and generates 275 kg of dried feed per tonne of food waste of an average starting moisture of 75%.

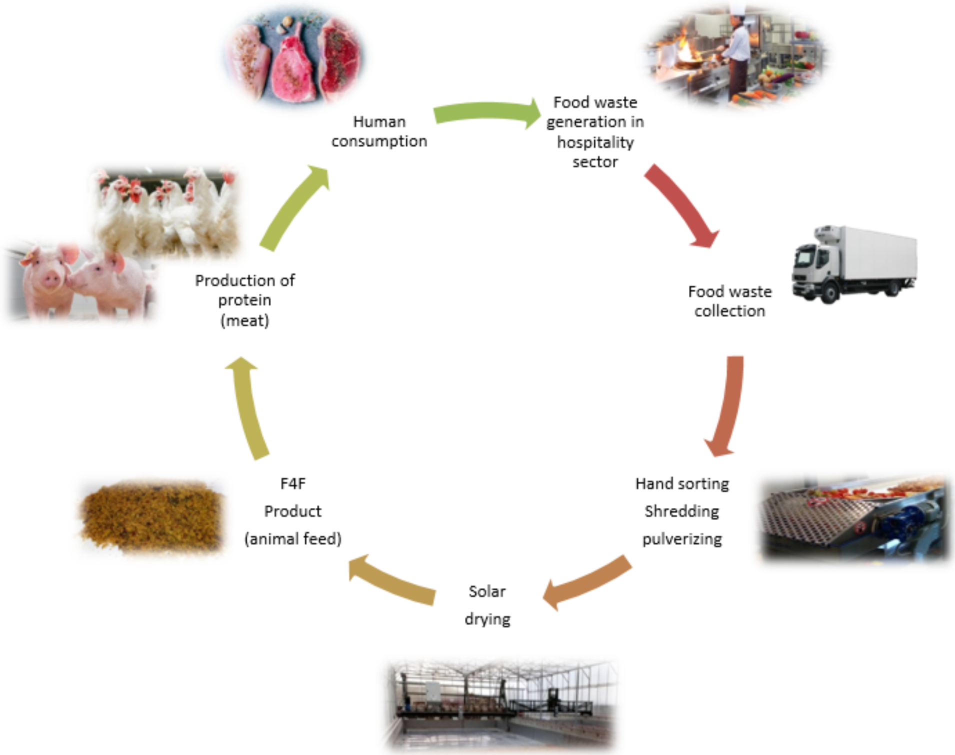


Figure 7. The F4F food waste management system.

The first stage of the food waste management takes place into the prefabricated building and concerns hand sorting of the food waste to remove unwanted materials (paper, plastic, metal etc.). At the end of the hand sorting belt, the food waste is forward into a shredder and then into a pulveriser. With a screw and then with a high-power pump the pulverised food waste is introduced into the solar drying tanks of the solar drying unit. Each drying hall is fed with the pulverised waste until to a specific level inside the hall (about 15cm height) and then operates in a closed loop until the moisture content is reduced from the 75% of the original material to 12% or lower.

6 ASSESSMENT OF THE AMOUNT AND NATURE OF FOOD WASTE AVAILABLE FOR REUSE

The practicalities of using food waste in the production of animal feed can be evaluated with an appreciation of the amount of food waste available and what type and quality is available. There are several reports on waste volume and type already available and these were used to calculate the overall amount of food waste. Data was not always available for all the sources, especially for volumes of former foodstuffs from the retail sector and this made the analyses for this section difficult to achieve.

Table 4 summarises the current figures for food waste management routes. The data was found to be incomplete and not detailed.

Table 4: Quantity of food waste[1] processed by currently available management routes (tonnes) in Greece[3].

Food waste management		Landfill	Land spreading	Incineration with or without energy	Rendering/ processing for animal feed	In Vessel Composting	Anaerobic Digestion (dedicated food waste facilities)	Mechanical Biological Treatment	Home composting and feed to household animals	TOTAL
Current situation	t/y	**1,847,263**	-	-	-	**139,244[2]**	-	**51,280[2]**	**91,144[2]**	**2,128,931**
	%	86.8%				6.5%		2.4%	4.3%	100.00%
Final Target		Disposal	Organic fertiliser/ soil nutrients	Energy production/ disposal	Recycling into various products	Organic fertiliser/ soil improvers	Organic fertiliser/ soil improvers	Land recovery/ energy	Organic fertiliser/ soil improvers/ pet food	

Notes:

1. Source: National Waste Management Plan, ESDA 2020.
   The National Waste Management Plan does not include separate management routes for food waste. It is included in the biowaste (food and green waste). The calculations of Table 4 assume that food waste, garden and park waste and vegetables oils represent the 87%, 10% and 3% of the total biowaste. respectively.
2. It includes some quantities of waste vegetate material (ESDA 2020).
3. Own processing.

7 THE PROCESSES CURRENTLY USED FOR COLLECTING, MOVING AND TREATING FOOD WASTE

The principal challenges associated with processing mixed food waste into feed ingredients are the high moisture, the compositional variability, and the potential presence of animal and human pathogens. The methods used for processing food waste must be designed to obtain a product that is stable and free from pathogens and contaminants. Moreover, from the feed industry perspective, comprehensive analysis of the nutritional profile and digestibility of the product will be required as well as consistency of quality and supply. **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.** summarises the general steps and issues involved in producing animal feed from food waste.

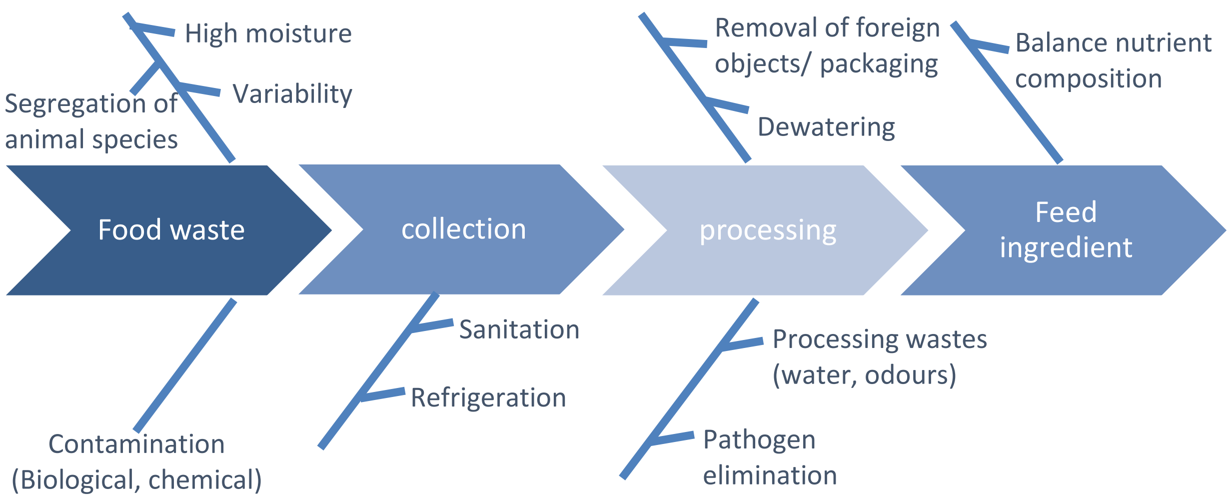


Figure 8. Principal issues to consider when converting food waste into animal feed ingredients.

Many different methods can be used for processing food waste. In many cases, the nature of the food and even the species for which the ingredient is intended will determine the method that can be used. Currently, the range of food waste materials that may be processed into animal feed is severely restricted in the EU. Former foodstuffs that can be recycled for use in farm animal feed (from premises such as bakers, supermarkets, retail stores, crisp manufacturers, and confectioners, but not from kitchens and restaurants) include baked goods, milk and milk products, eggs, and egg products. Baked goods must be free of meat and not been in contact with meat; eggshells must be rendered and powdered before use. Other materials currently allowed in animal feed (with exceptions and conditions) include used cooking oil (but not from catering sources and only of non-animal origin), fishmeal and fish oils. A wide range of safety requirements are in place to ensure that the waste does not contain restricted products and that food waste is treated to prevent pathogens growing or to reduce the pathogen load to acceptable levels, e.g., by heating the product.

Processes for treating food waste to produce animal feed are in place in other countries, such as USA, Japan, and others, and are routinely used. Processing systems usually involve size reduction or shredding followed by pasteurisation or sterilisation processes, which involve the application of heat or a combination of heat and pressure to remove pathogenic organisms. In the USA, a range of processes are used including rendering, cooking at 100 °C for 30min and/or extrusion at 140 °C for 30 secs. This is followed by drying where required. Japan has a protocol to produce Ecofeed (animal feed from food waste), which involves pre-heating at 70 °C for 30 min or at 80 °C for 3 minutes when waste may contain meat (and preferably also when it does not contain meat). This is followed by a processing method that may be dehydration, lactic fermentation, or ensiling. In some cases, a final drying step is included. One common feature to different countries is that due to the risk of TSE diseases in ruminants, specific requirements and limitations regarding permitted animal materials and processing methods apply to animal feed production for these species.

The available processes are well known and could be implemented under modifications of the current regulations. Naturally, these processes require expensive and energy demanding methods such as heating (to eliminate pathogens) and drying (to reduce the high moisture content of food waste). The economic and environmental burden of recycling food waste into animal feed will depend on many different factors such as waste stream, nature of the waste, technology involved, final product to be achieved, etc.

8 THE ECONOMICS OF USING FOOD WASTE IN ANIMAL FEED COMPARED WITH CURRENT MANAGEMENT METHODS

Traditionally many animal producers have used food waste as animal feed, and it is likely that they may become increasingly attracted to seek to use food waste as feed as the price of conventional arable based animal feeds increase. An important factor is the feeding conversion rate (i.e., the ratio between the weight of food waste and weight gain) of the food waste. Producers will be willing to pay a significantly lower price for food waste that is of a low feeding value. Associated with this, the proportion of producers who will switch to food waste products is related to the relative price and feeding value. At very low feeding values, it is shown that very few producers will be better off using food waste unless it is subsidised.

Therefore, the link between opportunity costs (which can be considered as the loss associated with not using conventional feed, e.g., if nutritional value is low longer feeding periods may be required) and the use of food waste is explored. The results indicate that the use of food waste as animal feed is only justified when the price of food waste products is relatively low. In fact, even if the food waste feed is fully subsidised (i.e., available to producers at zero cost) the use of these feed products is only profitable if the opportunity costs do not increase the total cost by more than around 10 per cent. If feed derived from food waste costs the same as conventional feed, then the enterprise is shown to be less profitable, due to the opportunity costs.

A detailed full cost accounting for 5 types of existing and planned municipal solid waste management facilities (sanitary landfills, anaerobic digestion, biodrying, incineration, aerobic mechanical and biological, material recovery) in Greece has been performed[47]. The investment costs (IC), operating costs (OC) and future (restoration) costs (FC) was used to calculate the actual total unit cost (€/t) of the above types of facilities in 2012 prices. Mathematical cost functions were developed to describe the total cost (€/t) as a function of the MSW input rate (t/y). Actual data from several operating facilities in Greece were used, as well as estimated costs from facilities that are planned or are under construction in Greece. Results showed that the sanitary landfills follow the economy of scale with an average total unit cost of €45/t. The unit cost of the planned anaerobic digestion facilities ranged from €50 to €104/t. The biodrying facilities' unit cost ranged from €48 to €138/t, whilst the sole MSW incineration facility was found to have a unit cost of €115/t. Aerobic MBT facilities did not follow the economy of scale.

The same methodology was used to calculate the actual total cost of a F4F facility with an annual capacity of 10,000 t, able to produce 2,000-2,500 tonnes of dried feed component.

TC:	total unit cost of the facility (€/t),	$= \frac{(IC \times CRF + OC)}{MSW}$
IC:	investment cost (€), that did not include land acquisition costs,	1.961.350,78 €
OC:	operating cost (€/y); OC was based on estimates of operating cost reported in technical studies,	946.229,02 €
MSW:	MSW input rate into the facility (t/y),	10,000 tonnes

[47] Komilis D., Liogkas V., (2014). "Full Cost Accounting on Existing and Future Municipal Waste Management Facilities in Greece. Global NEST Journal, Vol 16, No 4, pp 787-796.

CRF:	capital recovery factor,	$= \frac{i \times (1+i)^n}{(1+i)^n - 1}$
i:	annual discount (depreciation) interest rate (a constant 6% annual rate was used as a default value),	6%
n:	design life of a new (future) facility (a 20-year default value was used for all planned facilities).	20 years

So,

$$CRF = \frac{i \times (1+i)^n}{(1+i)^n - 1} = \frac{6\% \times (1+6\%)^{20}}{(1+6\%)^{20} - 1} = 0.0872$$

$$Total\ Cost\ (TC) = \frac{(IC \times CRF + OC)}{MSW} = \frac{(1.961.350{,}78\ € \times 0.0872 + 946.229{,}02\ €)}{10{,}000\ tonnes} = 111.72 \cong \mathbf{112\frac{€}{t}}$$

The following table compares the total cost of the MSW facilities with the total cost of a full scale F4F facility.

Table 5. Total Cost of the MSW management facilities in Greece

Type of facility	Status	Number of units	Year of construction	Design lives (y)	Range of MSW input rates, (10^3 t/y)	Total Cost (€/t)	Operating Cost
Sanitary landfills	Operating	50	1993-2011	5 to 28	0.045 to 1.931	45 €	
Anaerobic digestion facilities	Planned	5		20	65, 67, 128, 128, 300	€50/t to €104/t	
Biodrying facilities	Operating	2	2011	18	25, 75	€48/t - €138/t	€31/t - €109/t
	Planned	3		20	130, 450, 700		
Incineration	Planned	1		20	450	€115/t	€73/t
Aerobic MBT facilities	Operating	3	1997-2002, 2005-to date	13, 15	19, 100, 220	€37/t to €66/t	
	Planned	5		20	13 to 400	€37/t [220.000 t/y] to €66/t [400.000 t/y]	
F4F Facility	**Planned**	**1**		**20**	**10**	**112 €**	**95 €**

It also be noted that the cost of landfill does not include the landfill tax, which is set to €20 per tonne of waste landfilled in 2022 and rising to €35 in 2025. From 1 January 2026 the landfill fee is set at €45 per tonne of waste and increases to €55 per tonne from 1 January 2027, which remains stable for the following years.

The F4F process compares competitively with the other processes commonly used for food waste management. It can be even more competitive if the income from the produced feed sales is taken in account, resulting in a cost reduction by 25-30%.

9 THE POTENTIAL RISKS TO HUMAN AND ANIMAL HEALTH THAT MIGHT ARISE FROM THE USE OF FOOD WASTE IN ANIMAL FEED.

Food waste containing meat or meat products can be a potential source of infection from a range of bacteria (including antimicrobial-resistant strains) viruses, parasites, and various toxins. Transmissible spongiform encephalopathy agents (Scrapie, BSE, CJD, v-CJD, CWD) are highly resistant to heat and chemical inactivation but as specified risk materials (SRM) from cattle and sheep do not enter the food or animal feed chain and are currently disposed of by incineration, it is assumed that this situation will continue and therefore TSEs can be considered to present a negligible risk.

Food waste has been fed to domestic animals particularly pigs and poultry, whilst historically, ruminants have been fed meat and bone meal produced from rendered carcasses. The feeding of food waste to pigs is a traditional practice that is still carried out in several countries. For example, in New Zealand, legislation requires that any waste containing meat is cooked (100 °C for 1 hour). This was the situation in Britain, where swill feeding to pigs was controlled under the Food waste Order 1973, and the subsequent Animal By-Products Order 1999 and its amendments. However, following the outbreak of Foot and Mouth Disease in 2001, the Government prohibited the feeding of catering waste to animals that contained or had been in contact with animal by-products. This restriction was subsequently reflected by the EU Animal By-Products Regulation and became mandatory in all Member States. Feeding catering waste to farmed livestock is currently not permitted. The Spongiform and Encephalopathy Advisory Committee (SEAC) also recommended that all intra-species recycling should be avoided to prevent the risk of a TSE being spread through recycling in animal feed. These restrictions, amongst others, were implemented under the (EC No 1069/2009), Animal By-Products Regulations as well as the TSE regulations (EC No 999/2001) Prior to the prohibition, legislation required that any waste containing meat or meat-products was cooked (100 °C for 1 hour). Other conditions and temperatures are used in for example rendering, but for the purposes of this review, this temperature and treatment time were considered as the international standard. Further research into cooking or processing in higher temperature, pressure cooking systems that require shorter cooking times is required. A requirement may also be needed to specify a maximum feedstock particle size similar to that set in the EU standard treatment for AD, for example, 12 mm.

If done correctly, cooking at 100 ºC for 1 hour is adequate to destroy most pathogens. They include several non-spore-forming bacteria such as *Brucella*, *Campylobacter*, *Salmonella*, *Escherichia coli*, and *Listeria*; viruses such as Classical Swine Fever virus, avian influenza virus, norovirus, and SARS coronavirus, and parasites such as *Cryptosporidium* and *Trichinella*. Heat treatment is generally lethal to microorganisms, but each species has its own specific heat tolerance. Some microorganisms are more heat-resistant than others, so consequently more stringent time and temperature combinations are required. Gram-positive bacteria tend to be more heat resistant than Gram-negative bacteria; yeasts and moulds tend to be fairly heat-sensitive as are parasites.

Cooking is the usual way of destroying microbes in food, although the process is neither uniform nor instantaneous. There is a range of data on the thermal death characteristics of microorganisms, derived from many studies were conducted over a period of several decades, and there is little or no harmonisation between them; consequently, the information derived from them is not homogeneous, e.g., different time-temperature combinations were tested for different species, and different food types were tested. To acquire a more precise overview of the thermal death characteristics of the variety of bacterial agents that have been studied a thorough systematic review of published studies and other available information and meta-analysis of the extracted data would need to be undertaken. This should focus on attempting to distil consensus D-values (the time in minutes at a given temperature required to destroy 90 % of the target microorganism) and Z-values (the number of degrees (ºC or ºF) required to change the D value by a factor of ten) for each bacterium/ food substrate combination.

There are several spore or toxin-forming bacteria (e.g., *B. anthracis*, *B. cerus*), for which available information indicates that heating to 100 ºC for 1 hour would be sufficient to reduce spore numbers by at least 6 $\log_{10}$. However, because of their ability to form spores, it was considered prudent to give them a higher risk of categorisation than non-spore formers. Also considered as low to medium risk are viral agents such as foot and mouth disease virus or swine vesicular disease virus, which might become located in bone tissue which may have a protective effect against heating.

Disease agents in the medium to high-risk category comprise spore or toxin-forming bacteria (e.g. *C. sordelli*) and some fungal mycotoxins. For these disease agents and the toxins, insufficient information may be available to determine if heat-treatment at 100 ºC for 1 hour is sufficient to reduce the risks from re-feeding of waste to negligible levels. Further research is recommended to define the thermal death characteristics of these agents in the food types in which they may be found, and in food wastes. These practical studies should be harmonised, e.g., by examining the effect of identical temperatures, times, and contamination levels, and model food wastes should be used so that the accruing data is comparable between studies.

Viral agents of exotic, notifiable, and high economic impact diseases (Foot and Mouth Disease virus, Swine Vesicular Disease virus) can show varying degrees of thermal resistance. However, again there is no harmonised information, and the recommendation of a systematic review and meta-analysis equally applies.

For several organisms such as *Brucella ovis*, *Clostridium chauvoei*, PRRS virus, and *Streptococcus pneumoniae*, specific heat inactivation data are not available, but meanwhile, they have been placed in the same categories as related agents. It is recommended that harmonised experimental studies, as described above, are performed to fill in the gaps in knowledge, so that a definitive assessment may be given of the risk of their transmission through consumption of food waste.

10 SUMMARY OF THE OPTIONS FOR SUSTAINABLE AND SAFE USE OF FOOD AND CATERING WASTE

When considering the potential for additional food waste materials to be recycled into animal feed many different factors come into play, including nutritional value, environmental impact, economic cost, animal and human health, practicality, social impact, and legislation. Undoubtedly, a large proportion of food and catering waste has a high nutritional value, and the feed industry has the technological capability to handle and process these materials.

Perhaps the most important aspect to consider about recycling food waste into animal feed is the risk to animal and human health. The outbreak of FMD in 2001, and concerns over the risks of spread of prion-induced diseases such as BSE, have led to the banning of feeding most food waste materials to animals in the EU. Currently, only food waste that does not contain and has not been in contact with meat or fish is permitted as animal feed. If animal by-products were to be re-introduced as animal feed, it is envisaged that prohibitions on intra-specific recycling would remain in place.

A relaxation of the feed ban maintaining the prohibition of intra-species recycling would imply that food waste derived from different species would have to be segregated and the control mechanisms are in place to avoid cross-contamination. This would carry significant compliance costs, which might inhibit uptake. On the other hand, these measures would only seem possible in the manufacturing and retail sectors, where large amounts of single ingredients are handled in a structured fashion and controls can be implemented and monitored. In the hospitality sector there are still many companies that do not separate food waste from general waste, therefore meat/fish segregation by species, or indeed from fruit and vegetables, would appear too ambitious and difficult to implement in the medium term.

Public acceptance of products of animal origin being re-introduced into the food chain is another factor that may influence the likelihood of part of the feed ban being lifted in the future. In 2011, the FSA(UK) commissioned research to gauge public's attitude towards a change in the current ban on using processed animal protein (PAP) in feed and reported that the majority of people taking part were against a relaxation of the ban[48]. Likewise, the retail sector will not accept any products that might be perceived as a risk to human health. *The BSE and the foot and mouth crises had a big impact on public opinion about food safety and any changes to the feeding prohibitions will need to be backed up by strong evidence of food safety in order to be accepted by consumers*.

In order to allow the use of food waste of animal origin for feed, important legislation changes would be required at both national and European level. These legislative changes can be difficult to bring about.

The environmental and economic impact of converting food waste into animal feed is remarkably variable, depending on the specific processes and methods involved (Takata et al. 2012). One aspect influencing the overall benefit impact is the level of uptake of the final product. Kim & Kim (2010) analysed the risks of not being able to use the products of wet feed production, dry feed production and composting in Korea and having to dispose of them *via* incineration or landfilling. This study showed that wet feeding production was the best method in terms of environmental impact if the feed produced was consumed, however, if surplus had to be incinerated, this resulted in the worst option, with a global warming power even higher than direct landfilling of the initial food waste. In order to minimise these risks and to further promote food waste recycling, the Japanese system has introduced the concept of the "recycling loop" whereby industrial and commercial food waste emitters are required to buy products from farms that use animal feed from

[48] *www.food.gov.uk/multimedia/pdfs/publication/bitewinter11.pdf*

recycled food waste. This measure guarantees a destination for the feed product, and this, together with food recycling subsidies, has led to a marked increase in the number of food recycling facilities in Japan since 2007 (Takata *et al.,* 2012).

In conclusion, the fact that recycling practices can be carried out in other countries without incurring problems with animal and human health illustrates that there are opportunities to recycle food waste into animal feed in Greece safely. However, it is accepted that these processes must be controlled to assure the production of a safe product. In Greece (and EU), there are in place a range of complex regulations and quality schemes to produce animal feed and control of ABP. These could be relatively easily adapted to allow the recycling of more categories of food waste into animal feed, particularly those categories that were temporarily banned under the current regulations. Processes do already exist for the treatment of catering waste, e.g., rendering, for integration into the animal feed streams, but these may prove expensive and environmentally less sustainable than its use in AD plants and may not be justified when the feed product produced is likely to be of low quality. Segregated waste streams are likely to yield higher value feed ingredients compared to catering waste containing animal material from mixed sources. There is a need for further research in Greece into processes that could be used to recycle food waste into animal feed, to determine their safety, environmental implications, and economic value.

The table (**Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**) below summarises the environmental sustainability, health Impact, animal risk and climate change potential and the cost of current processes for food waste management.

Table 6. Sustainability, Health Impact, Animal Risk and Climate Change Potential and Cost of current processes for food waste management

Treatment	Environmental Sustainability	Health Impact	Animal Health Risks	Climate Change Kg eCO_2/ t_{FW}	Cost
Landfill	-Generation of landfill gas and leachate +Energy generation	Risk of infestations	Risk of spread of animal pathogens	+948.5	€20-45*
Incineration	-Air pollutants emissions +Energy replacement	Emissions of fine particulates, of toxic metals and of more than 200 organic chemicals, including known carcinogens, mutagens, and hormone disrupters.	Total elimination of bacteria and spores due to high temperatures	+325.4	€49-112
Rendering and biodiesel production			Effective method for the destruction of pathogenic viruses, bacteria, and other microorganisms	+36 (bioethanol)	€0.0458/litre
Biological Treatment					
Composting				+9.4	€31-67 (mixed food and garden waste) €35-67 (food waste)
Anaerobic Digestion (AD)				-150.1	€39-67
Mechanical Biological Treatment (MBT)				+140	€72-93

Treatment	Environmental Sustainability	Health Impact	Animal Health Risks	Climate Change Kg eCO_2/ t_{FW}	Cost
Land spreading	Potential environmental risks (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 surface water and groundwater.				minimal
Animal feed and pet food production				Wet feed = --30 Dry feed = +2.1	60-90€

*Not including possible landfill, environmental or any type of land disposal tax.

11 OUTLOOK AND PROSPECTS

With appropriate co-operation between animal feedstuff producers and the waste management industry it should be possible to identify a combined approach that utilises the food waste stream sustainably. The feasibility of this approach would need to be linked to a clear food waste segregation to avoid potential contamination of food waste that does not contain animal material and in this instance animal feed production provides a sustainable option as does F4F. Where a high energy-demanding process like rendering is required to produce safe animal feed, AD would be a more sustainable means of treatment. The re-use of waste vegetable, fruit, dairy and bakery items as a macerated or pulped feedstock for the pig and poultry sector has high environmental sustainability where there is a local requirement for the material.

From an economic perspective, managing food waste through both AD and animal feed production appear to be able to attain relatively equivalent societal savings. Both are likely to provide positive societal benefits.

If changes do take place, it is important to handle the reintroduction of the utilisation of food waste and former foodstuffs in a proactive manner. For example, positive targeted promotion of food recycling with incentives like those introduced to promote composting or anaerobic digestion would be necessary to ensure its success, e.g., demonstration events and sites and subsidies/incentives for production and use of recycled feed.

There is no sense at all in throwing perfectly healthy food into landfill and then having farmers pay good money for feed. It can a substantial improvement from that. Further research is required to generate quantitative data specific to Greece to enable a robust comparison of different food waste recovery routes and improve the subjective 'qualitative' nature of the current assessment. There is a particular need for more accurate data on volumes and types of former foodstuffs and food waste available from manufacturing and retail premises. There is also a need for more data on processes for animal feed production from food waste to allow the assessment of environmental impacts.

It is recommended that a formal systematic literature review and meta-analysis is carried out to fully define the effectiveness of heating to 100 ^{o}C for 1 h, particularly against spore-producing pathogens, and viral agents of exotic, notifiable, and high economic impact diseases. Further research is recommended to define the thermal death characteristics of agents classed as low to medium risk, and as medium to high risk, in the food types in which they may be found, and in food wastes. These practical studies should be harmonised, e.g., by examining the effect of identical temperatures, times, and contamination levels, and model food wastes should be used so that the accruing data is comparable between studies. These studies should also be performed for agents for which specific heat inactivation data are not available. A survey of food waste streams to establish the most common human and animal pathogens present is recommended if the systematic review does not identify adequate information. There is also a need to survey the food waste streams to establish the most common human and animal pathogens present.

If it is considered that food waste should be re-introduced into the animal feed industry, particularly if mixed waste is used, it is likely that further work will be required including pilot studies and demonstrations to demonstrate suitable production processes and the level of benefits achievable by utilising this resource. This could be combined with a study on the social issues involved in its reintroduction. Sensible usage of food waste for stock feeding of animals (animal feed from food waste process) must play a part in tackling our food waste concerns. Moreover, sensible legislation and treatment of food waste are vital to ensure health, safety, and animal welfare.

12 REFERENCES

Amutha Rani, D., Boccaccini, A.R, Deegan, D. & Cheeseman, C.R. (2008). Air pollution control residues from waste incineration: Current UK situation and assessment of alternative technologies. *Waste Management* 28, p.2279–2292.

British Society for Ecological Medicine (2008). The Health Effects of Waste Incinerators 4th Report of the British Society for Ecological Medicine Second Edition June 2008.

Defra (2011a). Commercial and Industrial Waste Survey 2009 Final Report. May 2011 Jacobs Engineering UK Ltd.

Defra *(*2011b). Government Review of Waste Policy in England 2011.

Eunomia (2007a) Dealing with Food Waste in the UK.

Eunomia (2007b). Managing Biowastes from Households in the UK: Applying Life-cycle Thinking in the Framework of Cost-benefit Analysis.

Eunomia (2008). Greenhouse gas balances of waste management scenarios - report for the Greater London Authority.

Eunomia (2011). Anaerobic digestion market outlook. Eunomia Research and Consulting Bristol.

EFSA (2012). European Parliament and Council Regulation 183/2005 of 12 January 2005 laying down requirements for feed hygiene.

IGD (2012). Waste management: Animal Feed. Online guide. IGD.com.

Kim, M. H.; Kim, J. W. Comparison through a LCA evaluation analysis of food waste disposal options from the perspective of global warming and resource recovery. Science of the total environment. 2010, 408(19), 3998-4006.

Papargyropoulou, E., Lozano, R., Steinberger, J.K., Wright, N., bin Ujang, Z. 2014. The food waste hierarchy as a framework for the management of food surplus and food waste. Journal of Cleaner Production. 76:106-115. http://dx.doi.org/10.1016/j.jclepro.2014.04.020.

Takata, M.; Fukushima, K.; Kino-Kimata, N.; Nagao, N.; Niwa, C.; Toda, T. The effects of recycling loops in food waste management in Japan: based on the environmental and economic evaluation of food recycling. Science of the total environment. 2012, 432, 309-317; doi: 10.1016/j.scitotenv.2012.05.049.

Teigiserova, D.A., Hamelin, L., Thomsen, M. 2020. Towards transparent valorization of food surplus, waste and loss: Clarifying definitions, food waste hierarchy, and role in the circular economy. Science of the Total Environment. 706:136033. https://doi.org/10.1016/j.scitotenv.2019.136033.

Westendorf, M. L., Ed. Food waste to animal feed, 1st, ed.; Iowa State University Press: Iowa, 2000.

WRAP (2003). A review of the literature on the occurrence and survival of pathogens of animal and humans in green compost. Jones, P. & Martin, M.

WRAP *(*2009*). Down the drain: quantification and exploration of food and drink waste disposed of to the sewer by households in the UK.* Banbury, UK. ISBN: 1-84405-431-4.

WRAP (2011a). A study of the UK organics recycling industry in 2009. Banbury, UK.

WRAP (2011b). New estimates for Household Food and Drink Waste in the UK. Banbury, UK.

ESDA 2020. Υπουργείο Περιβάλλοντος και Ενέργειας, 2020. Εθνικός Σχεδιασμός Διαχείρισης Αποβλήτων 2020. Αθήνα. Ελλάδα. Υ.Α. Πράξη 39 της 31.8.2020/2020 (Α 185/ 29.9.2020).