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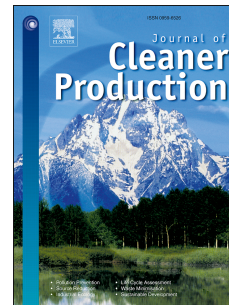
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Accepted Manuscript

The food waste hierarchy as a framework for the management of food surplus and food waste

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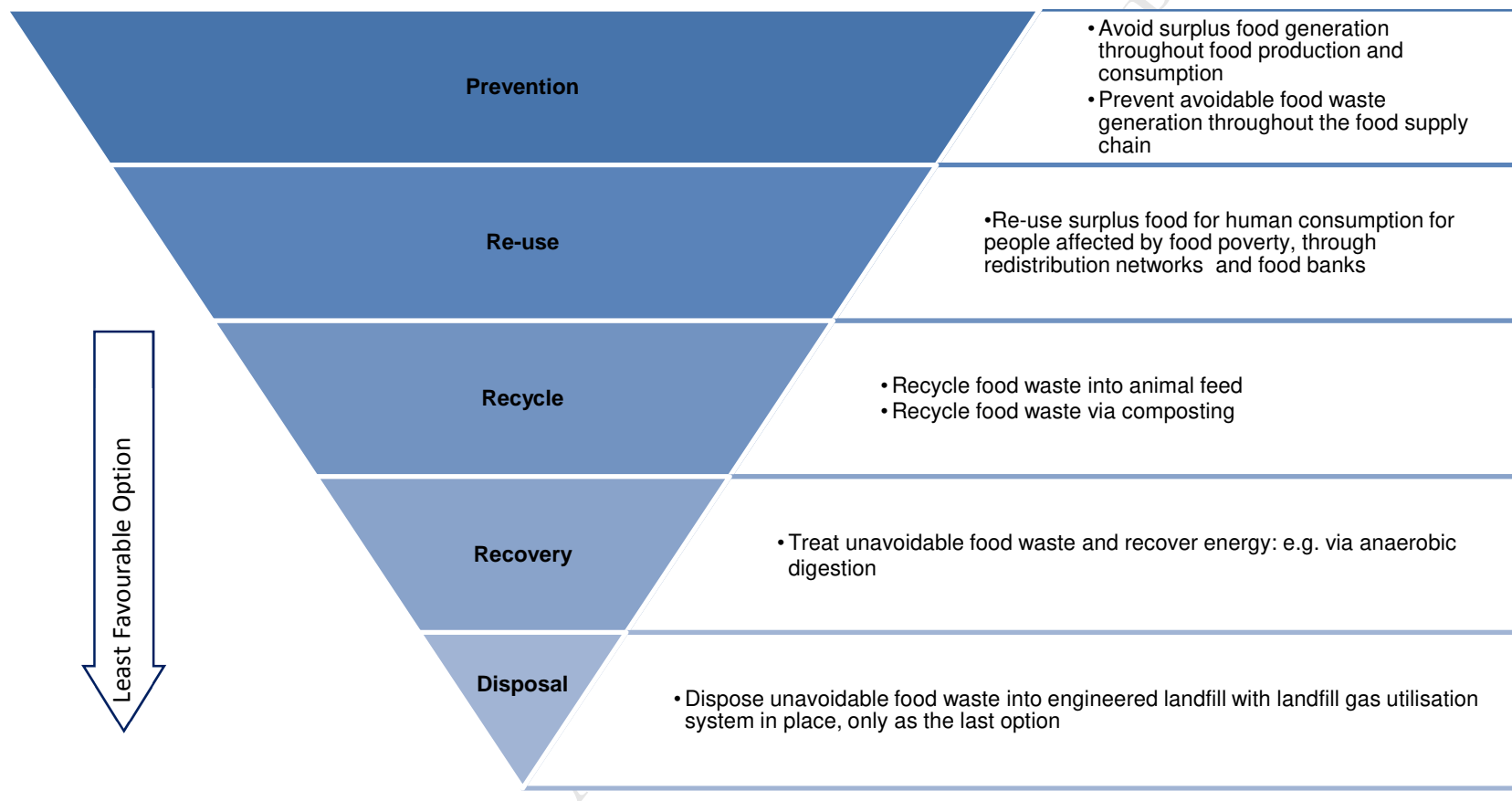
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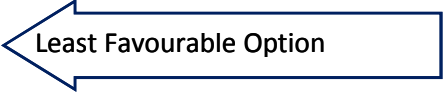
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ACCEPTED MANUSCRIPT

Title: The food waste hierarchy as a framework for the management of food surplus and food waste

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Abstract

The unprecedented scale of food waste in global food supply chains is attracting increasing attention due to its environmental, social and economic impacts. From a climate change perspective, the food sector is thought to be the cause of 22 per cent of the global warming potential in the EU. Drawing on interviews with food waste specialists, this study construes the boundaries between food surplus and food waste, avoidable and unavoidable food waste, and between waste prevention and waste management. This study suggests that the first step towards a more sustainable resolution of the growing food waste issue is to adopt a sustainable production and consumption approach and tackle food surplus and waste throughout the global food supply chain. The authors examine the factors that give rise to food waste throughout the global food supply chain, and propose a framework to identify and prioritize the most appropriate options for the prevention and management of food waste. The proposed framework interprets and applies the waste hierarchy in the context of food waste. It considers the three dimensions of sustainability (environmental, economic, and social), offering a more holistic approach in addressing the food waste issue. Additionally, it considers the materiality and temporality of food. The food waste hierarchy posits that prevention, through minimization of food surplus and avoidable food waste, is the most attractive option. The second most attractive option involves the distribution of food surplus to groups affected by food poverty, followed by the option of converting food waste to animal feed. Although the proposed food waste hierarchy requires a fundamental re-think of the current practices and systems in place, it has the potential to deliver substantial environmental, social and economic benefits.

Key words: Food waste, food surplus, waste minimization, waste prevention, waste management, food poverty, waste hierarchy, sustainable consumption and production (SCP)

Highlights

Food waste has significant environmental, social and economic global implications

The food waste hierarchy is proposed for preventing and managing food surplus and waste

Distinction between food surplus and waste is crucial in the food waste hierarchy

The food waste hierarchy also distinguishes between avoidable and unavoidable waste

Food waste can be prevented by reducing food surplus throughout the food supply chain

1. Introduction

Appropriate waste management is recognised as an essential prerequisite for sustainable development (UNEP, 2011; UNHSP, 2010). Historically, in urban contexts, public waste management focused on removing potentially harmful substances or materials away from human settlements (Wilson et al., 2012; Velis et al., 2009). As the environmental, social and financial implications of unsustainable use of raw materials and growing waste generation in the short and long term became apparent (The Government Office for Science, 2011a; Stern, 2006), waste management began to shift from a mere pollution prevention and control exercise, towards a more holistic approach.

Frameworks and concepts such as the waste hierarchy (Figure 3), the '3Rs' (Reduce, Re-use, Recycle), extended producer responsibility, polluter pays principle (Engel et al., 2008), life cycle assessment and Sustainable Consumption and Production (SCP) (Pires et al., 2011) were introduced and the paradigm of 'sustainable resource management' was developed (Barton et al., 1996). Sustainable resource management is grounded on the notion that 'waste' can be a 'resource' (Bringezu & Bleischwitz, 2009). Restricting resource use to more sustainable levels and applying resource efficiency can effectively reduce Greenhouse Gas (GHG) emissions linked to climate change, as well as offer other benefits of economic and social nature (Barrett & Scott, 2012; Defra, 2011; WRAP, 2010).

In the evolving waste management field, a waste stream receiving growing attention is food waste. As the scale of food waste's negative environmental, social and economic impacts are becoming more apparent, and global food security is becoming more pressing, food waste is increasingly recognised as being central to a more sustainable resolution of the global waste challenge (EPA, 2012; Defra, 2011; Government of South Australia, 2010). Recognizing the significance of food waste, this study aims to address the following research question: 'how can food surplus and food waste be managed more sustainably?'

Building on the expertise of food waste specialists, the authors conducted a number of interviews that provide insights into the current practices, future trends, barriers and opportunities for more sustainable management of food surplus and food waste. The key themes that emerged from the interviews inform and shape the development of a comprehensive framework for the management of food surplus and waste throughout the food supply chain through the use of Grounded Theory (GT). This framework conceptualizes food waste, and builds on this to interpret and apply the waste hierarchy in the context of food waste. The resulting food waste hierarchy aims to act as a guide in establishing the most appropriate options for dealing with the mounting food waste challenge.

The remainder of this paper is structured as follows. Sections 2 and 3 provide the context by offering a brief overview of the scale of the food waste challenge, and relevant waste and sustainability concepts. Section 4 presents the methods employed for data collection and analysis. Section 5 provides a discussion on the findings of this study and proposes the food surplus and food waste framework. Finally, the conclusions of this research are presented in Section 6, along with the implications of the study.

2. The global food waste challenge

In response to concerns over escalating GHG emissions and other environmental impacts associated with food waste, a growing number of national and regional policies identify food waste as a priority waste stream (EPA, 2012; Defra, 2011; Government of South Australia, 2010). Food security is an increasingly pressing global issue (The Government Office for Science, 2011b; UNEP, 2009; FAO, 1981) and it raises questions about the amount of food wasted in the global Food Supply Chain (FSC) that could have otherwise been used to feed people (Stuart, 2009).

2.1 The global food supply chain: food losses and waste

Food is lost or wasted throughout the FSC, from the initial stage of agriculture to the final consumption stage (Parfitt et al., 2010; Smil, 2004). Figure 1 illustrates the stages in the FSC that give rise to food losses and waste.

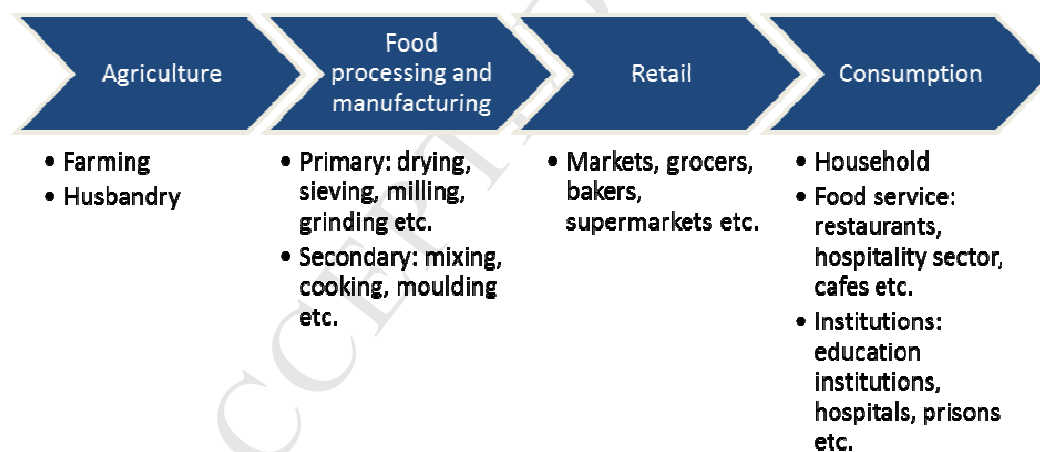


Figure 1: Activities giving rise to food losses and waste in the food supply chain

Source: Adapted from Parfitt et al. 2010; Smil 2004; Lundqvist et al. 2008

Three main definitions of food waste can be found in the literature. Firstly, The Food and Agriculture Organization (FAO) defines food waste as wholesome edible material intended for human consumption, arising at any point in the FSC that is instead discarded, lost,

degraded or consumed by pests (FAO, 1981). Secondly, Stuart (2009) adds to the FAO's definition, by stating that food waste should also include edible material that is intentionally fed to animals or is a by-product of food processing diverted away from the human food chain. Finally, Smil (2004) suggests that food waste covers the definitions above, but adds over-nutrition, the gap between the energy value of consumed food per capita and the energy value of food needed per capita. Stuart's definition provides a wider scope for food surplus and waste management opportunities, because it includes food losses due to animal feeding and the diversion of food processing by-products. For this reason and for the purpose of this study, Stuart's definition is adopted.

Food waste, or losses, refer to the decrease in edible food mass throughout the human FSC (Gustavsson et al., 2011). Food losses or spoilage take place at production, postharvest and processing stages in the FSC (Gustavsson et al., 2011; Grolleaud, 2002). At the final stages of the FSC such as during retail and final consumption, the term food waste is applied and generally relates closer to behavioral issues (The Government Office for Science, 2011a; Parfitt et al., 2010). Food losses/spoilage, conversely, relate more to systems that require investment in infrastructure. Table 1 presents examples of food waste and losses during different stages of the FSC.

Table 1: Examples of food waste and losses throughout the food supply chain

Stage	Examples of food waste/loss
Harvesting – handling at harvest	Edible crops left in field, ploughed into soil, eaten by birds, rodents, timing of harvest not optimal: loss in food quality Crop damaged during harvesting/poor harvesting technique Out-grades at farm to improve quality of produce
Threshing	Loss through poor technique
Drying – transport and distribution	Poor transport infrastructure, loss owing to spoiling/ bruising
Storage	Pests, disease, spillage, contamination, natural drying out of food
Primary processing – cleaning, classification, de-hulling, pounding, grinding, packaging, soaking, winnowing, drying, sieving, milling	Process losses Contamination in process causing loss of quality
Secondary processing – mixing, cooking,	Process losses

frying, molding, cutting extrusion	Contamination in process causing loss of quality
Product evaluation – quality control: standards recipes	Product discarded/out-grades in supply chain
Packaging – weighing, labeling, sealing	Destructive testing
Marketing – publicity, selling, distribution	Inappropriate packaging damages produce
	Grain spillage from sacks attack by rodents
	Damage during transport: spoilage
	Poor handling in wet market
	Losses caused by lack of cooling/cold storage
Post-consumer – over- or inappropriate purchasing, storage, preparation, portioning and cooking	Buying more than is needed
	Plate scrapings and surplus food cooked and not used
	Poor storage/stock management in homes: discarded before serving
	Poor food preparation technique: edible food discarded with inedible
	Food discarded in packaging: confusion over ‘best before’ and ‘use by’ dates
End of life – disposal of food waste/ loss at different stages of supply chain	Food waste discarded may be separately treated, fed to
	Livestock/poultry, mixed with other wastes and landfilled

Source: Adapted from The Government Office for Science 2011a; Parfitt et al. 2010

Studies on the magnitude of food losses and waste, across the production and consumption stages of the FSC have been undertaken in developing and developed countries (Gustavsson et al., 2011; Parfitt et al., 2010; Smil, 2004). Such studies argue that there are major knowledge gaps in relation to global food losses and waste. According to Lundqvist et al. (2008), as much as half of all food grown is lost or wasted before and after it reaches the consumer. Figure 2 illustrates the global food losses and waste throughout the FSC according to Smil (2000). ‘From field to fork’, postharvest losses are estimated at 2,600kcal per capita per day, which includes animal feed and waste in distribution and households. Stuart (2009) estimates that North America and Europe discard 30 to 50 % of their food supplies, enough to feed the world's hungry three times over. Gustavsson (2011) suggests

that one third of the edible parts of food produced for human consumption gets lost or wasted through the global FSC, amounting to 1.3 billion tons per year.

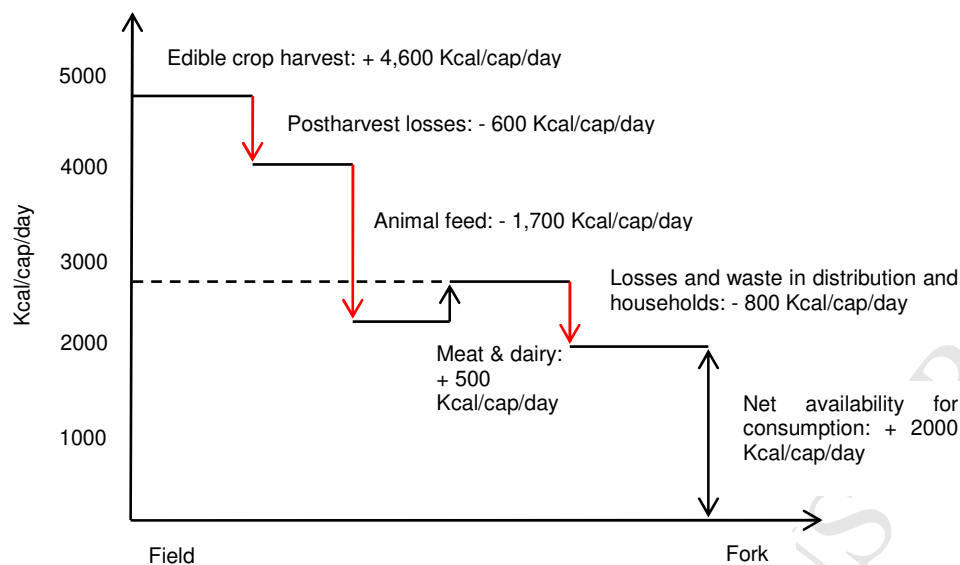


Figure 2: Amount of food produced at field level globally and estimates of the losses and wastage in the FSC

Source: Adapted from Lundqvist et al., 2008 and Smil, 2000

The distribution of food losses and waste varies between developed and developing countries, and between rich and poor producers and consumers (Gustavsson et al., 2011; Hodges et al., 2010; Lundqvist et al., 2008). Overall food losses and waste are higher in developed countries than those in developing countries, with an average of 280-300 kg per capita per year food loss in Europe and North America and an average of 120-170 kg per capita per year food loss in Sub-Saharan Africa and South and Southeast Asia. In developing countries, the majority of the food losses occur in the first stages of the FSC (Gustavsson et al., 2011). This is due to poor harvesting technologies, lack of transport and poor storage in combination with extreme climatic conditions. In developed countries food waste during the consumption stage accounts for over 40% of the total food losses and waste in the FSC (Gustavsson et al., 2011).

2.2 Economic, environmental, and social implications of food waste

Food waste has substantial economic impact (Evans, 2011b; WRAP, 2011; Morrissey & Browne, 2004). The economic cost of global food wastage in 2007 was estimated at USD 750 billion (FAO, 2013). Quested et al. (2011) suggest that the food and drink wasted in UK homes that could have been eaten has a retail value of approximately £12 billion. WRAP's study estimates that each household throws away between £4.80 and £7.70 of food that

could have been eaten each week, which amounts to £250-£400 a year or £15,000-£24,000 in a lifetime (WRAP, 2007). The Sustainable Restaurant Association states that food waste costs UK restaurants approximately 2-3% of their turnover (Sustainable Restaurant Association, 2010).

Gustavsson et al. (2011) and Lundqvist et al. (2008) highlight the economic value of the food produced throughout the FSC. They suggest that avoidable food losses have a direct and negative impact on the income of both farmers and consumers. For the smallholders living on the margins of food insecurity, a reduction in food losses could have an immediate and significant impact on their livelihoods. For consumers affected by food poverty the priority is to have access to food products that are nutritious, safe and affordable. Food insecurity is often more a question of access (related to purchasing power and prices of food) than a supply problem. Improving the efficiency of the FSC has the potential to bring down the cost of food to the consumer and thus increase access. Considering the magnitude of food losses in the FSC, making profitable investments in reducing losses could be one way of reducing the cost of food.

The US Environmental Protection Agency (EPA) highlights the economic implications of food waste and encourages food producers, retailers and the food service sector to reduce food waste in order to achieve substantial cost savings. These costs are not only linked to reduced purchasing costs, but also to the final waste disposal costs (EPA, 2003, 2012). UNEP places emphasis on the economic benefits of resource efficiency and waste reduction and suggests that minimization of resource use, waste and other emissions have the potential to yield cost savings, identify new business fields, and increase employment and competitiveness (UNEP, 2011).

One of the main environmental impacts of food waste is related to its final disposal in landfills. When food waste is disposed in landfills, methane and carbon dioxide are produced as part of its natural decomposition process. Methane and carbon dioxide are GHGs contributing to climate change, with methane being the more potent of the two, trapping 21 times more heat than carbon dioxide (Adhikari et al., 2006). It is estimated that the waste sector accounts for approximately 3% of global GHG emissions, with the same figure applicable for the UK (Defra, 2011; UNEP, 2010; Stern, 2006). Defra identifies food waste as a priority waste stream for action as it accounts for almost half of all CO₂ emissions associated with waste in the UK (Defra, 2011).

Another environmental impact of food waste is linked to the embedded carbon from the previous life cycle stages of food before it became waste. Activities associated with the production of food such as agriculture (including land use change), processing,

manufacturing, transportation, storage, refrigeration, distribution and retail have an embedded GHG impact (Padfield et al., 2012; Tuncer & Schroeder, 2011; Lundqvist et al., 2008). Agriculture is associated with nearly 22% of all GHG emissions, with livestock production accounting for approximately 18% of total GHG emissions (Lundqvist et al., 2008; McMichael et al., 2007; Steinfeld et al., 2006).

Barrett and Scott (2012) analyze how the food sector is one area where significant reductions in GHG emissions are possible. They calculate that preventing food waste has the potential of a 456 million tons GHG emission reduction by year 2050 in the UK. WRAP estimates that avoidable food waste led to 17 million tons of CO₂ eq. in 2010, equivalent to the emissions of 1 in 5 cars on UK roads (WRAP, 2011). Within the European Union (EU), food, housing and transportation are the three sectors responsible for approximately 70% of overall environmental impact of human consumption and production (Tukker et al., 2010). Food products rank second in terms of highest production-cycle-wide resource use and environmental impact potential in Germany (Moll & Jose, 2006). It is estimated that the food sector is the cause of approximately 22% of the global warming potential in the EU (European Commission, 2006).

Other environmental impacts of food waste include natural resources depletion (such as soil nutrients, water and energy), the disruption of the biogenic cycles of nitrogen and phosphorus used in agriculture as fertilizers (Rockström et al., 2009; Smil, 2002), and the environmental pollution potential throughout the FSC but particularly during waste disposal (FAO, 2013; Lundqvist et al., 2008; Lundie & Peters, 2005).

In addition to environmental and economic impacts, food waste also has social implications (Salhofer et al., 2008). These tend to focus around the ethical and moral dimension of wasting food, in particular in relation to the inequality between on the one hand wasteful practices, and on the other food poverty (Evans, 2011c; Stuart, 2009; Wrigley, 2002). As the issue of global food security is becoming increasingly important in local and global agendas, the reduction of food losses and waste throughout the FSC, as well as alternative diets, are considered as a first step towards achieving food security (Haberl et al., 2011; Schönhart et al., 2009; Engström & Carlsson-Kanyama, 2004).

Edwards and Mercer (2007) make mention of the 'ethics of food waste' and explore the emergence of 'freeganism' and 'gleaning' movements in Australia as an alternative to current consumption patterns. These groups consume food that has been thrown away, in order to minimize their environmental impact and address social inequality in terms of food access (Edwards & Mercer, 2007). Gregson et al. (2013) highlight the conflict between the social values attached to 'thrift' and the environmental values that underpin re-use and the

implications of this conflict for waste generation and prevention. Evans (2011a) discusses the link between frugality and sustainable consumption, arguing that frugality relates to being moderate or sparing in the use of money, goods and resources with particular emphasis on careful consumption and the avoidance of waste. Evans suggests frugality has a strong moral dimension and is indeed linked to more sustainable forms of consumption (Evans, 2011b). This is particularly true to food waste and the notion that wasting or diverting food away from human consumption is immoral (Parfitt et al., 2010). Gregson et al. (2013) raise the significance of the social context in the transition of surplus, to excess and eventually to waste. Evans (2012) highlights the particular material culture of food waste that complicates and eventually prevents recirculation and recovery.

2.3 The time dimension

It is important to consider the dimension of time in the analysis of the food waste challenge and identify key parameters that will influence the scale and nature of the problem in the future (for a discussion on the time dimension of sustainability see Lozano, 2008). Two of these parameters are the growing world population and climate change. As the global population is rising, food waste generation is not diminishing and food security is becoming an increasingly urgent issue (Gustavsson et al., 2011; The Government Office for Science, 2011b; Lundqvist et al., 2008). In addition, while efforts to accurately predict the impact of climate change on crop yields and food production highlight uncertainties over future scenarios (Haberl et al., 2011), UNEP (2009) estimates that up to 25 % of the world food production may become 'lost' during this century as a result of climate change, water scarcity, invasive pests and land degradation. As previously discussed, food losses and waste across the FSC contribute GHG emissions linked to climate change. With climate change becoming an increasingly critical challenge, it is anticipated that the environmental implications of food waste will come under more scrutiny (FAO, 2013).

In addition, time is an important consideration in the discussion about food waste due to food's material nature i.e. it decomposes with time thus becomes inedible and eventually waste. Unlike other waste materials such as glass, metals, paper, plastic etc., food's properties change within a relatively short amount of time. For this reason, the time dimension is crucial to the transition of food into food waste (for a discussion on the implications of food's materiality on the broader socio-temporal context of food practices see Evans, 2011a). As a consequence, food's materiality and temporality becomes central to the interpretation and application of the waste hierarchy within the context of food waste.

3. Concepts in waste management and sustainability

The waste hierarchy and the concept of sustainable consumption and production provide the theoretical foundation to this study. An overview of these concepts is provided in the section below.

3.1 *The waste hierarchy*

The principles behind the waste hierarchy were introduced into European policy as early as the 1970s, with the 1975 Directive on Waste (European Parliament Council, 1975) and the EU's Second Environment Action Program in 1977 (European Commission, 1977). The waste hierarchy was then clearly defined in European legislation in the Community Strategy for Waste Management in 1989 (European Parliament Council, 1989). Since then, the waste hierarchy has been adopted worldwide as the principal waste management framework. Other frameworks promoted by Japan and countries across Asia, such as the '3Rs, provide a similar approach to waste management by prioritising the options of reducing, re-using and recycling waste (Sakai et al., 2011; Shekdar, 2009; Yoshida et al., 2007).

The aim of the waste hierarchy is to identify the options most likely to deliver the best overall environmental outcome. As illustrated in Figure 3, the most favorable option is 'prevention', and at the bottom of the inverted pyramid, the least favorable option is 'disposal'. Although the European Waste Framework Directive (European Parliament Council, 2008) advises the Member States to consider the social and economic impacts as well as the environmental, the waste hierarchy, as a framework, primarily focuses on delivering the best environmental option. The focus of the waste hierarchy on the environmental over economic factors has been the basis of criticism from a number of economist urging for the waste hierarchy to be considered as a flexible guideline for formulating waste strategies (Rasmussen et al., 2005; Porter, 2002; Price & Joseph, 2000).

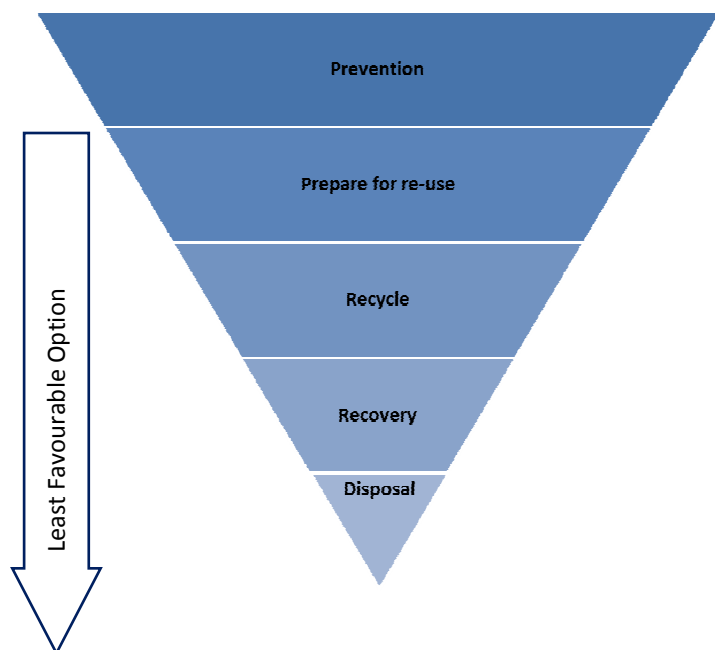


Figure 3: The Waste Hierarchy

Source: Adapted from European Parliament Council, 2008a

3.2 Sustainable production and consumption

The United Nations Environmental Program (UNEP, 2008) defines Sustainable Consumption and Production (SCP) as the “production and use of goods and services that respond to basic needs and bring a better quality of life, while minimizing the use of natural resources, toxic materials and emissions of waste and pollutants over the life cycle, so as not to jeopardize the needs of future generations”. In this context, the SCP approach is seen as a practical implementation strategy to achieve sustainable development, encompassing the economy, society and environment with the use of both technological and social innovation.

SCP policies include strategies aiming to decouple economic growth from environmental degradation, meet basic human needs, and avert the rebound effect, a term used to describe the phenomenon where the negative impacts of growing consumption outweigh the benefits of efficiency and technological improvements (Barrett & Scott, 2012; Sorrell & Dimitropoulos, 2008; Greening et al., 2000). SCP is an integrated approach, targeting both the supply of and demand for goods and services, by reducing the adverse impacts of both their production and consumption (UNEP, 2008).

On the sustainable production side, some traditional examples include cleaner production, pollution prevention, eco-efficiency and green productivity, although often the term ‘cleaner production’ is used as an umbrella term for all the sustainable production activities (Almeida

et al., 2013). On the consumption side, SCP connects the consumer with the product and the producer, allowing more sustainable choices to be made (Tukker et al., 2010). Some traditional examples include eco-labeling, sustainable procurement, supply chain management, waste minimization, recycling and resource efficiency measures (Tukker et al., 2010). However, one of the fundamental principles of SCP is the integration of sustainable production concerning the supply side, and sustainable consumption referring to the demand side of human economic activities (Tuncer & Schroeder, 2011). SCP embraces 'life-cycle thinking' in order to avoid problem shifting from one life cycle stage to another, one geographical area to another and one environmental medium to another (Clark, 2007).

Waste is often incorrectly considered as an issue that is more prominent in the consumption stage of a product's life (Tuncer & Schroeder, 2011). In reality, waste is generated throughout all the stages of production and consumption (UNEP, 2008). In line with SCP, sustainable resource and waste management is relevant to the whole life cycle of products and services. This study follows this approach, applying it to the food supply chain.

4. Methods

The authors conducted a number of interviews with food waste specialists that informed and shaped the development of the proposed framework for the management of food surplus and waste throughout the food supply chain. Seven group interviews were conducted with 23 food waste specialists. The group interviews were conducted with individuals from the following organizations: the Department for Environment, Food and Rural Affairs (Defra), the Waste and Resource Action Program (WRAP), Fareshare, Brook Lyndhurst, the Sustainable Restaurant Association (SRA), Harper Adams University College and SKM Enviros. The organizations were selected to represent different food waste stakeholders, such as government bodies, private companies, non-governmental and not-for-profit organizations. The selected organizations focus on different elements of food surplus and waste management, including policy development and delivery, strategy implementation, food waste treatment operation, research, food poverty reduction, engineering and consultancy. Table 2 presents a brief profile of the interviewed organizations.

Table 2: Interviewed organizations' profile

Organization	Role
Defra	Responsible for producing the waste strategy for England and Wales
WRAP	Responsible for delivering Defra's waste policy

Fareshare	UK charity that redistributes food surplus to groups affected by food poverty
Brook Lyndhurst	Research and strategy consultancy
Sustainable Restaurant Association	'Not-for-profit' membership organization that assist restaurants in becoming more sustainable
Harper Adams University College	Agricultural university that treats organic waste with an on-campus anaerobic digestion plant
SKM Enviros	Environmental engineering consultancy

UK based organizations were selected for the interviews due to the UK's strong commitment and focus on addressing food waste, and the recent evidence of food waste prevention (WRAP, 2011). The latest estimates suggest that the UK food waste household generation was reduced by approximately 13 % in the period between 2006/07 and 2009/10 (WRAP, 2011). Although a number of different factors are likely to have contributed to the observed decrease of food waste generation at the household, this figure is nonetheless a commendable result towards food waste prevention. In addition, England managed to increase the average household waste recycling rate from 10 % in the year 2000/01, to 40 % in year 2010/11 (Defra, 2011).

4.1 Data collection

The interviews were a combination of semi-structured and in-depth interviews. This interview format provided a degree of structure in order to cover specific key questions, but equally, offered flexibility by allowing the introduction of new questions (Saunders et al., 2009). The group interviews provided insight into the current practices, future trends, barriers and opportunities for more sustainable management of food surplus and waste. An interview framework was prepared in advance to provide a general guide to the discussions, including:

- i. Brief organization profile and role of individuals within it
- ii. Current role and practices of organization, in relation to food surplus and waste
- iii. Motivation and drivers for more sustainable management of food surplus and waste
- iv. Barriers and constraints to more sustainable management of food surplus and waste
- v. Opportunities and suggestions for more sustainable management of food surplus and waste

4.2 Data analysis

The qualitative data collected during the interviews were analyzed through a series of analytical processes linked to the grounded theory research approach (for more information on grounded theory see Saunders et al., 2009; Jupp, 2006; Glaser & Strauss, 1967). Initially the data collected in the form of interview notes were classified into meaningful categories partially derived from the interview framework and from the data themselves. This process revealed three key themes, namely the distinction between food surplus and food waste, between avoidable and unavoidable waste, and finally between waste prevention and waste management. Following this, emergent patterns and relationships amongst the key themes were identified through the processes of reduction and rearranging of the data into more manageable and comprehensible forms. Once the relationships between food surplus and food waste, and between avoidable and unavoidable waste were mapped, the options for prevention and management were identified and prioritized according to the principles of the waste hierarchy. Finally, the key themes, the relationships between them and the prioritized options for prevention and management, were synthesized and presented in the food surplus and waste framework discussed below.

4.3 Limitations

This study proposes a framework for addressing the food waste challenge. The proposed options and the prioritization of these options were derived based primarily on the environmental and social aspects of food surplus and waste, when comparing options like for like. Whether the most favorable options are financially more advantageous than the least favorable options, and whether there is only one answer to this question, can be argued. A cost benefit analysis of the options in the proposed framework is outside the scope of this study, however such an exercise would be useful in validating this framework in real-life, specific scenarios. As with any framework, it intends to act as a guide in the decision making process and not provide a 'one solution fits all' approach. This paper draws on expertise and experiences from Europe, in particular the UK. Contributions from other parts of the world would complement this study and increase its generalizability. Threats to reliability and validity of the research findings, such as subject error and bias, and observer error and bias were minimized by carefully formulating the research design (Saunders et al., 2009).

5. Findings and discussion

The findings of the study are presented below. The discussion is structured under the three main themes that emerged from the interviews; namely the boundaries between food surplus

and food waste, avoidable and unavoidable food waste, waste prevention and waste management.

5.1 Food surplus, food security and waste

The first theme that emerged from the interviews relates to the issues of food surplus, food security and waste, and the relationships between them. During the interviews it became apparent that the distinction between the terms 'food surplus' and 'food waste' is essential to a more sustainable approach to addressing food waste. Often food surplus is incorrectly referred to as food waste, missing the subtle difference between the two terms, as Fareshare points out. However, food surplus is food produced beyond our nutritional needs, and waste is a product of food surplus. Interviewees from Brook Lyndhurst advise that up to a point, food surplus acts as a safeguard against unpredictable weather patterns affecting crops. However, as interviewees from WRAP highlight, the current scale of global food surplus is in fact threatening, not safeguarding, global food security. Comparing the average daily nutritional needs per person against the actual food available at the retail level in high-income countries highlights the growing gap between food production and consumption.

This argument is prominent in the literature, where agronomists suggest that a food supply of 130 % over our nutritional needs should guarantee food security (Smil, 2004; Bender & Smith, 1997). The actual daily food requirements are rarely above 2,000 kcal per person per day. Applying an increase of 130 %, an approximate 2,600 kcal per person per day food supply should be sufficient to cover daily nutritional needs and ensure food security (Lundqvist et al., 2008; Smil, 2004; Bender & Smith, 1997). However, according to FAO's food balance sheets, retail in high income countries now make available over 3,000 kcal of food per person per day (FAO, 2010). The figure for the US exceeds 3,800 kcal per person per day and the EU mean is 3,500 kcal per person per day (Smil, 2004). Comparing the food made available with the actual food requirements (covering nutritional needs and a buffer for food security) reveals the extent of undesirable food surplus of over 1,000 kcal per person per day in some high-income countries.

According to Fareshare, inequalities in access to the global FSC exist not only between affluent and poorer countries, but also within individual countries. The number of people affected by food poverty is increasing even within the most affluent countries in the world, especially during the current economic recession. The disparity between food waste on one hand and food poverty on the other, draws attention to the social and ethical implications of food waste. Therefore, making the distinction between the 'desired' food surplus acting as a safeguard of food security, the undesired excessive food surplus and food waste, is particularly relevant when considering the options available to combat food waste.

5.2 Avoidable and unavoidable food waste

An important distinction in the process of developing a sustainable framework for addressing food waste is the one between 'avoidable' and 'unavoidable' food waste. This distinction provides insight into the degree to which food waste prevention is feasible or not, thus it is pivotal in the formulation of strategies for food waste minimization, as Brook Lyndhurst and Defra suggest.

WRAP defines avoidable food waste as food thrown away because it is no longer wanted or has been allowed to go past its best. The vast majority of avoidable food is composed of material that was, at some point prior to disposal, edible, even though a proportion is not edible at the time of disposal due to deterioration (e.g. gone moldy).

Avoidable food waste includes foods or parts of food that are considered edible by the vast majority of people. Unavoidable food waste is described as waste arising from food that is not, and has not been, edible under normal circumstances. This includes parts of foods such as fruit skin, apple cores and meat bones. Although this classification provides insight into the degree to which food waste prevention is feasible (i.e. there will always be an amount of food waste produced that is unavoidable) it can be subjective, as WRAP explains. What is considered edible by 'a majority of people' depends on a number of factors, such as culture in the form of shared values and common practices, religious beliefs, social norms and personal preferences.

Brook Lyndhurst, Defra and WRAP interviewees stress the significance of the distinction between avoidable and unavoidable food waste, as it reveals how unnecessary food waste is and emphasizes the substantial potential for food waste prevention.

5.3 Waste prevention and waste management

The third theme that emerged from this study involves the distinction between the terms 'waste prevention' and 'waste management'. There are occasions when the waste hierarchy is wrongly referred to as the waste management hierarchy, interviewees from Defra point out. This misconception originates from the fact that the hierarchy was initially developed as a tool designed to assist in identifying the most appropriate solution once waste has been generated.

Waste prevention includes activities that avoid waste generation, for instance, reduction of food surplus, whereas waste management includes the options available to deal with food waste once it has been generated, such as composting and anaerobic digestion, SKM Enviros explains.

The SRA explains how first they provide practical advice to restaurants on methods to avoid food waste generation as a priority, and then suggest more sustainable ways to manage the remaining food waste.

Defra's policy on food waste makes the distinction between waste prevention and management clear, although, as the interviewees from Book Lyndhurst add, waste prevention is a lot more challenging to achieve.

As the concepts of sustainable resource management, life cycle management and sustainable consumption and production alter the way 'waste' is perceived, the divide between waste prevention and waste management becomes more apparent.

5.4 Food surplus and waste framework

The three themes that emerged from this study informed the proposed food waste framework presented in Figure 4. The proposed framework interprets and applies the waste hierarchy in the context of food waste, provides and prioritizes options for dealing with food surplus, avoidable and unavoidable food waste. The most favorable options are presented first and are placed at the top of the framework, with the least favorable options presented lower down the framework. The prioritization of the options for dealing with food surplus and food waste is based on the waste hierarchy. The framework is summarized into the food waste hierarchy presented in Figure 5.

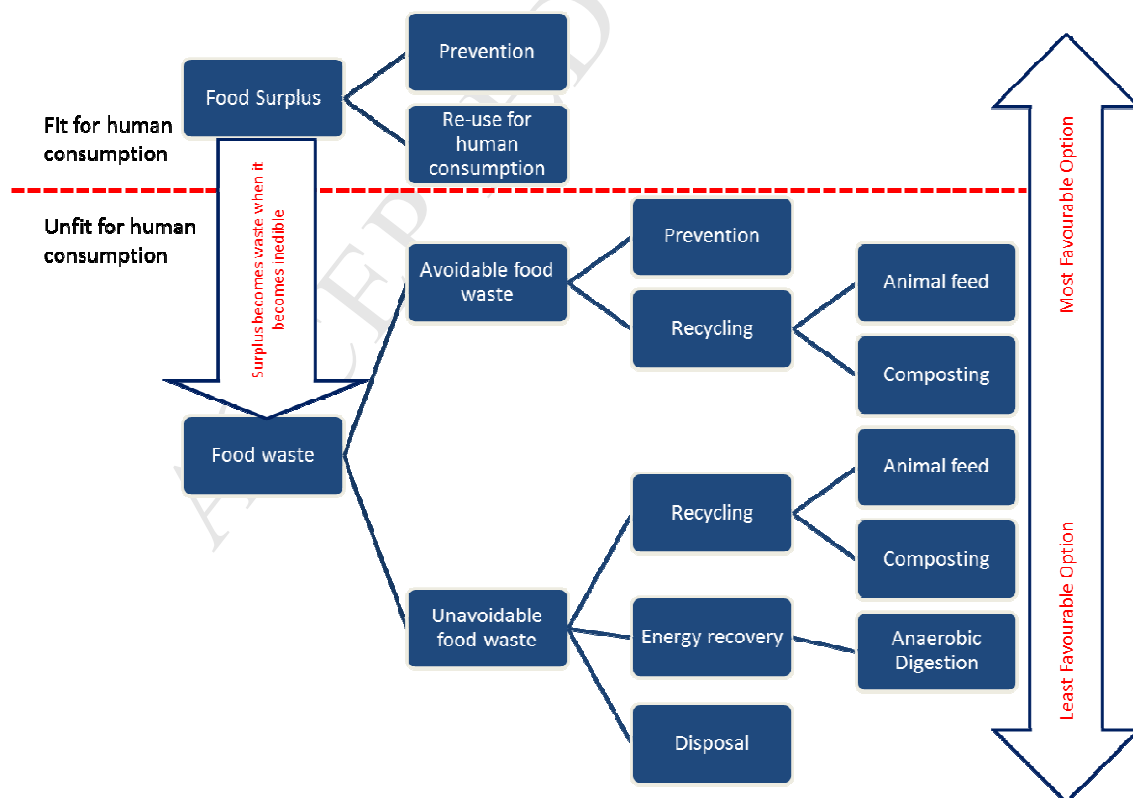


Figure 4: Food surplus and waste framework

Starting from the issue of the undesirable food surplus, the priority is to prevent overproduction and oversupply of food beyond human nutritional needs at all the stages of the FSC. In agriculture and food production, this includes production of only the necessary amount of food to cover global nutritional needs and safeguard food security. In retail and the consumption stages, such as the food service sector and households, food surplus prevention includes the supply of only what is required, correct portion sizing and addressing unsustainable consumption patterns. For the surplus food that has not been consumed, the option of redistributing it to groups affected by food poverty is proposed; assuming food safety can be ensured.

As illustrated in Figure 4, the instant food surplus becomes unfit for human consumption it becomes food waste. At that point, the distinction between avoidable and unavoidable food waste becomes central in the decision making process for the most appropriate waste management options. The greatest potential for prevention of avoidable food waste in developing countries lies in the earlier stages of the FSC where the majority of the food losses are observed. This includes improved agricultural infrastructure, technological skills and knowledge, more efficient storage, transport and distribution techniques. Food waste prevention in developed countries should focus more on the retail and consumption stages such as the food service sector and consumers. A shift to more sustainable consumption patterns and practices, and increased awareness of food waste's impact on the environment, have the potential to reduce generation of avoidable food waste. Other methods of preventing avoidable food waste include improved food labeling, better consumer planning when shopping and preparing food, as well as technological improvements in packaging and improving shelf life for perishable foods. Once the options for prevention are exhausted (as far as practicably feasible), it is proposed for avoidable food waste to be recycled into animal feed, and via composting as a secondary option, when recycling into animal feed is not feasible. Once recycling efforts are exhausted, treatment of food waste with energy recovery, such as with anaerobic digestion, is the next preferred option. Finally, disposal in landfill is the least favorable option for managing the remaining fraction of unavoidable food waste once all the other options are exhausted.

Finally, the proposed food surplus and waste framework is summarized into the food waste hierarchy presented in Figure 5.

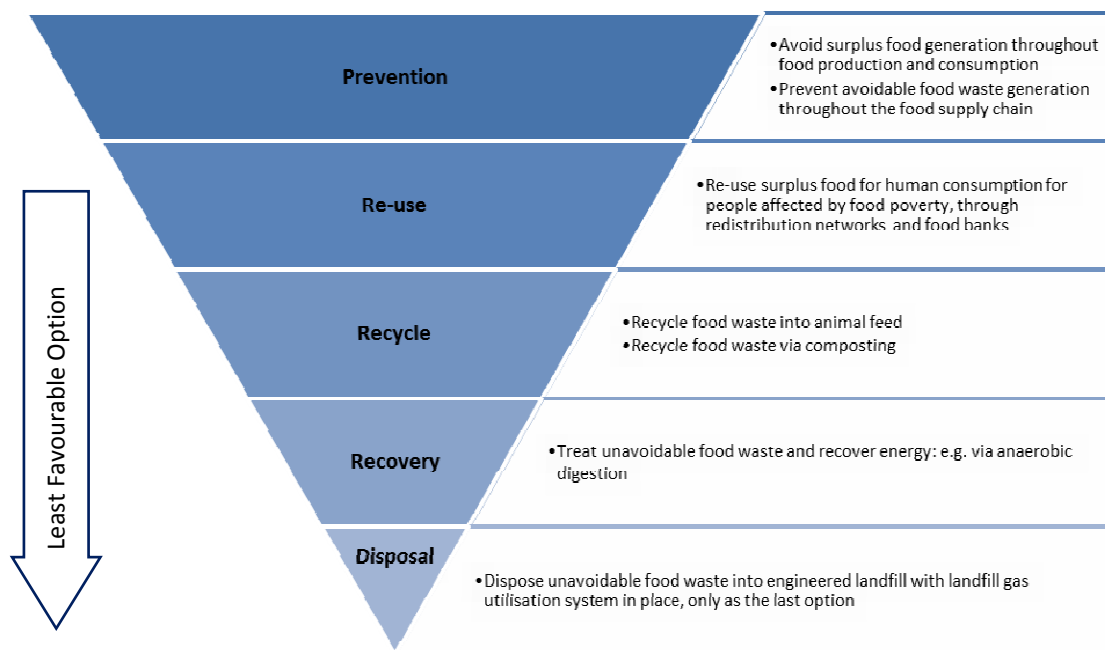


Figure 5: The Food Waste Hierarchy

6. Conclusions

Food waste is becoming an increasingly important issue at both a local and global level. The GHG emissions from food production and consumption, as well as from its final disposal, depletion of natural resources and pollution are the most prominent environmental impacts associated with food waste. Food waste has economic implications for everyone within the food supply chain, from the farmer to the food producer and the consumer. These include food production and purchasing costs, as well as costs associated with the final disposal of food waste. In the context of a fast growing world population and diminishing natural resources, the disparity between food poverty and food wastage raises concerns over global food security and highlights the social and moral dimensions of food waste.

Considering the environmental, economic, social implications of food waste through time, this study suggests that the first step towards a more sustainable resolution of the growing food waste issue is to adopt a sustainable production and consumption approach and tackle food surplus and waste throughout the entirety of the global food supply chain, as opposed to focusing only on the consumption stage. The distinction between food surplus and food waste on one hand, and avoidable and unavoidable food waste on the other, are crucial in the process of identifying the most appropriate options for addressing the food waste challenge.

By applying the waste hierarchy in the context of food, this study proposes the food waste hierarchy as a framework to identify and prioritize the options for the minimization and management of food surplus and waste throughout the food supply chain. The resulting food

waste hierarchy considers the three dimensions of sustainability (environmental, economic, and social), offering a more holistic approach in addressing the food waste issue. Additionally, the food waste hierarchy takes into account the materiality and temporality of food and encompasses the dimension of time in the discussion. Prevention, in the form of food surplus and avoidable food waste reduction, features as the most advantageous option within the food waste hierarchy. Although prevention requires a fundamental re-think of the current practices and systems in place, it has the potential to deliver substantial environmental, social and economic benefits.

The proposed food waste hierarchy aims to challenge the current waste management approach to food waste, contribute to the debate about waste management and food security, and influence the current academic thinking and policies on waste and food to support more sustainable and holistic solutions. The authors hope that the food waste hierarchy is relevant to policy makers, waste producers throughout the food supply chain, as well as researchers. In the case of minimizing food waste produced in the household, interventions should tackle both the individual practices of consumers, and the material and social context within which food waste is generated. Preventing food waste in agriculture and food processing requires improved infrastructure and technological solutions in harvesting, storage, transport and distribution, supported by large-scale investment and local policies. Additionally, the issue of food waste should be considered earlier within the food supply chain in order to capture and maximize the waste prevention opportunities. Waste management policies should be integrated and aligned with the wider policies on food, agriculture, food standards, food poverty alleviation and sustainable production and consumption. Finally, further research is required to provide the evidence base to support this shift to a more sustainable food surplus and waste management and to inform policy implementation.

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Table 1: Examples of food waste and losses throughout the food supply chain

Stage	Examples of food waste/loss
Harvesting – handling at harvest	Edible crops left in field, ploughed into soil, eaten by birds, rodents, timing of harvest not optimal: loss in food quality Crop damaged during harvesting/poor harvesting technique Out-grades at farm to improve quality of produce
Threshing	Loss through poor technique
Drying – transport and distribution	Poor transport infrastructure, loss owing to spoiling/ bruising
Storage	Pests, disease, spillage, contamination, natural drying out of food
Primary processing – cleaning, classification, dehulling, pounding, grinding, packaging, soaking, winnowing, drying, sieving, milling	Process losses Contamination in process causing loss of quality
Secondary processing – mixing, cooking, frying, molding, cutting extrusion	Process losses Contamination in process causing loss of quality
Product evaluation – quality control: standards recipes	Product discarded/out-grades in supply chain Destructive testing
Packaging – weighing, labeling, sealing	Inappropriate packaging damages produce Grain spillage from sacks attack by rodents
Marketing – publicity, selling, distribution	Damage during transport: spoilage Poor handling in wet market Losses caused by lack of cooling/cold storage
Post-consumer – over- or inappropriate purchasing, storage, preparation, portioning and cooking	Buying more than is needed Plate scrapings and surplus food cooked and not used Poor storage/stock management in homes: discarded before serving Poor food preparation technique: edible food discarded with inedible Food discarded in packaging: confusion over 'best before' and 'use by' dates
End of life – disposal of food waste/ loss at different stages of supply chain	Food waste discarded may be separately treated, fed to Livestock/poultry, mixed with other wastes and landfilled

Source: Adapted from The Government Office for Science 2011a; Parfitt et al. 2010

Table 2: Interviewed organizations' profile

Organization	Role
Defra	Responsible for producing the waste strategy for England and Wales
WRAP	Responsible for delivering Defra's waste policy
Fareshare	UK charity that redistributes food surplus to groups affected by food poverty
Brook Lyndhurst	Research and strategy consultancy
Sustainable Restaurant Association	'Not-for-profit' membership organization that assist restaurants in becoming more sustainable
Harper Adams University College	Agricultural university that treats organic waste with an on-campus anaerobic digestion plant
SKM Enviros	Environmental engineering consultancy

Highlights

Food waste has significant environmental, social and economic global implications
The food waste hierarchy is proposed for preventing and managing food surplus and waste
Distinction between food surplus and waste is crucial in the food waste hierarchy
The food waste hierarchy also distinguishes between avoidable and unavoidable waste
Food waste can be prevented by reducing food surplus throughout the food supply chain

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