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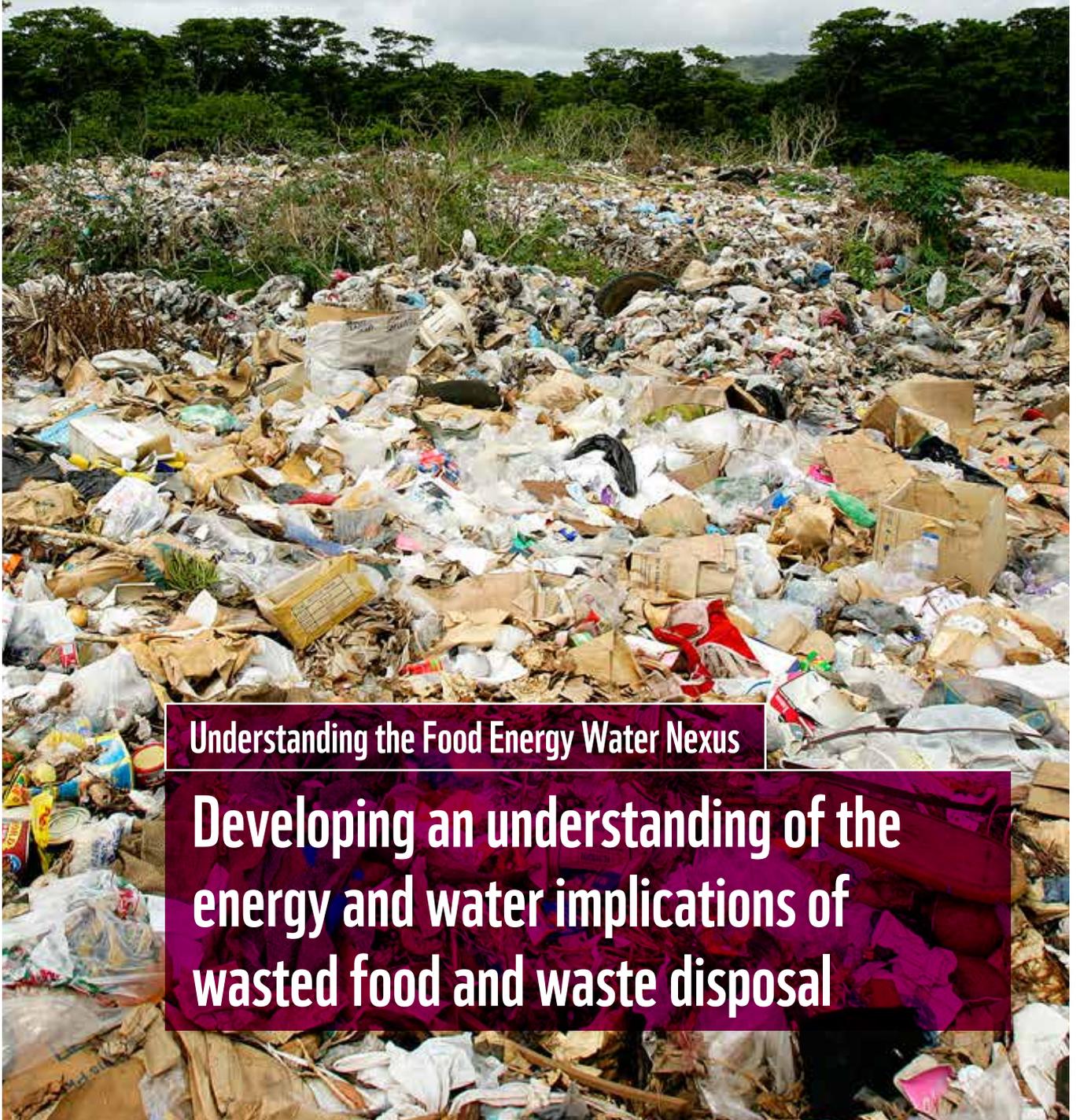
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Understanding the Food Energy Water Nexus

Developing an understanding of the  
energy and water implications of  
wasted food and waste disposal

# AUTHORS

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# ABOUT THIS STUDY

Food, water and energy security form the basis of a self-sufficient economy, but as a water-scarce country with little arable land and a dependence on oil imports, South Africa's economy is testing the limits of its resource constraints. WWF believes that a possible crisis in any of the three systems will directly affect the other two and that such a crisis may be imminent as the era of inexpensive food draws to a close.

WWF received funding from the British High Commission to establish a research programme exploring the complex relationship between food, water and energy systems from the perspective of a sustainable and secure future for the country. This paper is one of nine papers in the Food Energy Water Nexus Series.

# PAPERS IN THIS STUDY

1. *Climate change, the Food Energy Water Nexus and food security in South Africa:* Suzanne Carter and Manisha Gulati
2. *Developing an understanding of the energy implications of wasted food and waste disposal:* Philippa Notten, Tjasa Bole-Rentel and Natasha Rambaran
3. *Energy as an input in the food value chain:* Kyle Mason-Jones, Philippa Notten and Natasha Rambaran
4. *Food inflation and financial flows:* David Hampton and Kate Weinberg
5. *The importance of water quality to the food industry in South Africa:* Paul Oberholster and Anna-Maria Botha
6. *The agricultural sector as a biofuels producer in South Africa:* Alan Brent
7. *Virtual water:* James Dabrowski
8. *Water as an input into the food value chain:* Hannah Baleta and Guy Pegram
9. *Water, energy and food: A Review of integrated planning in South Africa:* Sumayya Goga and Guy Pegram

# ABOUT WWF

The World Wide Fund for Nature is one of the World's largest and most respected independent conservation organisations, with almost five million supporters and a global network active in over 100 countries. WWF's mission is to stop the degradation of the Earth's natural environment and to build a future in which humans live in harmony with nature, by conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

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# EXECUTIVE SUMMARY

This paper reviews the available information on the food waste issue in South Africa, and extrapolates this to give ballpark estimates of the energy and water costs associated with this wastage.

Unsustainably high food wastage and loss occurs, with roughly one-third of the edible portion of food produced for human consumption lost or wasted globally (FAO 2011). Particularly notable is that this high wastage and loss occurs in both developed and developing world regions. The major difference, however, is that food wastage in developing countries primarily occurs at an early stage in the food value chain, while in industrialised countries, wastage occurs primarily at the retail and consumption stages. These high levels of food wastage have important consequences for the Food Energy Water Nexus because of the high energy, water and land inputs associated with agricultural production. When food is wasted, all the embedded energy and water required to produce it is also wasted.

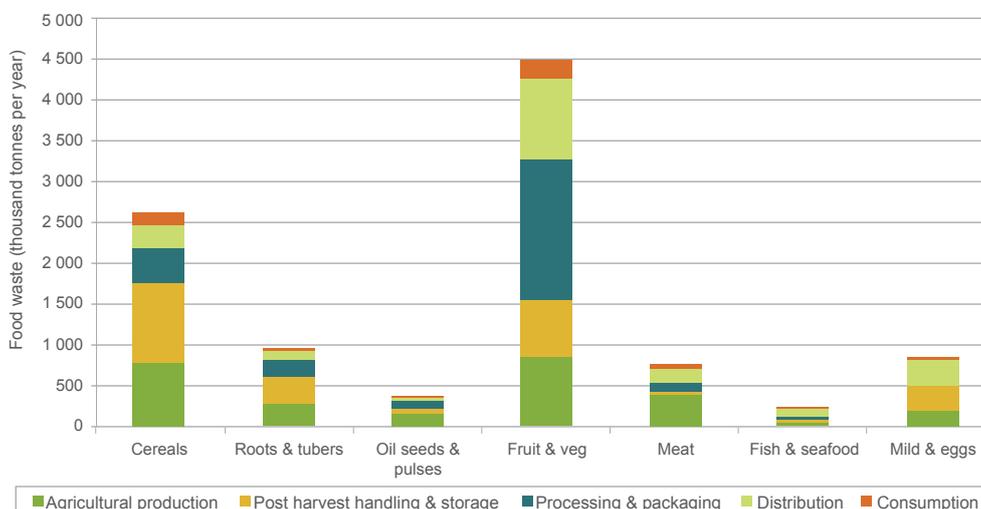
The term food waste is applied here in a broad sense to include both food losses and food wastage, i.e. it includes all food originally intended for human consumption that is ultimately never consumed. Food losses at the production, post-harvest and processing stages of the food value chain occur as a result of inefficiencies in the food supply chain such as poor infrastructure, poor logistics and a lack of access to markets. At the other end of the value chain, food wastage results from oversupply and poor management at the retail stage, and from wasteful consumer behaviour. Food waste includes only the edible portion of food that is wasted; it does not include unavoidable food waste such as bones, organs, skins, seeds and peels.

Nahman and De Lange (2013) estimate that about 10 million tonnes of food is lost to waste in some form or other across the supply chain – from an estimated 31 million tonnes of food available in South Africa. This translates to a per capita food waste of about 210 kg per person per year, assuming the average population for South Africa was 48.6 million in 2007–2009 (DAFF 2012). The spread of this food waste across seven key food commodity groups is shown in Figure A1 – redrawn from the results of Nahman and De Lange (2013), who apply food wastage percentages for sub-Saharan Africa from a study by the Food and Agriculture Organization (FAO) and annual average food production and consumption data for South Africa,<sup>1</sup> to estimate the tonnes of food lost at five points in the food supply chain: agricultural production, post-harvesting handling and storage, processing and packaging, distribution and retail, and the consumer. Food wastage is highest for fruit and vegetables, where over 50% of produce is wasted along the supply chain, primarily at the processing and packaging stage. Cereals and potatoes also show high tonnages of avoidable food wastage, with the majority of the wastage occurring at the post-harvest handling and storage stage. Meat and milk are wasted to a lesser extent (at around 25% of production).

Figure A1 also shows that the bulk of food wastage in South Africa occurs at the early stages of the food value chain. Consumer waste is low for all commodities, while for fruit & vegetables and fish & seafood, and to a lesser extent meat and milk, distribution losses also play a significant role. However, to calculate these food wastage estimates, South Africa’s food waste profile is taken as that of sub-Saharan Africa as a whole so this supply chain breakdown is to be expected. These figures should therefore only be taken as preliminary rates, as food wastage across supply chains in South Africa is potentially very different from other sub-Saharan African countries. On the one hand South Africa has more sophisticated distribution networks and infrastructure, which reduce wastage prior to food reaching the consumer, but on the other hand there are more affluent consumers and an associated increase in wastage.

**Figure A1: Estimated food waste in South Africa per food commodity group**

Source: Nahman & De Lange (2013)



<sup>1</sup> Food production and consumption data for South Africa sourced from the FAO Food Balance Sheets, and applied as a three-year average (2007–2009).

A ballpark figure for the cost of embedded energy wasted as a consequence of food waste is R1 billion. This figure should be viewed with extreme caution – it uses extremely rough commodity wide estimates of the embedded energy of food products, an extremely approximate combined diesel and electricity cost, and high uncertainty in estimating waste quantities based on statistics for sub-Saharan Africa. Nonetheless, it is evident that the quantity is very large, with the energy wasted every year in South Africa for producing food that is never consumed estimated to be sufficient to power the City of Johannesburg for roughly 16 years. Also notable is the fact that the food products with the highest waste tonnages contribute the least to this overall cost. For example, fruit and vegetables account for 44% of the food waste, but for just 15% of the cost of wasted energy.

About 1.7 km<sup>3</sup> of water is extracted from ground and surface water bodies to produce food that is subsequently wasted in South Africa (using 2012 figures). This is around one-fifth of South Africa's total water withdrawals and represents approximately 600 000 Olympic-sized swimming pools, at a ballpark cost of R260 million. The production of waste fruit and vegetables accounts for the largest share, with the production of waste cereals and meat also being significant contributors to the cost of the embedded water wasted.

These water and energy costs, together with the cost of disposing of the waste, means that food wastage comes at a very significant price to the South African economy and environment. Furthermore, the landfill disposal of food waste represents the loss of a valuable energy resource. Food waste offers considerable potential for energy generation, with anaerobic digestion in particular being a well-established technology for producing biogas that can subsequently be burnt to produce heat and/or electricity. However, a lack of clarity in waste regulations and a lack of information on the quality and quantities of food waste available are currently barriers to the uptake of waste-to-energy applications.

The scale and spread of the wastage problem means that reducing high levels of waste is beyond the capability of individual farmers, distributors, retailers or consumers. With the highest overall waste tonnages and costs, the supply chain of fruit and vegetables is a clear target area (especially the processing and packaging stages).

However, from an energy and climate perspective, addressing waste in the production of cereals and meat offers the greatest potential gains. The meat supply chain (both the production and distribution of meat) is also of high priority in terms of water provision impacts and costs to the economy. The actions required to reduce food waste are well known; the challenge is transferring this knowledge to where it is needed, and to create the political and social environment conducive to adopting the available ideas.

Recent studies on food waste, both locally and globally, have revealed major data gaps in the knowledge about global food waste, especially with regard to quantifying food losses at various stages in the supply chain. Furthermore, when data is available, it is often accompanied by major uncertainties. Global efforts such as the Food Loss and Waste Protocol guidance document currently under development will be helpful, but further research in South Africa is essential as it is not possible to accurately cost the problem, or to determine the potential for energy recovery from food waste, without first knowing where and at what quantities and qualities the waste is being generated.

## KEY WORDS

Food waste, food loss, food value chain, food supply chain, energy implications, water implications, energy cost

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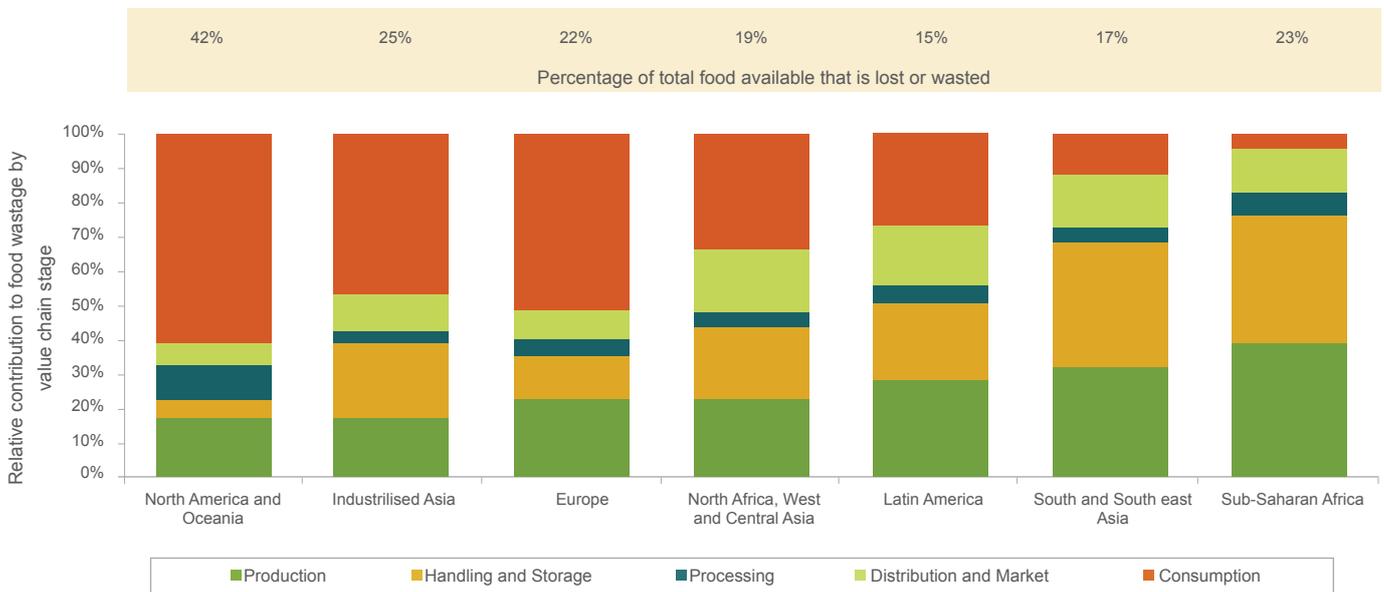
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# 1. INTRODUCTION

WWF has launched a research initiative titled *Understanding the Food Energy Water Nexus* and its vulnerability to climate change to inform policy, planning and business practice in South Africa. The research aims to develop an understanding of the complex relationship between water, energy and food systems from the perspective of ensuring a sustainable and secure future for South Africa.

This paper considers the implications of wasted food and its associated waste disposal for the Food Energy Water Nexus. Until fairly recently, food waste was a surprisingly neglected topic, but it received prominence with the release of a report by the Food and Agricultural Organization (FAO) of the United Nations – *Global Food Losses and Food Waste* – in 2011. This report revealed that roughly one-third of the edible portion of food produced for human consumption is lost or wasted globally – an amount of about 1.3 billion tonnes per year. Particularly interesting is the finding that this high wastage and loss of food occurs across the globe, with the percentage of food lost or wasted ranging between 15 and 25% of the total food available (Lipinski et al. 2013). The exception is North America and Oceania, where food loss and waste is approximately 42% of the total food available (see Figure 1). As could be expected to a degree, in North America and Europe the bulk of the food wastage occurs at the consumer level (FAO 2011).<sup>2</sup> However, when the whole food supply chain is considered, depending on the particular food group, the percentage produced that is never consumed can be as high in developing countries as it is in industrialised countries (FAO 2011).<sup>3</sup> The major difference, however, is that food losses in developing countries occur primarily at the post-harvest and processing stages, while in industrialised countries food losses occur primarily at the retail and consumption stages (see Figure 1, with the aspects of food loss and wastage considered at each stage in the value chain given in Box 1).

Figure 1: Food lost or wasted by region and stage in the food supply chain in 2009 - food calorie basis



Source: Lipinski et al. (2013). World Resources Institute (WRI) analysis based on data in *Global Food Losses and Food Waste* (FAO 2011).

<sup>2</sup> Per capita food waste estimated at 280–300 kg/year in Europe and North-America, and 120–170 kg/year in sub-Saharan Africa and South/Southeast Asia. However, food waste by consumers is estimated at 95–115 kg/year in Europe and North America, and at only 6–11 kg/year in sub-Saharan Africa and South/Southeast Asia.

<sup>3</sup> For example, North Africa, West and Central Asia have the highest waste rates of fruit and vegetables, while North American and Oceania have the highest waste rates of roots and tubers.

## BOX 1

### Aspects of food loss and waste considered across the food value chain

Agricultural production	Postharvest handling and storage	Processing	Distribution	Consumption
<b>Losses Occurring</b>				
During or immediately after harvesting on the farm	During handling, storage and transportation between farm and distribution	During domestic or industrial processing and/or packing	During distribution to market and at wholesale markets, supermarkets and other retail outlets	In the home or business of the consumer
<b>For vegetable commodities and products includes:</b>				
Mechanical damage and/or spillage during harvesting (e.g. in threshing or fruit picking)	Crops eaten or damaged by pests, fungus or disease	Produce rejected as not suitable for processing;	Product rejected for being below quality	Product rejected for quality reasons
Crops rejected in post harvest sorting for not meeting quality standards		Spillage and degradation during processing (e.g. in juice production, canning etc.)	Product expiry before purchase	Product expiry before consumption
Crops left behind in fields due to poor mechanical harvesting or sharp drops in prices		Losses occurring during washing, peeling, slicing and boiling	Product spillage or degradation at markets	Product cooked but not eaten
		Losses occurring during process interruptions and accidental spillages		
<b>For Animal commodities and products includes:</b>				
Animal deaths during breeding	Animal deaths during transport to slaughter and condemnation at slaughterhouse	Trimming during slaughtering and losses during additional industrial processing, e.g. sausage production	Product rejected for being below quality	Product rejected for quality reasons
Milk discarded due to dairy cow sickness (mastitis)	Milk spillage and degradation during transportation	Milk spillage during industrial milk treatment (e.g. pasteurization) and processing to other dairy products, e.g. cheese and yoghurt	Product expiry before purchase	Product expiry before consumption
			Product spillage or degradation at markets	Product cooked but not eaten
<b>For fish and seafood products includes:</b>				
Discards during fishing	Spillage and degradation during icing, packing, storage and transportation after landing	Losses during industrial processing such as canning or smoking	Product rejected for being below quality	Product rejected for quality reasons
			Product expiry before purchase	Product expiry before consumption
			Product spillage or degradation at markets	Product cooked but not eaten

Source: *Global Food Losses and Food Waste (FAO 2011)*

This high level of food wastage across the globe has a number of sustainability implications:

- It represents a missed opportunity to improve global food security. Estimates are that food production needs to be 60% higher by 2050 if production is to meet the demands of a growing world population (FAO 2012). The World Resources Institute (WRI) estimates that cutting global food wastage by half could close the gap between the food available today and that needed in 2050 by roughly 22% (on a food calorie basis). Reducing food loss and waste could thus be one of the leading global strategies for achieving a sustainable food future (Lipinski et al. 2013).
- The high energy, water and land inputs associated with agricultural production are well known. Thus food wastage represents a significant waste of these important resources. The environmental impacts associated with these wasted resources have been estimated in a recent study, Food Wastage Footprint, Impacts on Natural Resources (FAO 2013a). To produce the food that is ultimately never consumed every year requires 250 million m<sup>3</sup> of fresh water (blue water, in the terminology of the Water Footprint Network – approximately the volume of 100 million Olympic-sized swimming pools) and 1.4 billion ha of land (nearly 15% of the land surface area of the planet). In addition, it causes 3 300 million tonnes of greenhouse gases (carbon dioxide equivalent, or CDE) to be emitted. This is more than the annual national greenhouse gas emissions estimate of any country, with the exception of China and the USA. Reducing food wastage can therefore play a large role in reducing global water demand and greenhouse gas emissions, as well as pressure on competition for land resources for ecosystem preservation and water provision.
- Disposal of food waste in landfills represents a further waste of resources, where food waste could be used as a source of energy, as animal feed, or to make compost. The environmental costs of food waste are further exacerbated by the energy required for landfill disposal; also, unless measures have been put into place, methane gas<sup>4</sup> is emitted when it degrades. The scale of the problem is indicated by the fact that 1.3% of global greenhouse gas emissions are attributed to landfills,<sup>5</sup> with food waste (which makes up a considerable share of the organic waste in landfills) giving rise to these emissions.

This paper explores the food wastage issue in South Africa, and particularly its implications for energy and water. When food is wasted, all the embedded energy and water required to produce it is also wasted. This occurs throughout the food value chain – in agriculture, transportation, processing, packaging, storage, retail and preparation. Food waste therefore does not represent a problem only because of its disposal, even though the impacts due to the disposal of organic waste in landfills are considerable, but also because of the energy, water and other resources consumed throughout its value chain that can also be considered wasted as a result.

This paper starts by looking at available information on food wastage in South Africa with the view to estimate the scale of the problem, both in terms of the mass of food waste produced and the wasteful consumption of energy and water associated with producing food waste in South Africa. The second part of the paper looks at what can be done about the food waste problem, looking first at the regulatory environment concerning organic waste and the potential for energy recovery from food waste, and finally at actions that can be taken by key role-players in the food value chain to prevent food wastage from occurring.

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<sup>4</sup> The latest IPCC assessment report puts methane as 34 times more potent than carbon dioxide in terms of its contribution to global climate change (IPCC 2013).

<sup>5</sup> <http://www.ecofys.com/files/files/asn-ecofys-2013-world-ghg-emissions-flow-chart-2010.pdf>

## 2. FOOD WASTE AND ITS IMPACTS IN THE VALUE CHAIN

### 2.1 WHAT IS MEANT BY FOOD WASTE?

There is no globally accepted definition for food waste, and the term food waste is applied in this paper in the broader sense to encompass both food losses and food wastage:

- Food loss refers to food originally intended for human consumption but that never reaches the consumer. It thus occurs in the stages preceding retail and the consumer – at the production, post-harvest and processing stages of the food supply chain (Parfitt et al. 2010). Food loss occurs as a result of inefficiencies in the food supply chain, such as poor infrastructure, technology and capacity; poor logistics and management practices; a lack of access to markets, and even natural disasters (FAO 2013a).
- Food waste (when applied in a narrow sense) refers to food losses at the retail and consumer stages and refers to food suitable for human consumption that is discarded due to spoilage or expiry (FAO 2013a). Food waste results from oversupply and poor management at the retail stage, and from wasteful consumer behaviour.

Food intended for human consumption, but then deemed unsuitable and subsequently redistributed to non-food uses such as animal feed and bioenergy, is also considered food waste under this broad definition (FAO 2011). However, overnutrition – the gap between the energy value of food consumed per capita and the energy value of food needed per capita – is not considered food waste here. Furthermore, food waste, as applied here, does not include unavoidable food waste such as bones, organs, skins, seeds and peels, which are usually discarded or used in non-food products (Lipinski et al. 2013). Food waste thus refers only to the edible portion of food products that is not consumed. This distinction is not always straightforward, for example, potato skins can be eaten depending on the manner in which the potatoes are cooked, and the percentage of food waste that can be considered “avoidable” varies between studies. A study conducted of UK households concluded that approximately 60% of consumer food waste could be considered avoidable (WRAP 2008). While looking broadly across six commodity food groups and the whole food supply chain, an FAO study finds that 80% of food products discarded can be considered avoidable (FAO 2013a).

This lack of consistency in the definition and measurement of food waste has been identified as a barrier to addressing the global problem of food wastage. In response to this, the WRI (together with a number of partners) is developing a global standard for measuring food loss and waste. Called the Food Loss and Waste Protocol,<sup>6</sup> the forthcoming guidance document will enable countries and companies to measure and monitor the food loss and waste that occur within their boundaries and value chains in a credible, practical and consistent manner.

The simplest method of estimating food waste is on a mass basis, e.g. the fraction of food wasted per tonne of food available. A food calorie basis is sometimes also used (e.g. the fraction of food wasted per 1 000 calories available for consumption), which in some respects provides a more meaningful measure but requires the energy content of the food to be known. Food waste is often reported as volumes (e.g. cubic metres) as this relates to the landfill space required for its disposal. However, this requires the density of the waste to be known. The simple mass basis is applied throughout this paper, with waste estimates provided as tonnages per year.

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<sup>6</sup> <http://www.wri.org/food/protocol>

## 2.2 FOOD WASTE IN SOUTH AFRICA

No accurate figures on food waste are available in South Africa, with very few figures having been reported on organic waste volumes. The National Waste Information Baseline Report confirms this, where the estimate of organic waste produced in South Africa in 2011 had to be extrapolated from information contained within the Integrated Waste Management Plans (IWMPs) of the various municipalities. The accuracy of information contained in IWMPs is at times questionable and mostly based on predictions rather than measured values (DEA 2012). The National Waste Information Baseline Report estimates organic waste produced in South Africa at 3.02 million tonnes, with an estimated 1.97 million tonnes of that landfilled and the balance finding beneficial use (DEA 2012). However, this baseline figure on total organic waste removed to landfill gives little information on the quantities of food waste for the following reasons:

- Organic waste includes garden waste. Even less information is available on organic waste characterisation than on waste volumes (DEA 2012a), but the few studies on waste characterisation that have been done show the food waste component of domestic waste to vary with income-level group, on average making up 10 to 18% of the household waste stream (Nahman et al. 2012).
- The national baseline organic waste figure captures only the formal waste streams handled by municipal services, and thus significantly underestimates certain waste streams. Agricultural wastes, in particular, are not reflected as these are generally processed near the point of generation and reused back in the agricultural sector, rather than entering municipal waste streams (DEA 2012a).

A study by researchers at the CSIR estimated that 31% of average annual food production in South Africa (on a mass basis<sup>7</sup>) is wasted (Oelofse & Nahman, 2013). A subsequent update of this study estimates that 10.2 million tonnes of food is wasted in South Africa per year<sup>8</sup> (Nahman & De Lange 2013) – a figure very much higher than the national organic waste baseline estimate for South Africa. However, these estimates are only partly specific to South Africa because they apply food wastage percentages for sub-Saharan Africa to calculate the quantity of food wasted in South Africa. The food waste percentages, taken from the Global Food Losses and Food Waste study (FAO 2011), estimate the fraction of food lost at five points in the food supply chain (see Box 1).

Food wastage rates across supply chains in South Africa are potentially very different from other sub-Saharan African countries. On the one hand, more sophisticated distribution networks and infrastructure in South Africa reduce wastage prior to food reaching the consumer, but on the other hand consumers are more affluent, with associated increased wastage. Indeed, in some respects South Africa's waste generation profile might resemble those of other world regions more closely rather than that of sub-Saharan Africa. Figure 1 shows the large diversity in food wastage profiles across the food value chain in the different world regions. On the other hand, the variation in total food wasted as a percentage of food available across the world regions is relatively small (from 15 to 25%, except for the USA at 42%). Thus the use of sub-Saharan waste percentages to represent South Africa might be less of an issue in terms of predicting the total food waste quantities.<sup>9</sup> Furthermore, it should be noted that the waste percentages applied in the Global Food Losses and Food Waste study (FAO 2011) are in themselves uncertain and in many instances are the best assumptions of the authors with large gaps in the knowledge, especially for developing countries (FAO 2013b).

Notwithstanding the above limitations in the data, it is only when we see some numbers that we can start to appreciate the scale of the food waste problem. The FAO waste percentages are thus a useful starting point to gaining an understanding of the scale of the problem and its spread across the food supply chain. It is in this spirit that the following food waste figures for South Africa, and the subsequent estimations of the energy and water costs of food waste, are provided in this paper. The figures should only be seen as indicative of the magnitude of the problem, and much work needs to be done to accurately characterise the values involved.

<sup>7</sup> This is not directly comparable to the values given in Figure 1, which are on a food calorie basis.

<sup>8</sup> For food production and consumption data for South Africa based on a three-year average (2007–2009), taken from the Food Balance Sheets published by the Statistics Division of the FAO.

<sup>9</sup> For example, sub-Saharan Africa and Europe have very different food waste profiles across the value chain, but very similar percentages of total food available that is lost or wasted.

## 2.2.1 ESTIMATING FOOD WASTE IN SOUTH AFRICA

Before considering the average per capita food waste in South Africa, it is useful to put this into context by considering the average diet of South Africans. Table 1 gives three different literature sources of per capita food consumption in South Africa. It should be noted that these are average figures for South Africa as a whole, and do not indicate the wide variety of diets across South Africa's disparate income levels. The first two data sources (DAFF 2012; Nahman & De Lange 2013) and the data provided by Nel and Steyn (2002) give interesting different perspectives in that the Nel and Steyn data is generated from the "bottom up" using food consumption studies, rather than the more typical "top down" approaches using food production and import/export statistics. The two approaches are unfortunately not directly comparable because the food consumption studies are on a cooked basis, while the Department of Agriculture, Forestry and Fisheries (DAFF) and FAO food balance statistics are on an uncooked basis. However, the data of Nel and Steyn provides a useful source of greater detail on the different foods consumed in an average South African diet (e.g. to estimate that apples make up 20% of the daily intake of fruit and vegetables).

The analysis of Nahman and De Lange (2013) estimates that 27% of the edible portion of food available in South Africa is lost to waste in some form or other across the supply chain – amounting to about 10 million tonnes of food waste from an estimated 31 million tonnes of food available in South Africa. This translates to per capita food wastage of about 210 kg per person per year, assuming that the average population for South Africa was 48.6 million over 2007–2009 (DAFF 2012). Figure 2 and Figure 3 graphically reproduce the results of Nahman and De Lange (2013). Imports are assumed to enter the supply chain at the distribution stage.<sup>10</sup> Thus the waste associated with producing imported food is not included as this occurs in the country of origin and only food waste associated with the distribution, retail and consumption of imported food is included in the South African food waste totals. The fraction of food produced in South Africa that is lost to waste thus stands slightly higher when imports are excluded, with 31% of locally produced edible food lost to food waste across the supply chain.

This waste is highest for fruit and vegetables, where over 50% of produce is wasted along the supply chain – primarily at the processing and packaging stage. Waste rates of potatoes are also very high, with the majority of the waste occurring at the post-harvest handling and storage stage. Meat and milk are wasted to a lesser extent (at around 25% of production) while fish losses are higher at 33%,<sup>11</sup> although fish makes up a relatively small proportion of the average South African diet. Cereals losses across the supply chain are relatively small (less than 20%), but they are consumed in the highest quantities; thus waste cereals are the second highest overall in terms of mass of food commodity wasted. Figure 2 and Figure 3 both clearly emphasise that consumer waste is low, while for all commodities the bulk of the food loss occurs in the early stages of the food value chain. For fruit & vegetables and fish & seafood, and to a lesser extent meat and milk, distribution losses also play a significant role. However, South Africa's waste profile is taken as that of sub-Saharan Africa's, so this supply chain breakdown is to be expected – and the limitations of using the Global Food Losses and Food Waste percentages (FAO 2011) (as discussed above) should be kept in mind.

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<sup>10</sup> This simplification is acknowledged by Nahman and De Lange (2013) since some imported food types require some level of further processing locally. However, it is deemed necessary given the complexity, uncertainty and lack of data regarding waste associated specifically with the processing of imports.

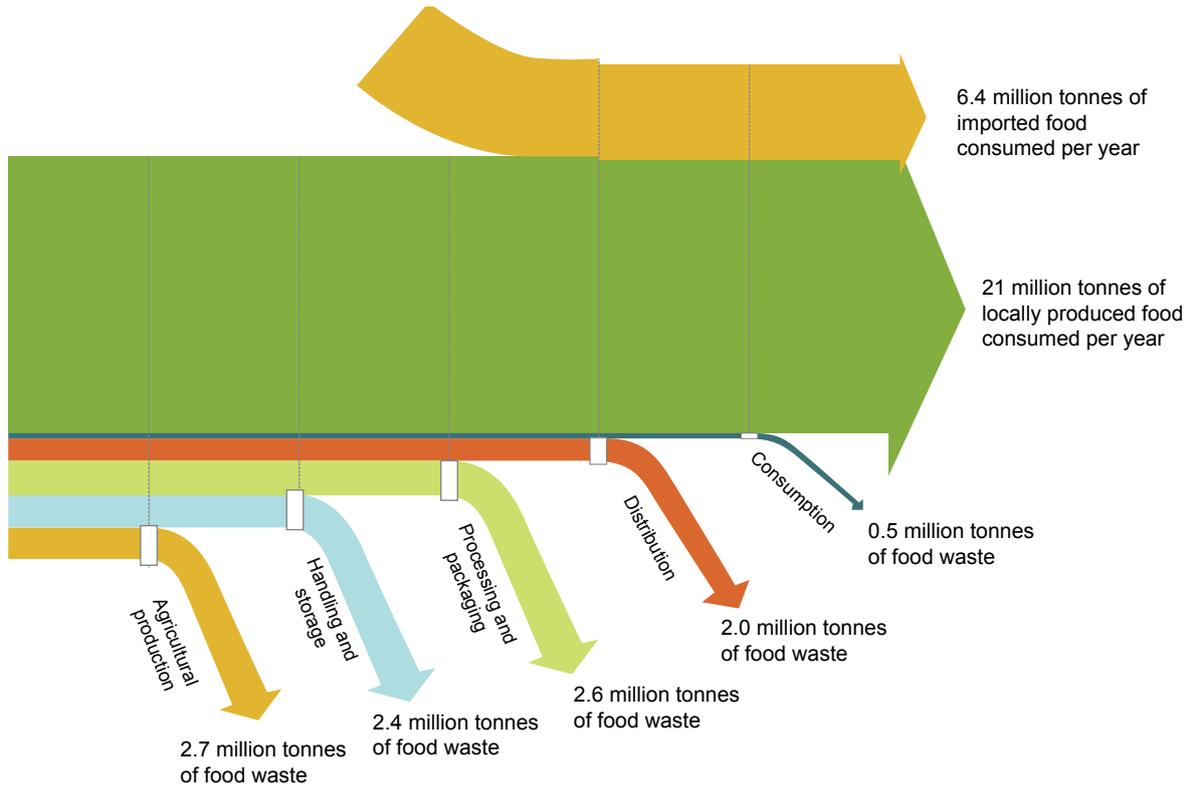
<sup>11</sup> Fish waste should be interpreted with caution due to a lack of agreement in how to define fish waste and how to quantify fishing discards, i.e. the proportion of total catch that is returned to the sea (FAO 2011).

**Table 1: Per capita food consumption in South Africa (kg per person per year)**

	FAO food balance sheets (average over 2007-2009) kg/person.year	Agricultural consumption statistics kg/person.year	Household surveys of daily dietary adult intake
Source	Nahman & De Lange (2013) <sup>12</sup>	DAFF (2012)	Based on data from Nel & Steyn (2002)
Basis	Uncooked basis	Uncooked basis	Cooked basis
Cereals	291	136	283
		49	57
		4.6	1.6
		80	213
			11
		1.8	0.6
Roots & tubers	42	37	20
Oil seeds & pulses	27	10	16
Fruit & vegetables	99	84	61
		45	31
		38	30
Apples			12
Bananas			5.5
Citrus		12	4.9
Other fruits			7.8
Meat	54	60	36
		24	22
		36	14
Fish & seafood	10		4.9
Milk	59	38	37
Eggs		8.7	5.8
Sugar products		33	38
Beverages			172
Oils & fats			4.1
Other			2.8
Total food consumed	581	405	681

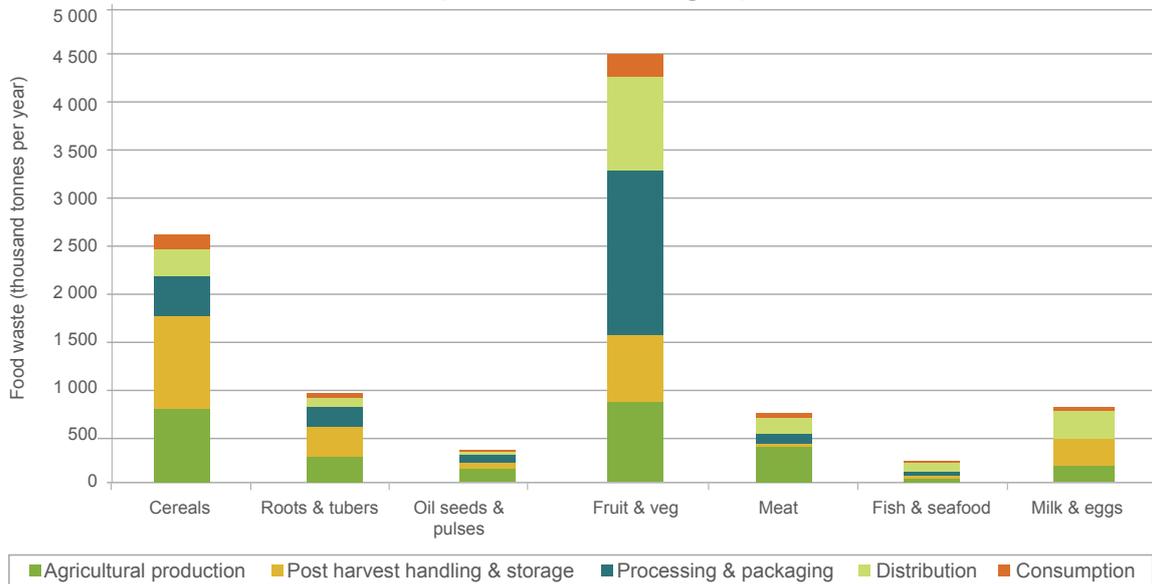
<sup>12</sup> Calculated from food consumption data presented in Nahman & De Lange (2013) and assuming an average population for South Africa of 48.6 million over 2007–2009 (DAFF 2012).

Figure 2: Estimated food waste across the supply chain in South Africa



Source: Reproduced from data in Nahman and De Lange (2013)

Figure 3: Estimated food waste in South Africa per food commodity group



Source: Reproduced from data in Nahman and De Lange (2013)

There is very little quantitative waste information in South Africa against which to check the food waste estimates calculated using the FAO methodology. Nahman et al. (2011) estimate household food waste at 1.4 million tonnes per year (based on average per capita household waste generation rates and food waste content), which translates to 28 kg per person per year. This is higher than the 10 kg per person per year extrapolated from the results of Nahman and De Lange (2013). However, Nahman et al. (2011) point out that their waste quantities may well be overestimated due to the difficulty of extrapolating food waste quantities from reported organic waste quantities. Nonetheless, this possibly points to the FAO waste percentages for sub-Saharan Africa underestimating consumer waste in South Africa, which is to be expected to a degree, given that food waste has been shown to increase with income level.

Another study by the City of Cape Town estimates food waste at 0.3 million tonnes in 2007 (Tsekoa et al. 2007). With a population of 3.5 million in 2007 (Small 2008), this translates to an average of about 85 kg per person per year. If the City of Cape Town figure is assumed to include retail and some industrial food waste, then 85 kg per person per year for the City of Cape Town is reasonably close to the non-agricultural component of per capita food waste extrapolated from Nahman and De Lange (where 105 kg per person per year is estimated for the processing, distribution, retail and consumption stages). With an anticipated higher consumer waste fraction than presented in the results, it can be inferred that the waste fraction associated with processing, distribution and retail could be lower in South Africa compared to the sub-Saharan average.

The following section uses the waste quantities presented here to estimate the further cost and environmental burdens of this high food wastage – notably the energy and water used in its production – but also the costs associated with its disposal.

### **3. ENERGY AND WATER COSTS OF FOOD WASTE IN SOUTH AFRICA**

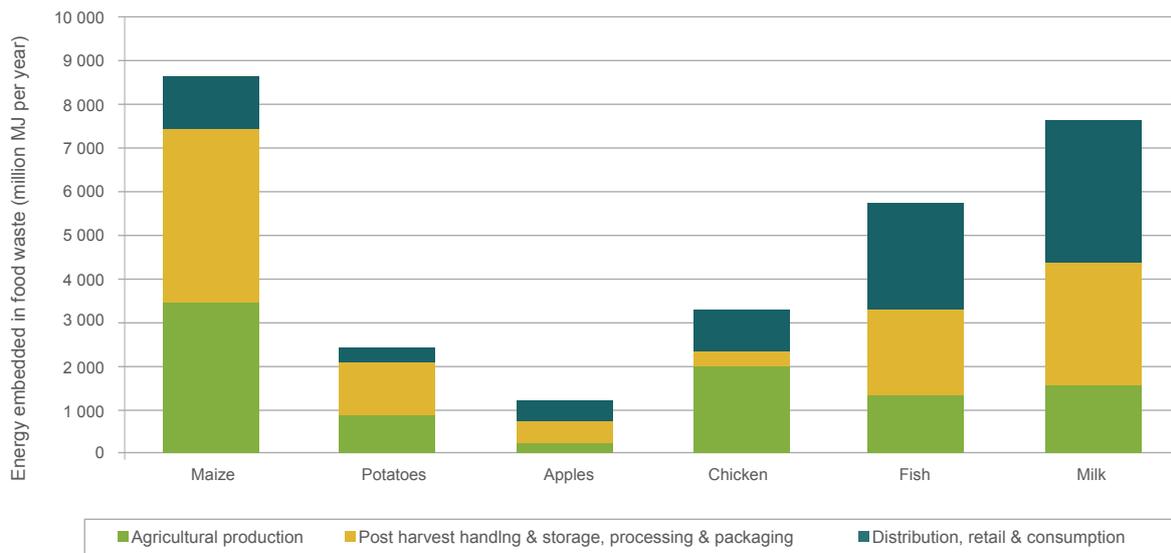
Agricultural production is both energy and water intensive, with a further impact on water provision through high land-use requirements. By extension then, the “overproduction” of approximately 10 million tonnes of food per annum is an important issue for the Food Energy Water Nexus debate, and addressing the issue holds significant potential for reducing water and energy consumption (and by extension, carbon emissions). This section estimates the energy and water requirements associated with producing the quantities of food waste estimated for South Africa in the previous section. The energy costs of food waste disposal are also discussed.

#### **3.1 ENERGY COST OF FOOD WASTE IN SOUTH AFRICA**

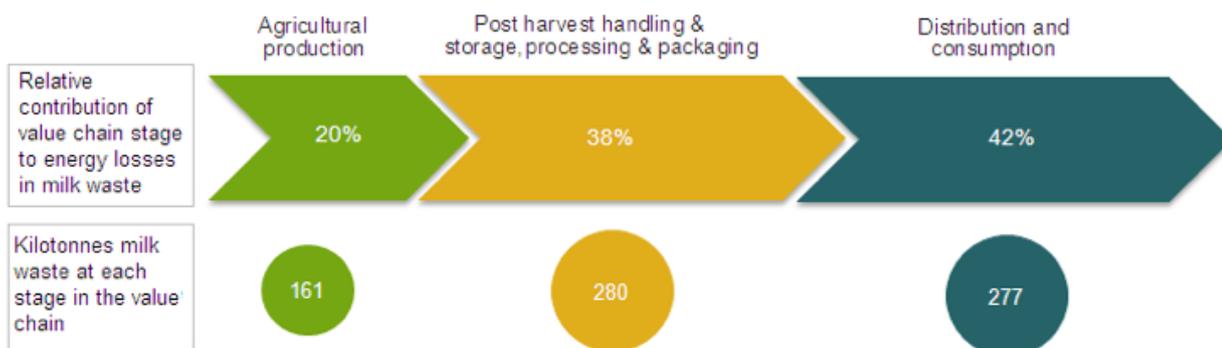
Energy profiles across the food value chain for six South African food items were developed in a briefing paper (Mason-Jones et al. 2013). The energy profiles developed provide the energy intensity of the food product at three points in the value chain: at the farm (agricultural production); at the processed food product (i.e. after post-harvest handling, storage and processing); and at the consumer (i.e. after distribution and retail). Consumer energy use, such as refrigeration or cooking of the food product, is not included. To estimate the embedded energy in food waste, the energy intensity profiles for the six case study foods are combined with the waste quantities estimated in the previous section, with the detailed dietary breakdown shown in Table 1 (based on data contained in Nel & Steyn 2002) used to estimate the share of the particular case study food item for the commodity group. For example, maize is estimated to comprise 75% of cereals, and thus maize waste is estimated to account for 75% of waste cereals.

The results of this analysis are shown in Figure 4, and while the data is extremely preliminary, some interesting trends emerge. Food products with a high embedded energy (e.g. fish, milk and chicken) have disproportionately high waste energy costs, even though their waste quantities are relatively small. In contrast to this, wastage of apples and potatoes is high, but the energy costs are brought down to levels comparable with the other commodities. Also, because embedded energy is cumulative, in those food products with a high embedded energy (most notably fish and milk), the latter stages of the food value chain have a higher relative share of the waste energy costs than the earlier stages – even though the earlier stages typically account for the greater share of waste generation (see Figure 5).

**Figure 4: Energy associated with food waste for annual consumption of six staple foods in South Africa**



**Figure 5: Tonnes of milk waste and relative contribution to wasted energy**



To estimate a ballpark cost of wasted energy associated with waste food required some gross simplification; to estimate the total energy wasted per commodity food group it was assumed that the case study food could be considered representative of the commodity group, for instance that the energy profile of apples could be assumed representative of fruit & vegetables as a whole. Furthermore, in the case studies presented in Mason-Jones et al. (2013), sufficient data was not available to differentiate between energy sources used across the food supply chain. Thus the cost of wasted energy is based on an extremely approximate average cost per unit of energy delivered, i.e. a combined diesel and electricity price, estimated at 30c per MJ.<sup>13</sup> Nonetheless, even with these simplifications it is evident that the quantity is very large, with the energy wasted every year in South Africa in producing food that is never consumed sufficient to power the City of Johannesburg for roughly 16 years.<sup>14</sup>

A ballpark figure for the cost of energy wasted as a consequence of food wastage is R1.3 billion. This figure should be viewed with extreme caution – it uses extremely rough commodity-wide estimates of the embedded energy of food products, an extremely approximate combined diesel and electricity cost, and high uncertainty in estimating waste quantities based on statistics for sub-Saharan Africa. Nonetheless, the fact that it is in the region of a billion rand a year is notable, as is the fact that the food products with the highest waste rates contribute the least to this overall cost. For example, fruit & vegetables account for 44% of the food waste, but for just 15% of the energy waste cost; while fish accounts for just 2% of food waste, but for 13% of the waste energy costs. Waste cereals account for the highest waste energy cost, followed by meat.

<sup>13</sup> Electricity cost varies considerably with tariff (e.g. 7.5–58c/MJ), while diesel costs 35c/MJ (2013).

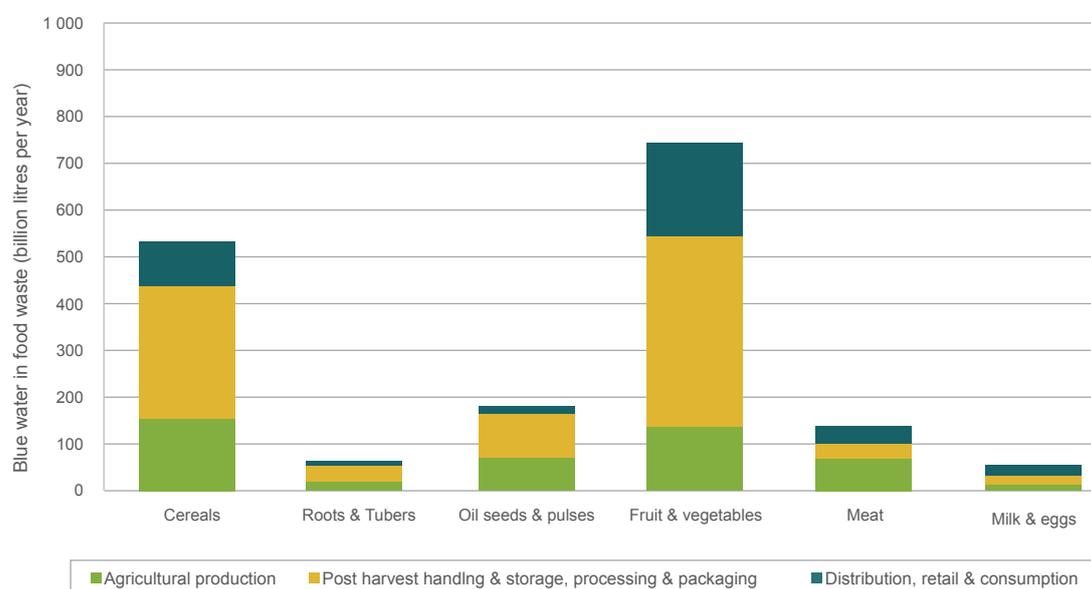
<sup>14</sup> Based on the assumption that the average electricity usage by Johannesburg is 5 000 MW.

## 3.2 WATER COST OF FOOD WASTED IN SOUTH AFRICA

Consumption of agricultural products is estimated to account for 92% of the water footprint of humanity (Hoekstra & Mekonnen 2012). It thus stands to reason that food waste incurs a high water cost. The water footprint factors for southern Africa published in the Food Wastage Footprint technical report (FAO 2013a)<sup>15</sup> are applied here to estimate the water embedded in food waste in South Africa, with the detailed dietary data in Table 1, adapted from Nel and Steyn (2002), used to disaggregate the commodity-level food waste estimates to the same product level as the FAO water factors. Furthermore, the water footprint factors only include water consumption during agricultural production and thus underestimate the full value chain of water use. This simplification is deemed warranted given that water consumption in agriculture accounts for over 90% of water consumed in the production of most food products (Hoekstra et al. 2011). However, this simplification might still result in a significant underestimation of water costs because the cost of water increases substantially the higher one progresses up the supply chain,<sup>16</sup> even though the volumes of water consumed decrease.

Figure 6 and Figure 7 show the blue water and green water, respectively, associated with the production of food that is wasted in South Africa (based on the food waste quantities estimated by Nahman and De Lange in 2013). Blue water use in agricultural production is irrigation water withdrawn from groundwater or surface water bodies that is used by the crop in evapotranspiration or incorporated into the product, while green water is rainwater (soil water) used by the crop or incorporated into the product by non-irrigated agriculture (FAO 2013a). Green-water usage is a full order of magnitude larger than blue-water usage, but blue-water has the higher immediate environmental and cost implications such as salinisation and soil degradation. Animal products have particularly high green-water footprints, while fruit & vegetables show the highest blue-water footprint as these products are primarily grown under irrigation.

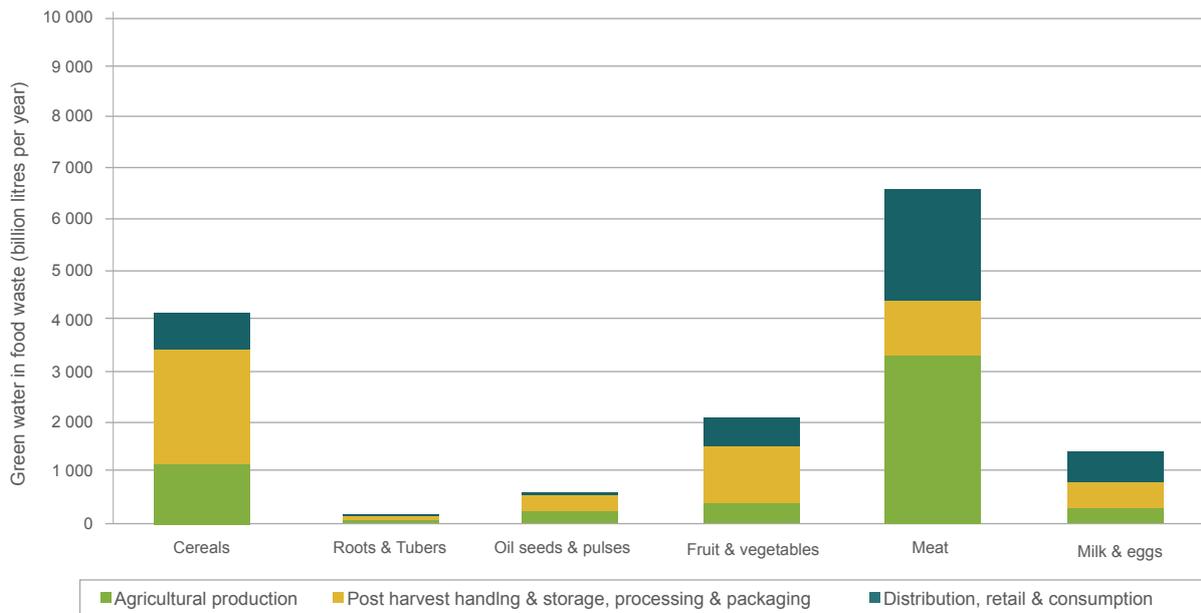
Figure 6: Estimate of blue water use embedded in food waste in South Africa



<sup>15</sup> The water factors reproduced in the FAO report are derived from the Water Footprint Assessment Manual (Hoekstra et al. 2011) aggregated to major food groups and global regions.

<sup>16</sup> With indicative cost ranges in 2013 of R0.01–R0.25 for irrigation; R0.03–R13 for domestic and industrial (raw); and R10–R25 for municipal water.

**Figure 7: Estimate of green water use embedded in food waste in South Africa**



About 1.7 km<sup>3</sup> of water is extracted from groundwater and surface water bodies to produce the food that is subsequently wasted in South Africa (2012 figures). That is approximately 600 000 Olympic-sized swimming pools, at a ballpark cost of R260 million.<sup>17</sup> South Africa’s water withdrawals in 2000 amounted to 12.5 km<sup>3</sup>, with 62% of this attributed to irrigation (FAO 2005). This indicates that around one-fifth of South Africa’s total water withdrawal is used to produce food that is never consumed. The production of wasted fruit and vegetables accounts for the largest share of this estimated water cost (at an estimated cost of R112 million), with the production of cereals and meat also contributing a significant water cost. Per capita, this equates to about 36 m<sup>3</sup> of water extracted per person per year to produce the estimated 210 kg of food wasted per person per year (about the volume of two typical household swimming pools). Approximately 95 m<sup>3</sup> of blue water is required per person per year to produce the annual food requirements of an average South African (for the food basket assumed here), with maize making up the greatest share of this (at 21 m<sup>3</sup> per person per year). However, vegetables make up the largest share of the water embedded in food waste (at 7 m<sup>3</sup> per person per year).

### 3.3 ENERGY COSTS OF DISPOSING FOOD WASTE

Besides the issue of wasting valuable resources, waste food also needs to be disposed of. In South Africa, the majority of industrial and consumer organic waste ends up in a sanitary landfill, while organic waste at farm level is disposed of on the farm or finds a use nearby<sup>18</sup> (DEA 2012a).

Landfill activities require energy in the form of both electricity and diesel. Average electricity and diesel consumption per tonne waste landfilled for the City of Cape Town in 2010 was 2.8 kWh/tonne and 0.44 litres/tonne respectively (Vossberg 2012). Extrapolating this to the total tonnes of post-agricultural food waste estimated by Nahman and De Lange (2013), this comes to a cost of approximately R12 million/year and R27 million/year<sup>19</sup> for electricity and diesel respectively. Diesel is also consumed in transporting waste to landfill, estimated at a cost of R232 million/year.<sup>20</sup> Leachate management in landfills represents a further energy cost, where leachate captured is either circulated back onto the landfill or diverted to energy-intensive anaerobic biological treatments (Traut 2007). The energy input required to transport and dispose of food waste is thus substantial, but it is less so when viewed in the context of the energy consumed in producing the food waste where, according to estimates made here, disposal adds just under 2% to the total energy associated with waste food.

<sup>17</sup> This is likely to be a considerable underestimate as it includes only water at production and assumes a water cost of 15c/m<sup>3</sup> (based on average raw water irrigation price).

<sup>18</sup> For example, left to rot in the field, used as animal feed, put in trenches, etc.

<sup>19</sup> Assuming an electricity price of 84c/kWh and a diesel price of R12/litre.

<sup>20</sup> Assuming that 0.38 litres of diesel is required per tonne of waste and per km transported (Ecoinvent Centre 2007) and a nominal 10 km transport distance.

The energy costs estimated above – at just over R50/tonne waste – are quite low in comparison to the total financial cost of a landfill, estimated by Nahman et al. (2012) at R240/tonne for household waste. In addition to the financial cost, there are a number of environmental and social costs associated with the disposal of food waste to landfill. These include emissions of landfill gas,<sup>21</sup> emissions to soil and water in leachate, and other problems, such as odours, dust, litter, vermin (e.g. rodents, flies), noise, traffic, visual intrusion and the risk of fires. These environmental and social costs were estimated by Nahman (2011) to add R111 per tonne to the financial cost of the landfill, resulting in an estimated total cost (financial cost plus externalities cost) of R351/tonne of waste disposed to landfill for the City of Cape Town. Applying this estimated total cost to the tonnes of post-agricultural food waste estimated for South Africa, the estimated cost of landfilling food waste comes to a very substantial R1.8 billion per year.

Food waste is particularly problematic when disposed of in landfills as it contributes disproportionately to landfill gas and leachate emissions, and should in fact be allocated a higher share of the average externality costs (Nahman 2011). Landfill gas can be captured and combusted to generate electricity. However, fewer than 10% of municipalities in South Africa currently have landfill gas utilisation projects in place (Van Rooy 2012). As an indication of the scale of the problem, organic waste contributes approximately 2.1% to South Africa's national greenhouse gas emissions (DEA 2009). Assuming that about 30% of organic waste to landfill is food waste (Tsekoa et al. 2007), approximately 2.8 million tonnes of greenhouse gas emissions (CDE) are emitted per year as a result of food waste to landfill. These emissions are ultimately avoidable, as food waste represents a valuable resource for energy generation or composting. This is explored in section 4.2.

### 3.4 ENERGY AND DISPOSAL COSTS OF FOOD PACKAGING

The sections above have not explicitly addressed whether waste food is discarded packaged or not. The estimates of waste energy associated with waste food provided in section 3.3 include the packaging of wasted food, as embedded energy in packaging is included in the embedded energy of the food product (where it contributes from 2 to 15% of the cumulative energy cost of the food product, depending on the particular food product) (Mason-Jones et al. 2013). However, the tonnes of food waste calculated do not include the mass of the packaging, thus the estimates of energy required in the landfill disposal are for the food waste alone. Thus where food is disposed of in a packaged state, as might occur at retail, the total tonnes of waste to landfill are an underestimate. Food might also be disposed in a packaged state at processing, although possibly to a relatively low degree, since processing facilities frequently rework or recycle waste packaging. Nonetheless, the additional volume of waste to landfill due to the packaging associated with waste food could be significant for some food products with a high packaging intensity. However, this is minimised by the majority of food waste occurring at the earlier stages of the food value chain (where it is disposed in an unpackaged state). Where food packaging consists of cardboard or paper, the packaging will also contribute to the emission of landfill gases.

In general though, energy required for the disposal of waste food is much lower than the energy losses that result from producing the waste food (and its packaging), where the former contributes only 2% of the total energy “wasted”. Thus, in terms of the energy associated with waste food, the fact that packaging is not included in estimates of food waste tonnages is unlikely to change the main conclusion that it is the production of the waste food itself that is the primary issue. The same argument holds true for water costs, where water consumed in the production of packaging is very much lower than that consumed in the production of the food product. However, the costs of landfilling food waste are extensive if the social and environmental costs are included, and these would be even higher if packaging tonnages were included.

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<sup>21</sup> Landfill gas consists of 50–55% methane, 40–45% carbon dioxide, with complex organic compounds that do not decompose, hydrogen sulphide and other sulphide compounds making up the remainder (CSIR 2011).

## 3.5 ECONOMIC COST OF FOOD WASTE

In a recent paper, Nahman and De Lange (2013) estimate the cost of food wastage for South Africa's economy. They do this by multiplying their estimates of food wastage at each stage of the value chain (as presented in section 2.2.1) by weighted average representative prices for each commodity group at each stage of the value chain. In this way, the total costs of food waste are estimated at R61.5 billion per year, equivalent to 2.1% of South Africa's annual GDP. In comparison to this figure, the ballpark energy and water costs developed here would appear to be underestimated, respectively accounting for only 2% and 0.5% of these total costs. Further work is required to accurately characterize these costs and the burden they represent to the South African economy.

## 4. ENERGY RECOVERY FROM FOOD WASTE

It is clear from the preceding section that the disposal of food waste comes at a high economic and environmental price to South Africa. However, it also represents a significant missed opportunity, where a potentially useful energy source is the cause of greenhouse gas emissions and fossil fuel use, instead of preventing fossil fuel use through the generation of bioenergy. This section thus looks at the potential for energy recovery from waste food. It starts with an overview of the waste regulatory environment in South Africa, specifically in terms of how conducive this is to the utilisation of organic waste as an energy source, and then discusses the use of food waste in energy production.

At present, there is no specific legislation promoting one application of organic waste over another. The National Organic Waste Composting Strategy, which aims to divert organic waste from landfill sites for composting, is careful to recognise that composting is only one of a suite of possible options for the use of organic waste (DEA 2012a). Energy recovery is thus only one possible application of food waste. Composting is a well-established alternative, as is the use of food waste as animal feed, especially at the early stages of the value chain, e.g. milk returns are fed to pigs. Thus the most suitable application for utilising food waste is likely to differ at the different stages of the value chain (e.g. composting might offer the best option at the consumer level). Nonetheless, this section focuses on energy applications of food waste, consistent with the energy focus of this paper. However, it is acknowledged that competing uses for food waste might eventually arise, and ultimately lead to its commoditisation. This means that food waste could, after being a nuisance and cost to the authorities and private waste generators, ultimately become a sought-after commodity with a price tag.

### 4.1 POLICY CONTEXT OF THE DISPOSAL OF ORGANIC WASTE

Historically, waste management in South Africa has had sufficient access to land, and there has been limited motivation to divert waste away from landfill sites and towards waste management alternatives. However, the landfill-only culture of South Africa is increasingly recognised as unsustainable, and an array of waste management methods and technologies are starting to emerge (Van Rooy 2012). Besides the constraint of finding suitable landfill sites in the more densely populated urban areas, the other main drivers behind diverting waste from landfill are developing the waste to energy (WtE) sector in South Africa, and government's ambitions to green the economy. Recovery of energy from waste in South Africa is tending less in the direction of incineration but rather towards composting, anaerobic digestion and refuse-derived fuel processes (Van Rooy 2012) – all of which provide important opportunities for food waste as an energy source.

As with other forms of waste that lend themselves to energy applications, food waste is governed by both waste management regulations and energy policy, making it especially complex to navigate the policy and regulatory frameworks. Increasingly stringent requirements for minimising, reporting and disposing of organic waste present specific opportunities for the potential of waste as an energy source. The most important policy documents and regulatory acts guiding and governing the management of food waste, as well as those that have implications for its use as an energy source, are summarised in Table 2.

**Table 2: Policy documents relevant to food waste**

<b>Policy document/Regulatory Act</b>	<b>Implications for food waste</b>
<p><b>National Environmental Management: Waste Act (NEM:WA) (2008):</b> Introduced the South African Waste Information System (SAWIS) to record, collect, manage and analyse data on the quantity and type or classification of waste generated, stored, transported, treated, transformed, reduced, reused, recycled, recovered and disposed of.</p>	<p>SAWIS should in future include detailed information on food waste; at present such information is extremely limited as submission was voluntary; this has changed with the Waste Information Regulations (August 2012) that made reporting to SAWIS obligatory. As the SAWIS database grows, the availability of food waste data in SA is expected to improve.</p>
<p><b>NEM:WA National Norms and Standards for the Disposal of Waste to Landfills (August 2013):</b> Lays out restrictions and a banning schedule for the landfill of certain types of wastes.</p>	<p>Bans infectious animal carcasses from landfill with immediate effect, and hazardous waste with a significant energy content in 4–12 years (depending on the energy content); the standards do not provide any further definition of such hazardous waste with significant energy content, so it is not clear whether certain types of food waste might fall under this category, e.g. expired meat products.</p>
<p><b>National Waste Management Strategy (NWMS) (2012):</b> Promotes the growing contribution of the waste sector to the green economy through stimulating job creation and broadening participation by SMEs and marginalised communities in the waste sector.</p>	<p>Collection and separation of food waste can be very labour-intensive activities, which are necessary for its further beneficiation. As such, the use of food waste for energy applications supports the goal of green job creation.</p>
<p><b>The National Development Plan 2030 (NDP) (2011):</b> A long-term economic strategy encompassing political and social development objectives. Sets out steps that aim to transform the SA energy system and reduce greenhouse gas emissions.</p>	<p>Food waste is one form of biomass that can be used for the generation of renewable energy.</p>
<p><b>The Energy Efficiency Strategy (EES), first review (2008):<sup>22</sup></b> Suggests reducing the energy demands of industrial and residential users through education and supplement their energy demands through on-site generation, especially by using waste already present or produced on site.</p>	<p>Mainly relevant for upstream food production; use of food waste in processes generating the energy needed for food processing.</p>

There are many other policy documents and regulatory Acts that have a direct or indirect bearing on the generation, management and reuse of food waste.<sup>23</sup> At this stage, the most notable observation is that waste management policy and regulation as well as government documents guiding and governing the potential use of food waste as an energy source are complex, fragmented and not sufficient to take advantage of the developments in waste management and the reuse options of organic waste, including energy applications.

The current lack of data on waste flows is the most important issue restricting the use of food waste in energy applications. Limits to the expansion of landfills have meant that some forms of waste (mainly commercial and industrial) are increasingly being recovered (Van Rooy et al. 2012). Unfortunately, the extent to which this is taking place is not certain, since the reporting of waste handled, transported, recycled and/or recovered has been legislated only very recently. There is therefore a lack of waste information at municipal and ultimately at national level (DEA 2012a). The Draft National Waste Information Baseline Report (DEA 2012) makes it clear that information related specifically to organic waste in South Africa is not readily available. This information gap needs to be addressed urgently, as planning for the use of organic waste (including food waste) cannot take place without having a quantitative understanding of the amount of waste generated. Hopefully, this will change as the SAWIS database grows.<sup>24</sup>

<sup>22</sup> The Draft Second National Energy Efficiency Strategy Review was published on 27 July 2012 but has not yet been finalised and gazetted.

<sup>23</sup> These include food safety regulations, environmental regulations, sanitation regulations, etc.

<sup>24</sup> The DEA should start producing annual statistics from SAWIS on waste management from 2014/15, and by 2016, all specified waste management facilities that are required to collect and report to SAWIS are to have waste quantification systems (DEA 2011).

It is also not clear whether food waste is subject to specific regulations or not. The recently published National Norms and Standards for the Disposal of Waste to Landfills does not mention food waste as a category of waste banned from landfill, but it could be that certain food waste may fall under the category of hazardous waste with significant energy content. Some sources also cite a government intention to ban organic waste from landfill (Oelofse 2012; Van Rooy 2012), although the *National Norms and Standards for the Disposal of Waste to Landfills* only provides restrictions on the landfill of garden waste.<sup>25</sup> Furthermore, in terms of South African legislation, there is no common definition for organic waste (DEA 2012a).

Finally, waste management in South Africa suffers from pervasive underpricing (DEA 2011), as reflected in the limited incentives for alternatives to landfilling. This situation can be solved by a policy and regulatory environment that actively promotes the waste management hierarchy. The previously mentioned National Norms and Standards for the Disposal of Waste to Landfills is a step in the right direction, though there is space for much more ambitious legislation to maximise the potential for energy recovery from waste in South Africa.

### 4.1.1 POLICY CONTEXT OF RENEWABLE ENERGY

The current push for a greater share of renewables in South Africa's electricity-generating mix can also be analysed as a driver for WtE developments. The main government support programme for renewable energy is a tendering mechanism known as the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) that sets specific procurement targets for different types of renewable energy generation options, including those that can produce energy from food waste such as biogas. So far, no bids have been submitted to develop biogas projects under the REIPPPP, mainly because the initial sunk costs make bidding under the REIPPPP prohibitively expensive for biogas projects, which rarely exceed the size of a few megawatts of output. To attract smaller projects, which typically have wider socio-economic benefits, the government has recently established a separate Small Generators programme under the REIPPPP, for electricity generation projects sized between 1 MW and 5 MW, with simplified bidding procedures. Its appeal for biogas developments is yet to be established.

Commercial applications have nevertheless slowly started to develop outside the REIPPPP.<sup>26</sup> The recently published National Norms and Standards for the Disposal of Waste to Landfills that significantly reduces the amount of garden waste allowed into landfill and bans the landfilling of infectious animal carcasses, will already contribute important feedstocks to any future biogas plants in South Africa. However, if this were to be extended to include all organic waste with a significant energy content (including food waste), rather than only waste classified as hazardous, it could certainly provide the much-needed push for the development of a local industrial-scale biogas sector. Together with the rapidly rising electricity prices, such a ban could shift the economics of biogas in favour of on-site developments for meeting on-site demand, to even exporting surplus electricity to the national grid.

## 4.2 APPLICATIONS OF FOOD WASTE IN ENERGY PRODUCTION

Energy recovery from food waste is possible in a number of WtE technologies. Food waste, whether early in the food value chain in the form of raw agricultural products or downstream in the form of processed food for consumers, is an important contributor to the total organic waste produced in South Africa and should be considered as a potential WtE feedstock. In this paper avoidable food waste is estimated at 10 million tonnes per year which, if combined with the unavoidable portion of food waste (which adds at least another 2.5 million tonnes per year) as well as other organic waste (e.g. garden waste), constitutes a sizeable feedstock for energy generation.

<sup>25</sup> This states 25% diversion from baseline of separated garden waste within the next five years, and 50% within the next 10 years, from date of coming into effect.

<sup>26</sup> At the start of 2013, about 12.5 MW of new capacity is in the pipeline (Smith 2013).

Although produced in large quantities, food waste is generated at a large number of dispersed sites. Identifying the larger points of production and aggregating them to economically add up to an amount large enough to feed an industrial-scale plant often represents a significant logistical challenge. The fact that the production of food waste in South Africa appears skewed towards the earlier stages of the food value chain might help in this regard – although it should be kept in mind that current estimates of the distribution of food waste across the food value chain in South Africa are based on those for sub-Saharan Africa as a whole and still need to be confirmed for South Africa.

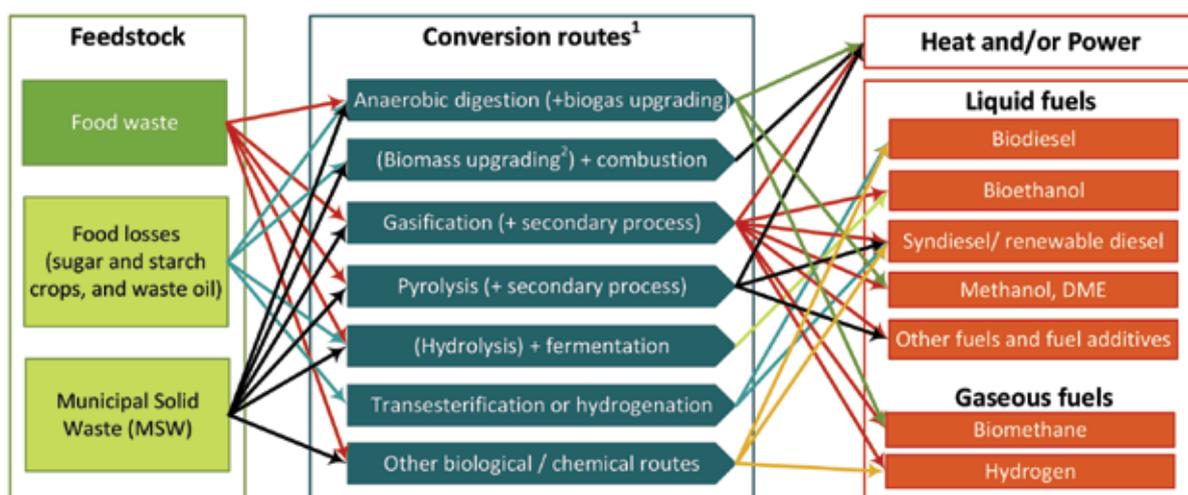
Furthermore, in some cases, alternative uses of food waste might already be in place at the farm level, for example as a source of animal feed, reducing the amount of food waste available for energy production. Nonetheless, post-harvest handling and storage as well as processing and packaging, which together constitute 50% of the total food waste, are particularly well suited for energy applications because significant food waste will be generated at a single source (large farms and processing plants). Retail and distribution also offer significant potential as the source of 20% of total food waste, especially if retailers form partnerships.

### 4.2.1 TECHNOLOGIES FOR ENERGY RECOVERY FROM FOOD WASTE

Figure 8 indicates the range of bioenergy routes available for the use of food waste in energy production. Certain technologies can utilise food waste alone, while others require a combination of organic feedstocks. Most food waste can be used as input for the generation of electricity (and heat), while only certain types can be used for the production of biofuels.

The simplest and most mature technology for the extraction of energy from wasted food is anaerobic digestion. Biogas can be operated purely on food waste, although it is more common to use food waste as a co-substrate with other animal and agricultural wastes (or with garden waste, which already requires separate disposal by the majority of municipalities in South Africa). The most common application for biogas produced in biodigesters is combustion for the production of power (and heat), although biogas can also be upgraded to biomethanol, which can be blended with gasoline, or to biomethane, which can be used as a replacement for natural gas. In South Africa so far, the biogas sector has been dominated by small-scale off-grid installations used by households and on farms (Melamu 2013). Industrial-scale biogas developments are only just starting to emerge,<sup>27</sup> and these are mainly based on animal manure (Melamu 2013). None are currently using food waste as feedstock.

Figure 8: Overview of the range of bioenergy routes for organic waste



<sup>1</sup> Each route also gives co-products

<sup>2</sup> Biomass upgrading includes any one of the densification processes (pelletisation, pyrolysis, torrefaction, etc.)

Source: Adapted from E4TECH (2009)

<sup>27</sup> The Bronkhorstspuit Biogas Project developed by Bio2Watt is a case in point; for more details see <http://www.bio2watt.com/projects>

Globally, there are a number of biodigesters using food crops as one of their feedstocks, especially in Germany (IEA Bioenergy 2012). However, these have come under criticism as they often do not use waste crops, but rather divert agricultural production (especially maize) from food to energy applications. Much less common are plants that are fully or partly based on food waste, but such examples do exist<sup>28</sup> and have proven the feasibility of the collection of supermarket, household and restaurant food waste for the production of biogas-based electricity

Anaerobic digestion, while the most well demonstrated, is not the only possible route to recover energy from food waste:

- Pyrolysis and gasification are emerging technologies, each able to deliver multiple final energy uses. While thermal waste gasification is still not a fully commercial technology, pyrolysis of plant waste is already taking place in South Africa under the Working for Water programme.
- The production of liquid biofuels from certain types of food waste has possible application in South Africa. The fermentation of sugar-rich food waste, such as fruit waste for the production of bioethanol, has been investigated in the Western Cape for the production of cooking fuel.
- Fluidised bed boilers represent another emerging technology nearing commercialisation, in which electricity is generated by the combustion of refuse. This technology is already used by the paper industry for the management of on-site wastes. Other industries, including the agro-processing sector, are becoming increasingly aware of the benefits of on-site waste management, and could in the future choose to include rejected foods as feedstock for fluidised bed boilers.

#### 4.2.2 SCOPE FOR FUTURE RESEARCH

The most pressing research need is a better understanding of the quantity and types of organic waste generated in South Africa. Without a good understanding of the quantities involved and where these are generated, it is not possible to evaluate the potential for energy recovery.

The energy recovery from food waste in biogas-based plants could be even more significant when used in combination with other waste streams, rather than when based on food waste alone. This is because when used to supplement other organic feedstocks, food waste serves to increase the yield of biogas (which is the reason why food crops are often used as co-substrates in biodigesters). Additional research is needed to test different combinations of co-substrate available locally, to maximise the yield of biogas (and thus electricity production).

Waste food is one of the main contributors to the generation of methane gas, released by landfills, which can be captured and combusted to generate electricity. The number of gas utilisation projects in South Africa is on the rise, although fewer than 10% of municipalities in South Africa currently utilise landfill gas (Van Rooy 2012). Diverting organic waste away from landfills will have implications for the recovery of methane from landfills, and consequently for the economics of landfill WtE projects. Possible interactions should therefore be researched before a particular waste strategy is promoted.

**The Bottom Line:** There are a number of opportunities for alternative uses of food waste. However, additional research is needed to correctly allocate this limited resource and to understand the economic, social and environmental impacts of the different options. An integrated approach, not just towards waste management, but broadly to understand the life cycles of environmental and social impacts of waste beneficiation, should be taken to optimise the use of different types of waste in the various possible applications and at the various stages of the food value chain.

<sup>28</sup> For example the 2.1 MW CHP biogas plant BioWerk Hamburg GmbH with a capacity to process 20 000 tonnes per year of food waste (<http://www.biowerk-hamburg.de/home.html>, in German).

## 5. ADDRESSING FOOD WASTE

Food wastage represents a significant economic and environmental cost to South Africa. The scale and spread of the food waste problem across the food value chain means that it is only through concerted action by a wide range of groups that these costs will be reduced. This section touches on only a few of these and should not be seen as exhaustive. The role of government and the waste regulatory environment towards the use of food waste was discussed in the previous section; this section looks specifically at actions to avoid food waste. The section closes by drawing on the results presented in the previous sections to highlight the priority areas for addressing food waste issues.

### 5.1 FOOD SECURITY AND FOOD WASTE

The huge volumes of food waste are particularly notable in South Africa, where 15 to 20% of South African households are food insecure (StatsSA 2013). However, food availability is not the issue, but rather the affordability of food (Mason-Jones et al. 2013). Food wastage is thus not a concern from the perspective of food availability – at least not at the current time, although it does have the potential to alleviate increasing food demand as population sizes and income levels grow (leading to greater demand for certain foods over others, notably meat). It also has the potential to reduce pressure on the agricultural system which already faces increasing water and climate stress. Thus, while reducing inefficiencies in the food chain will reduce the energy, water and land required per kilogram of food consumed, it is unlikely to have a major effect on food security in South Africa. More efficient production might help to stabilise price increases and thereby improve the affordability component of food security, although the large number of components contributing to the cost of food items means that this cannot be predicted with any clarity (Mason-Jones et al. 2013).

It is thus rather the redistribution of waste food through food banks and charities that holds the greatest potential for food waste to contribute to easing food insecurity in the poorest South African households. Excess food and food that has reached its “sell-by date” are successfully redistributed through organizations such as FoodBank SA,<sup>29</sup> and by retailers themselves. However, donating food is mired with food safety legislation and the excuse that it poses too high a risk to the organization involved is often cited as a reason for not doing so, leading to the large-scale dumping of food.<sup>30</sup> The government can play an important role here by amending food safety legislation to be more amenable to donating food. A further possibility here would be to require “sell-by” or “display until” labelling on food products. A ban on food waste to landfill would also provide a strong incentive to retailers, processors and restaurants to donate food before it becomes a waste-disposal issue.

### 5.2 RESPONSES ACROSS THE VALUE CHAIN

Food wastage occurs at every stage in the food value chain, thus it stands to reason that there are actions that can be taken at every stage to reduce food waste. What follows is just a sample of possible actions and role-players taken from the literature (primarily from Lipinski et al. (2013), FAO (2011), NRDC (2012) and IMechE (2013)). However, there is insufficient knowledge of food waste generation in South Africa to provide an action list specific to South Africa. Indeed, a good first step to addressing food waste in South Africa would be to research food waste quantities and the points of waste generation in detail, so as to be able to target those actors in the food value chain responsible for the greatest share of the food waste.

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<sup>29</sup> <http://www.foodbank.org.za/programs/food-rescue>

<sup>30</sup> See for example, recent media articles: <http://www.bdlive.co.za/national/science/2013/01/29/challenges-of-reducing-food-waste-while-millions-starve> and <http://www.iol.co.za/news/south-africa/poor-needs-saa-leftovers-1.1462489#.Uk6DsxayVBx>

## 5.2.1 RESPONSES BY THE CONSUMER

International data and the few waste characterisation studies available for South Africa indicate that food waste at the consumer stage is strongly linked to income level. Thus, while a relatively low contributor to South Africa's food waste overall, the consumer stage is likely to become more important as income levels rise. Consumer education, such as teaching home economics in schools, is important because much household food wastage can be avoided through good housekeeping.

The following are relevant actions that consumers can take (mostly applicable to middle-to high-income households):

- Prepare the right quantity of food to minimise cooked food subsequently being discarded, or if over-preparation occurs, freeze leftovers immediately. Dish out sensible portion sizes so that food is not left on plates and discarded but rather placed immediately in a fridge or freezer for consumption later as leftovers.
- Wiser shopping, including better meal planning, checking stock in the fridge before shopping and not falling for bulk deals (e.g. "buy-one-get-one-free") if unlikely to consume the large quantities.
- Buy local and seasonal produce wherever possible (food that has travelled far or been stored for long periods is likely to be associated with greater waste).
- Buy food from local markets where produce tends not to have the stringent quality standards for size and appearance required in supermarkets.

## 5.2.2 RESPONSES AT RETAIL

Retailers play an important role as they can influence the generation of food waste downstream at the consumer level, as well as upstream at the supplier level. Consumer groups and the government need to work with retailers to ensure that food wastage is minimised:

- Retailers should be required to adopt the "use-by" and "sell-by" food labelling concept, with clear and consistent labelling and, most importantly, educate consumers as to the correct reading of these labels. "Use-by" and "best before" labels can be confusing to interpret and promote consumer food waste if consumers interpret "best before" as "use-by", i.e. meaning that the food item is no longer safe to eat. Discarding the food item is unnecessary because it is still safe to eat, even if it is no longer at its prime.
- Retailers should avoid promotions that encourage consumers to purchase excessive quantities, e.g. "buy-one-get-one-free" promotions, and "buy-bulk-and-save" packages which, in the case of perishable foodstuffs, increase the likelihood of wastage in the home.
- Retailers should offer discounts on blemished or close-to-expiry produce, or offer these free or substantially discounted to their staff or charities.
- Retailers could provide information on good food storage practices and advice on lengthening the shelf life of fruits and vegetables, via in-store information or by printing it onto food packaging or the bags in which customers place their purchases.
- Retailers should be encouraged (or required) to allow night deliveries of perishable products, thereby minimising exposure of perishable produce to high day temperatures.
- Retailers should be discouraged from forming restrictive sales agreements with producers, and the rejection of food for cosmetic reasons should be addressed (i.e. rejection or return of items not perfect in shape or appearance). The latter will require a fair degree of consumer education to challenge existing perceptions of food quality.

### 5.2.3 RESPONSES AT FOOD PROCESSING AND PACKAGING

Responses at the food processing level are likely to be specific to the particular food product, but the following generic actions apply:

- Food processors should be encouraged to implement technologies that prolong product life, such as the filling of milk cartons under nitrogen to prolong shelf life without changing the nutritional value or taste of the product.
- Packaging design should focus on keeping food fresh for longer, rather than focusing only on minimising packaging materials. Innovations in packaging to extend shelf life are also required, e.g. “six-pack” packaging where smaller volumes can be opened as required, rather than half the bottle perishing before it is consumed. Inflexible bulk pack sizes also contribute to retailers ordering more than they can sell.
- Food processors should implement best practices in supply chain management and logistics to minimise waste due to oversupply, and to minimise losses in the distribution and handling of perishable produce. This should include having staff properly trained in the handling and storage of perishable produce, as well as having plans in place for rejected shipments (e.g. donations).
- Food processors should look for ways to improve the efficiency of food preparation processes, such as finding uses for food by-products (pips and skins)

### 5.2.4 RESPONSES AT PRODUCER LEVEL

Many innovations are possible at farm level, such as improved harvesting techniques and improved handling and storage of agricultural produce. These depend on the particular crop or animal being farmed. While a number of innovative solutions exist, the more critical aspect is the transfer of know-how to farmers to take advantage of developments, and to educate emerging farmers. The role of agricultural extension agencies and international agricultural development organizations is critical here to raise awareness of technologies and facilitate training.

The FAO approach of “train the trainers” programmes has been shown to be a cost-effective and rapid means of raising awareness and disseminating technical know-how (Lipinski et al. 2013). International development agencies, foundations and national governments also have a role to play in providing seed money or low-interest loans for the purchase of the necessary equipment.

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<sup>31</sup> See Lipinski et al. (2013) for a description of case studies on evaporative coolers, metal silos, storage bags and crates.

## 5.3 THE ROLE OF GOVERNMENT

The government, through its various agencies, has a role to play in nearly all the responses identified above, from amending food safety and food-labelling legislation to make this conducive to food donations, to creating a conducive waste-regulatory environment to prevent the dumping of food. In addition, the following are relevant to minimising food wastage:

- Maintaining roads and infrastructure to enable the efficient distribution of food and providing sufficient investment in infrastructure to ensure South Africa has an efficient system for the transport, handling and storage of food.
- Ensuring energy supply security to ensure that food products can be stored and transported under optimal conditions.
- Improving market access for farmers.
- Creating an enabling environment and investment climate for the private sector to invest in the food industry and to work more closely with farmers.
- Facilitating the transfer of technologies that minimise food waste, both at the producer and the processor levels, and providing incentive schemes for the uptake of such technologies.

More generally, the government also has a role to research the causes of food wastage and its prevention to gain a greater understanding of the food waste issue in South Africa, and to set targets and policies for reducing food wastage.

## 5.4 PRIORITY AREAS IN ADDRESSING FOOD WASTE

From the above it is clear that actions towards addressing food wastage are possible at each stage of the value chain. However, it makes sense to target those food commodities and stages of the food value chain that contribute the most to food wastage and its associated costs.

- In terms of waste quantity, Figure 3 clearly shows that it is in the processing and packaging of fruit and vegetables that the highest quantity of food waste arises. The next most significant in terms of waste quantity is the post-harvest handling and storage of cereals, followed closely by the distribution of fruit and vegetables.

**The Bottom Line:** Overall, these two food commodity groups are responsible for 70% of the food waste in South Africa, and are a clear priority for reducing the quantity of food waste.

- However, a slightly different picture emerges if one looks at the environmental and economic costs of food wastage. In terms of energy costs (and consequently also climate impact), fruit and vegetables are of relatively low concern. However, cereals remain the highest priority as the food commodity with the highest embedded energy costs.

**The Bottom Line:** In terms of energy costs, addressing food waste in the meat value chain becomes a high priority, especially at the agricultural production stage, but also at the retail and distribution stages.

- In terms of water costs, fruit and vegetables are the highest priority food commodity group, followed by cereals. Together, these two food commodity groups dominate the water costs associated with food wastage (where these are measured by embedded blue, or extractive, water use), accounting for 74% of the total.

**The Bottom Line:** In terms of impacts on water provision (i.e. in terms of embedded green water), the production of meat emerges as by far the most important commodity and value chain stage to address, followed by the distribution and retail of meat. Cereals also show high embedded green-water use, and are the next highest priority in terms of addressing the water provision impacts associated with food wastage.

- Another way of prioritising interventions to reduce food wastage is in terms of the cost to the South African economy. This is done by Nahman and De Lange (2013), who estimate the cost associated with food wastage based on the value-added prices of a range of representative commodities throughout their respective value chains. As expected, bringing market prices into the picture gives more weight to those commodity groups (e.g. meat, fish and seafood) and those value chain stages (e.g. distribution) where the associated market prices are higher. Nonetheless, despite the relatively low prices of fruit and vegetables relative to meat and seafood, the much higher quantity of fruit and vegetable waste in South Africa means that this commodity group still holds the highest potential for reducing the costs associated with food wastage.

**The Bottom Line:** From an economic perspective then, interventions should first and foremost be targeted at the processing and packaging of fruit and vegetables, followed by the distribution of fruit and vegetables. The distribution of meat products followed by the production of meat run a very close third and fourth in terms of economic priority (Nahman & De Lange 2013).

## 6. CONCLUSION

Food wastage represents a significant economic and environmental cost to South Africa, with ballpark costs of the energy and water required to produce food that is never eaten in the order of a billion rand. This, together with the cost of disposing of the waste, let alone the loss of a potentially valuable energy resource, shows that food waste comes at a significant cost to the South African economy and environment. In terms of addressing these costs and environmental impacts, the supply chain of fruit and vegetables is a clear target area (especially the processing and packaging stages). However, from an energy and climate perspective, addressing waste in the production of cereals and meat offer the greatest potential benefits. The meat supply chain (both the production and distribution of meat) is also of high priority in terms of water provision impacts and costs to the economy.

The scale and spread of the problem means that reducing these high levels of waste is beyond the capability of individual farmers, distributors, retailers and consumers. Indeed, to a large degree, food waste has more to do with social, political and economic norms than with agricultural practices. The solutions needed to reduce food waste are well known. It is rather the transfer of this knowledge to where it is needed, as well as creating the political and social environment in which these ideas can be adopted, that is the challenge.

Recent studies on food waste, both locally and globally, have revealed major data gaps in the knowledge of global food waste, especially with regard to the quantification of food losses at various stages in the supply chain. Furthermore, when data is available, it is often accompanied by major uncertainties. Global efforts, such as the Food Loss and Waste Protocol currently under development will help, but further research in South Africa is essential as it is not possible to accurately cost the problem or to determine the potential for energy recovery from food waste without first knowing where and at what quantities and qualities the waste is being generated.

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