Quantifying and valuing post-consumer food waste in South Africa

Anton Nahman

Sustainability Science and Resource Economics Research Group, Natural Resources and the Environment, Council for Scientific and Industrial Research, PO Box 320, Stellenbosch, 7599, South Africa.

Willem de Lange

Sustainability Science and Resource Economics Research Group, Natural Resources and the Environment, Council for Scientific and Industrial Research, PO Box 320, Stellenbosch, 7599, South Africa.

Suzan Oelofse

Pollution and Waste Research Group, Natural Resources and the Environment, Council for Scientific and Industrial Research, PO Box 395, Pretoria, 0001, South Africa.

Corresponding Author: Anton Nahman. Email anahman@csir.co.za. Tel +27 21 888 2403, Fax +27 21 886 6518

Abstract:

Food waste is problematic on a number of levels; including the loss of a potentially valuable food source or resource for use in other processes; wasted resources and emissions in the food supply chain; and problems associated with the disposal of organic waste to landfill. We quantify the post-consumer food waste stream in South Africa, in order to bring attention to

the magnitude of the problem. In addition, we estimate the economic value of the wasted food, as well as the costs associated with disposing putrescible food waste to landfill; in order to highlight the associated costs to society. Costs associated with the loss of a potentially valuable food source are valued using a weighted average market price of the wasted food. Costs associated with the disposal of food waste to landfill are estimated based on per-unit financial and external costs for landfilling estimated in previous work. In total, the costs to society associated with these two food-waste related problems are estimated at approximately R32.5 billion (approximately US$4 billion) per annum, or 1.22% of annual GDP. These costs are significant, particularly considering that food waste (as well as resource use and emissions) at pre-consumer stages of the food supply chain, which is where the majority of food waste occurs in developing countries, are ignored.

Key words:

Food waste

Food security

Global hunger

Economic valuation

Food supply chain

Post-consumer waste

Organic waste

Landfill

1. Introduction

Food waste is becoming an increasingly significant global issue. Ironically, so is global hunger. A study on food wasted in the United Kingdom (Waste Resources and Action Programme 2008) showed that consumers throw away about one third of the food that they buy; of which 61% is still suitable for human consumption. The most common reason provided by consumers for food being wasted is that it is left unused (61% of the avoidable waste) or that too much has been cooked or prepared (Waste Resources and Action Programme 2008). By buying more food than what is going to be eaten, the developed world uses up precious land and resources that could otherwise be used to feed the poor. Yet, vast quantities of food waste ends up in landfills worldwide, where it contributes significantly to the environmental impacts of waste.

Nevertheless, food that is thrown away by consumers is only one component of the overall food waste problem. Food loss[1] occurs at various stages in the food supply chain, including during food storage, transportation, processing, at retailers and in the kitchens of restaurants and households (Lundqvist et al. 2008). Food loss or spoilage often occurs because of a lack of or failing infrastructure (Parfitt et al. 2010). It is estimated that globally "as much as half of all food grown is lost or wasted before and after it reaches the consumer" (Lundqvist et al. 2008: 4).

The problem of food waste is therefore becoming an increasingly important issue. Food waste is "composed of raw or cooked food materials and includes food loss before, during or after meal preparation in the household, as well as food discarded in the process of manufacturing,

[1] Food loss refers to the decrease in food quantity or quality, which makes it unfit for human consumption (Grolleaud 2002)

distribution, retail and food service activities. It comprises materials such as vegetable peelings, meat trimmings and spoiled or excess ingredients or prepared food as well as bones, carcasses and organs" (European Commission 2010: 9).

The disposal of food waste represents the loss of a potentially valuable resource that could be used as an input to other processes, such as composting or the production of biogas or animal feed. Furthermore, a large portion of food waste consists of food which is essentially still edible (European Commission 2010). The results of studies carried out between August 2010 and January 2011 suggest that roughly one third of food produced for human consumption is lost or wasted globally, amounting to approximately 1.3 billion tons per year (Gustavsson et al. 2011). This means that a vast amount of food, much of which could potentially feed the almost 1 billion people worldwide (13% of the global population) classified as undernourished (Food and Agriculture Organisation 2011), is going to waste; thereby aggravating problems of hunger and food insecurity, particularly in poorer countries (Gustavsson et al. 2011). Massive reductions in the amount of food wasted after production are therefore needed in order to meet the challenge of feeding growing populations and the global hungry (Lundqvist et al. 2008).

Wasted food also implies that the resources used in producing the food are wasted. For example, the agricultural sector tends to use a significant proportion of global water supplies. By reducing food losses and wastages, water demand for agriculture could therefore be reduced (Lundqvist et al. 2008). In addition, greenhouse gasses are released during the production (especially meat production), transport, processing and storage of food; thereby contributing to climate change. Emissions associated with the production and processing of

food that ends up being discarded can be considered ‘wasted emissions’ (Gustavsson et al. 2011).

In addition, the disposal of organic waste (including food waste) to landfill is a significant contributor to both greenhouse gas and leachate emissions (Hartmann & Ahring 2006, Waste Resources and Action Programme 2008). Every tonne of food waste is responsible for 4.5 tonnes of CO_2 equivalent emitted to the atmosphere (Waste Resources and Action Programme 2008). In particular, methane, the concentration of which varies from 40% to 70% of landfill gas by dry volume (European Commission 2000), and which has a 20–25 times stronger warming effect than CO^2 on a molecular basis, contributes about 18% towards total global warming, or 500 million tonnes per year, of which 40–75 million tonnes are attributed to emissions from landfills. The methane present in landfill gas is therefore becoming a significant contributor to global warming (El-Fadel et al. 1997).

Disposal of organic waste (including food waste) to landfill is therefore outlawed in many countries (Department of Environmental Affairs 2010). In South Africa, where waste contributes about 4.3% to national greenhouse gas emissions (Department of Environmental Affairs 2009); the phasing out of these practices is becoming a priority (Department of Environmental Affairs 2010). With the coming into effect of the 2008 Waste Act (Republic of South Africa 2008), there is a strong intention by government to ban the disposal of organic waste to landfill (Department of Environmental Affairs 2010). In line with the internationally accepted waste hierarchy (Sakai et al. 1996), the emphasis in sustainable food waste management should be on waste avoidance, minimisation, re-use, recycling and treatment, with disposal only as a last resort.

While no accurate national figures exist for South Africa, ad hoc municipal studies show that post-consumer food waste and pre-consumer condemned foods make up a noticeable waste stream in South Africa. Nationwide, organic waste (including food waste and garden waste) contributes about 40% to the municipal waste stream (Mata-Alvarez et al. 2000, Van Nes 2006). The objective of this paper is to quantify the post-consumer (household) food waste stream in South Africa, in order to bring attention to the magnitude of the problem. In addition, we estimate the economic value of the wasted food in monetary terms, in order to highlight the costs associated with this wasted resource. We also estimate the costs (both financial and 'external') associated with the disposal of food waste to landfill.

In Section 2, we summarise international trends regarding food waste quantities; and identify the main sources of food losses at different stages along the food supply chain. The post-consumer food waste stream in South Africa is quantified in Section 3. The costs associated with these losses are estimated in Section 4. Section 5 concludes and provides recommendations for further research.

2. Review of food waste trends and sources

On a per capita basis, overall food wasted is far higher in developed countries than in developing countries For example, according to Gustavsson et al, 2011, food losses amount to 280-300 kg/person/annum in Europe and North America respectively; compared to 120-170 kg/person/annum for South/Southeast Asia and Sub-Saharan Africa respectively. However, given that per-capita *consumption* of food is far lower in developing countries as

compared to developed countries; the amount of food wasted in developing countries is relatively high.

Food waste is generated throughout the food supply chain, from initial agricultural production to final household consumption. There is a diversity of causes of food waste throughout the food supply chain. Causes in the manufacturing/processing, wholesale/retail and food service sectors might be expected to be relatively similar in different countries. Causes of household food waste, on the other hand, vary considerably, as a result of cultural practices, climate, diet and socio-economic factors (e.g. household size, household income and frequency of eating out) (European Commission 2010).

Food losses and waste in low-income countries arises mainly due to financial, managerial and technical limitations in harvesting techniques, storage and cooling facilities (exacerbated by difficult climatic conditions), infrastructure, packaging and marketing systems. In contrast, the causes of food losses and waste in medium/high income countries mainly relate to consumer behaviour and to a lack of coordination between different actors in the supply chain (Gustavsson et al. 2011).

As such, in the European Union, for example, 42% of total food waste is generated by households; 39% by the manufacturing sector, 14% by the food service and catering sector, and 5% by the retail/wholesale sector (European Commission 2010). By contrast; in sub-Saharan Africa, consumers are only responsible for approximately 3.5% of overall food waste; with the majority being generated during the pre-consumer stages of the food supply chain (Gustavsson et al. 2011) (see Figure 1). As such, consumers in Europe and North America waste, on average, 95 and 115 kg of food per person/year, respectively; while

consumers in sub-Saharan Africa waste only 6 kg of food per person/year (Gustavsson et al. 2011).

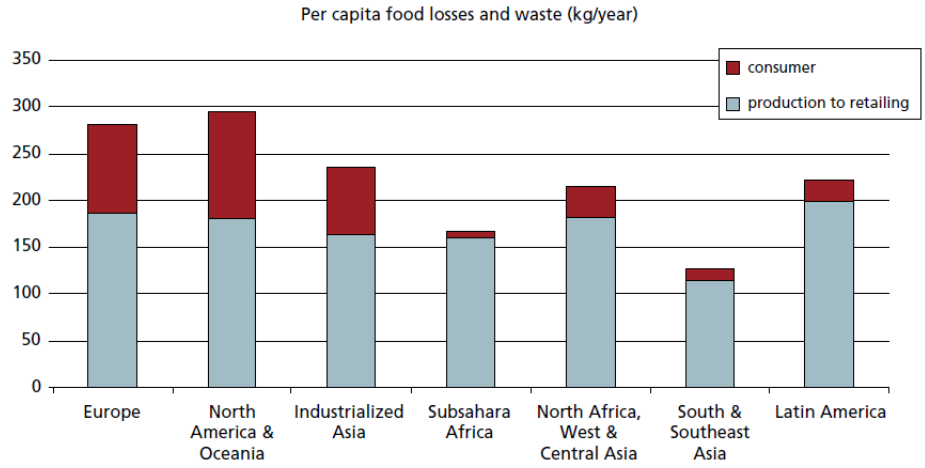

Figure 1: Per capita food losses and waste at consumption vs pre-consumption stages, in different regions (Gustavsson et al. 2011).

Gustavsson et al (2011) further provide the percentage of food lost at various stages in the food supply chain for different commodity groups in different regions of the world. Table 1 shows the percentage (by mass) of food entering each stage of the food supply chain that is lost or wasted, for sub-Saharan Africa.

Table 1: Percentage (by mass) of food entering each stage of the food supply chain that is lost/wasted – sub-Saharan Africa (Gustavsson et al. 2011)

Commodity group	Agricultural production	Post-harvest handling & storage	Processing & packaging	Distribution	Consumption
Cereals	6	8	3.5	2	1
Roots & tubers	14	18	15	5	2
Oil seeds & pulses	12	8	8	2	1

Fruits & vegetables	10	9	25	17	5
Meat	15	0.7	5	7	2
Fish & seafood	5.7	6	9	15	2
Milk	6	11	0.1	10	0.1

Again, it is evident that food losses at the post-consumer stage are low relative to the pre-consumer stages of the food supply chain in developing countries. Nevertheless, in this paper we focus only on quantifying and valuing food waste at the post-consumer stage in South Africa; that is, food that is thrown out by consumers/households. Although this is only a small component of the overall food waste problem in South Africa, there is currently insufficient data to quantify and value food losses at the pre-consumer stages of the food supply chain. In addition, one of the aims of the study is to raise awareness regarding the amount and value of food that consumers are throwing away. Given the current lack of information on the scope of the food waste problem in South Africa, the authors feel that this study represents an important first step towards an improved understanding of the issue. Quantifying and valuing food wasted at the pre-consumption stages of the food supply chain will form the focus of future research.

3. Quantifying post-consumer food waste in South Africa

Little information is available regarding quantities of food waste generated in South Africa. There are no national studies available on the perishable food balance (including waste) for South Africa, or on the tonnages of food waste that are disposed of each year. In this study, we estimate the quantities of post-consumer food waste in South Africa based on previous waste stream analyses that have attempted to characterise the overall household waste stream in terms of the relative contribution of different categories of waste (including food waste).

According to the Waste Background Paper produced for the South Africa Environment Outlook report on behalf of the Department of Environmental Affairs and Tourism (Fiehn & Ball 2005), 8.9 million tonnes of domestic (household) waste requiring collection and disposal was generated annually across South Africa in 2004. This is based on the mid-2004 population of 46.6 million, and on waste generation rates per income group (low, middle and high income) of 0.41, 0.74 and 1.29 kg/person/day respectively.

Extrapolating these waste generation rates to the mid-2011 estimated population of 50.59 million (Statistics South Africa 2011c), the total quantity of household waste currently being generated is estimated at 9.6 million tonnes per annum (Table 2). This assumes that waste generation rates for the different income levels, as well as the distribution of the total population across the income levels, have remained relatively unchanged since 2004.

Table 2: Domestic waste generated nationally in South Africa, by income group (2011)

Income level	Waste generation rates (kg/person/day)	Percentage Population distribution (%)	Mid-2011 population distribution	Domestic waste generated (t/a)
Low	0.41	73.97	37 421 423	5 600 116
Middle	0.74	21.44	10 846 496	2 929 639
High	1.29	4.59	2 322 081	1 093 352
		100	**50 590 000**	**9 623 106**

Unfortunately, little information is available on the proportion of food waste in the overall household waste stream at a national level in South Africa. Even at a municipal level, surprisingly few waste stream analyses have been conducted in South Africa. Silbernagl (2011) cites two studies in Johannesburg, two in the Western Cape, and one each in

Rustenberg and Bloemfontein. The available studies also tend to use different categorisations of waste, making comparison difficult. Some refer explicitly to food waste or 'kitchen waste' as a distinct category; while others refer only to 'putrescibles' (which includes animal carcasses and used diapers, in addition to food waste); or even to organic waste more broadly (which includes garden waste).

As will be seen in Section 4, for the purposes of valuation, it is useful to distinguish between food waste generation trends for different income groups. Only three municipal waste stream analyses have been found which present a breakdown of household waste composition for low, middle and low income areas; one each in the City of Johannesburg and the City of Cape Town (two large metropolitan areas), and one in Rustenburg, a smaller city in the North West Province.

According to a 1999 State of the Environment report on solid waste in the City of Cape Town (Department of Environmental Affairs and Tourism 1999),' kitchen waste' (which can be assumed to be synonymous with food waste) makes up 8.16% of household waste generated by low income households; 8.97% for middle income households, and 4.76% for high income households. It is not clear whether these percentages were calculated by mass or volume; although we will assume the former, given that this was the format used by the other studies.

A more recent study in the City of Cape Town (Arcus Gibb (Pty) Ltd 2008) found that food waste makes up 12.5% (by mass) of residential waste collected by the municipality; although no attempt was made to distinguish between different income categories. This estimate was derived by sorting and weighing samples of waste arriving at transfer stations and landfill sites in the City.

In the City of Johannesburg, a waste stream analysis was conducted on domestic waste entering three different landfill sites (Jarrod Ball and Associates 2001). The study found that putrescible waste (most of which was assumed to be food waste) as a percentage of total household waste (by mass) varies between 12% and 26.2% for low income households (average = 19.42), 6.5% -17.3% for middle income households (average = 10.63), and 7% - 7.6% for high income households (average = 7.31); depending on the site.

Finally, Silbernagl (2011) refers to a kerbside waste characterisation analysis study conducted in Rustenburg in the North West Province. Trash left at the kerbside for collection by a sample of households in different areas was sorted and weighed. The results of that study suggest that the proportion (by mass) of putrescible waste constitutes approximately 27% of the total household waste stream in low income areas, 13% in middle income areas, and 17% in high income areas.

The general finding of a higher proportion of food waste for low income households as compared to high income households can be explained by the fact that a higher proportion of low income household's expenditure is devoted to food as opposed to other goods. Thus, although high income households generate more waste (and probably more food waste) per capita as compared to low income households; the *proportion* of food waste relative to total waste is higher among low income households.

Table 3: Percentage (by mass) of food waste in the overall household waste stream in three South African cities

City	Low	Middle	High
Cape Town	8.16	8.97	4.76
Johannesburg	19.42	10.63	7.31
Rustenburg	26.67	13.33	16.67
Average	**18.08**	**10.98**	**9.58**

The results for the three cities are summarised in Table 3. Since no other studies have been found estimating the contribution of food waste to the household waste stream in South Africa, it is necessary to make certain assumptions regarding the applicability of the waste stream analyses conducted in Cape Town, Johannesburg and Rustenburg to South Africa as a whole. Although per capita waste generation is higher in Cape Town and Johannesburg than in other parts of South Africa (Fiehn & Ball 2005); there is no reason to suspect that the proportion of food waste in the total household waste stream will be any higher in these two cities than in other areas. Indeed, we might expect that food waste as a percentage of total household waste would be *higher* in rural areas as compared to urban areas, simply because people in rural areas have less access to other types of goods, packaging, etc. Indeed, the finding that the proportion of food waste in the total waste stream is higher among low income groups; and higher across all groups in Rustenburg as compared to Cape Town and Johannesburg; suggests that the food waste proportions for Cape Town and Johannesburg are particularly low relative to the situation in the rest of the country. Furthermore, Silbernagl (2011) cites estimates from a study of the Western Cape province which found that food waste fractions for urban landfills in the City of Cape Town ranged from 3.4% to 4.4%, compared with 8% to 24% for more remote 'rural' districts in the province. Thus, although waste generation per capita in rural areas is likely to be lower than in urban areas, the *proportion* of food waste relative to total waste may be higher in rural areas as compared to urban areas.

However, in the absence of more adequate information regarding the proportion of food waste in other areas of South Africa, it will be assumed that the proportions of food waste relative to total household waste in other areas are similar to those found in Johannesburg, Cape Town and Rustenburg. Indeed, based on the argument in the above paragraph, this may give rise to a conservative estimate of total food waste quantities in South Africa.

In Table 4, for each income group, the averages of the proportions of food waste in Cape Town, Johannesburg and Rustenburg are applied to the tonnages of household waste generated nationally per income group. This suggests that the total quantity of food waste generated in South Africa is approximately 1.4 million tonnes per annum.

Table 4: Quantities of food waste generated per income group in South Africa

Income level	Domestic waste (t/a)	Food waste (%)	Food waste (t/a)
Low	5 600 116	18.08	1 012 688
Middle	2 929 639	10.98	321 577
High	1 093 352	9.58	104 713
Total	**9 623 106**		**1 438 977**

4. Valuing post-consumer food waste in South Africa

Public decision making tends to be made on the basis of economic criteria. Social and environmental problems, even those that involve real losses in human well-being, such as those associated with food waste, often escape the attention of policy and decision makers. This is particularly the case in developing countries, where they must compete with other issues for limited resources. In large part, social and environmental issues are neglected because decision makers fail to appreciate the associated economic costs. An important way

of bringing these issues to the attention of policy makers is therefore to put an economic 'value' on the associated losses in human well-being. Economic valuation is the process by which economists quantify (in monetary terms) the losses in human well-being associated with social and environmental problems.

In Section 1, we identified a number of problems associated with food waste; including the loss of a potentially valuable resource for food or use in other processes; wasted resources and emissions in the food supply chain; and problems associated with the disposal of organic waste to landfill. In this section, we attempt to value the economic costs associated with two of these issues; namely the loss of a potentially valuable resource, and the impacts of disposing food waste to landfill. Costs associated with wasted resources and emissions in the food supply chain will form the subject of future research.

4.1 Costs of wasted food

Costs associated with the loss of a potentially valuable resource were valued in terms of wasted food that could have been used to feed the hungry; using a weighted average market price of the wasted food. An alternative method would have been to focus on prices that would be paid by potential buyers of organic waste for use as an input in processes such as composting or biogas production. However, these markets are currently underdeveloped in South Africa; and most organic waste is not used as an input in secondary production processes. We therefore argued that the market prices of the products found in the household food waste stream would be a proxy of the value being lost through this stream. However, this method assumes that all food waste disposed of to landfill has gone through the formal market, which is clearly not the case in South Africa, where a large proportion of food is

produced in backyard gardens. One could however argue that the bulk of such backyard garden waste will be used as input (compost) in such processes.

Comment [AN1]: Not quite sure what you mean here Willem?

The South African consumer price indices for a wide range of foodstuffs; together with the construction of typical food consumption 'profiles' for different income groups in South Africa, were used as a basis for calculation of the weighted average market price of food wasted by consumers. This assumes that food is wasted in the same proportion as it is consumed, which again may not be entirely true.

Monthly time series price data on each item in the 'basket' used to construct the South African consumer price index was obtained from Statistics South Africa (2011a) for the past four years (January 2008 until June 2011). The basket was modified to include foodstuffs only, i.e. all non-food items were excluded from the basket. The next step was to construct a typical food purchasing profile for high, middle and low income groups; taking into account basic nutritional requirements for different age groups; as well as actual food consumption patterns among different income groups in South Africa (Steyn et al. 2003). A nutritional requirement of between 1500 and 2300 calories (extracted from each major food group) per person per day was taken as the norm to build the purchasing profile for the three income groups (Marais 2011). Care was taken in building the purchasing profile to ensure that all food groups were represented; and to satisfy the nutritional requirements associated with a balanced diet.

121 different food items were identified for the typical food consumption profile of the high income group, 88 for the middle income group, and 62 for the low income group. The wider range of food items for the high income group was expected; given that high income earners

can afford more choice in terms of the items purchased to satisfy their nutritional requirements. The decision to exercise such choice is, of course, a function of the individual consumer. With regard to the composition of the profile, it was assumed that high income earners would tend to place a greater emphasis on quality, and to purchase more 'luxury' items such as chocolate, rather than 'basic' items such as maize meal. This implies that high income earners would purchase more expensive, higher quality foodstuffs on a more regular basis as compared to other income groups.

Low income earners were assumed to be more price sensitive; emphasising value for money in terms of higher volume, lower price (and lower quality) items; with fewer luxuries and more basic items. Finally, middle income earners would also emphasise value for money; but would also be interested in quality to a certain extent (more so as compared to low income earners); although not to the same extent as compared to high income earners. This income group would be price sensitive; although not to the same extent as low income earners. Clearly, these guidelines employed to construct the purchasing profiles were highly subjective. Significant deviation from the profiles may occur, particularly for the high income group. Nevertheless, it was necessary for the purposes of this research to make certain assumptions in this regard.

These profiles were then used to calculate a weighted average price per unit weight of food purchased (and wasted) by each income group. The weights were derived on the basis of the relative quantity of each item purchased within a specific time frame; in this case, one month. We estimated the number of units of each item that would be used within a month, subject to the basic nutritional requirements referred to above. Across the entire food profile, it was estimated that, on a per capita basis, high income earners consume approximately 72kg grams

of food and drink (excluding pure water) per month (or 2404 grams per day). The corresponding estimate for middle income earners was 65 kg per month (2168 grams per day); and for low income earners, 57 kg per month (1891 grams per day). These estimates are consistent with surveys of actual dietary patterns in South Africa (Steyn et al. 2003). The aggregated value of these purchases was R2568 per month for high income earners, R1978 per month for middle income earners, and R1038 per month for low income earners. These estimates translate into a weighted average 'price' of 3.56c/gram (R35 615 per tonne) of foodstuff purchased by high income earners, 3.04c/gram (R30 412 per tonne) for middle income earners, and 1.83c/gram (R18 298 per tonne) for low income earners[2].

Applying these costs per tonne to the tonnages of food waste generated by each income group (Table 5), it is clear that the costs of food waste in South Africa, purely in terms of lost food that could be used to feed the hungry, are significant; in the range of R32 billion annually. This equates to approximately 1.2% of annual gross domestic product (GDP)[3]. Although this is likely to be an overestimate, since wasted food is likely to be of lower quality (and therefore value) than food sold on the market; and since the ability to pay of the poor is lower than that of those who have access to food in formal markets; it nevertheless gives an indication of the order of magnitude of the value of wasted food (associated with post-consumer food waste only) in South Africa.

Table 5: Market value of wasted food (post-consumer food waste only) in South Africa (Rands per annum), valued at weighted average food basket prices

[2] R = South African Rands. 1 US Dollar = approximately 8 South African Rands at December 2011 exchange rates. c = South African cents (R1 = 100c)

[3] GDP for 2010 at current prices = R2 661 000 000 000 according to Statistics South Africa (2011b)

Income level	Food waste (t/a)	Cost / tonne	Value (R/annum)
Low	1 012 688	18 298.19	18 530 354 308
Middle	321 577	30 411.95	9 779 774 438
High	104 713	35 614.55	3 729 296 837
Total	**1 438 977**		**32 039 425 584**

4.2 Costs of disposing food waste to landfill

Aside from the issue of loss of a potentially valuable resource or food source, food waste going to landfill also creates costs in the form of unnecessary disposal of organic waste. In addition to the financial costs associated with disposing of solid waste to landfill; disposal of particularly organic waste to landfill gives rise to a number of 'external' (social and environmental) costs (or 'negative externalities')[4] (Nahman 2011). Firstly, decomposition of organic wastes produces both landfill gas (LFG) and leachate. LFG emissions impact negatively on both human health and the global climate; while emissions to soil and water (in the form of leachate) impact negatively on both human and ecological health. Secondly, there are externalities associated with the transport of waste to landfill sites, including air emissions, accidents, congestion, etc. Finally, there are 'disamenities' ('nuisances') associated with living in the vicinity of a landfill site, in the form of noise, odour, litter, vermin, dust, etc (Eshet et al. 2005, 2006).

Nahman (2011) estimates external costs per tonne of municipal solid waste entering landfill sites in the City of Cape Town, amounting to approximately R111 per tonne. This includes

[4] Externalities can be defined as the positive or negative side effects (external benefits or costs) of a particular economic activity (e.g. landfilling) that are not incurred by those with a direct financial stake in the activity (e.g. the landfill owner or operator); but are instead borne by other groups in society and/or by future generations; or are dispersed throughout society as a whole. Externalities associated with landfilling are not reflected in the financial statements of the landfill owner or operator, but affect social well-being more generally (Nahman 2011).

emissions of LFG and leachate, transport externalities, and disamenities. Further, financial costs are currently in the range of R240 per tonne of waste (De Wit & Nahman 2009, De Wit 2010). The total cost per tonne of municipal solid waste to landfill is therefore approximately R351 per tonne in the City of Cape Town.

Generalising this estimate to the national level requires taking into account differences in climatic, socio-economic and landfill operating characteristics between Cape Town and other regions in South Africa. Firstly, Cape Town has milder average temperatures and lower average rainfall relative to most other areas in South Africa, implying that LFG and leachate generation, which are positively correlated to temperate and rainfall, will be low in Cape Town relative to the rest of the country. External costs associated with landfilling may therefore be expected to be higher elsewhere in South Africa. However, property values in the City of Cape Town are higher than average for South Africa, implying that disamenities (which are often quantified based on their impact on property prices) are expected to be higher in Cape Town. Finally, landfills tend to be operated to internationally accepted standards in Cape Town; while in some other areas this is not yet the case. Thus, the financial costs of waste disposal may be higher in Cape Town; although the resulting environmental and social impacts of landfilling may be lower.

Taking all of these factors together, it cannot be said with certainty whether disposal costs per tonne of waste at a national level are higher or lower than those in Cape Town. Since there is no strong justification for using a higher or lower cost per tonne of waste, it may be best simply to assume that the estimate of R351 per tonne can be applied to the national level. Costs associated with disposal of post-consumer food waste to landfill (based on the above estimate of 1.4 million tonnes of food waste per annum) are therefore in the range of R505

million per annum. Note that this can be considered an underestimate, since the R351 per tonne was estimated on the basis of general municipal solid waste; whereas the organic waste fraction (particularly putrescible waste, such as food) is responsible for the most significant external costs. Costs per tonne of food waste disposed of to landfill can therefore be expected to be higher than the cost per tonne of general municipal solid waste disposed of to landfill.

5. Conclusion and Recommendations

The costs associated with loss of a potentially valuable food source, and with disposal of organic waste to landfill, are summarised in Table 6. In total, the costs to society associated with these two food-waste related problems are estimated at approximately R32.5 billion per annum, or 1.22% of annual GDP.

Table 6: Total costs to society of post-consumer food waste in South Africa (Rands per annum and % of GDP)

Costs associated with…	Value (R/a)	% of GDP
Wasted food source	32 039 425 584	1.20
Disposal to landfill	505 080 938	0.02
Total	**32 544 506 521**	**1.22**

However, these estimates ignore other food-waste related problems (e.g. wasted emissions and resource use associated with the production, transport and storage of food that goes to waste); which should be the subject of future research. In addition, estimates relate to post-consumer food waste *only*. Recall from Section 2 that post-consumer food waste only represents a small proportion of overall food waste in developing countries (3.5% for sub-Saharan Africa according to Gustavsson et al (2011)). Thus, although food wasted along the

supply chain cannot be valued using the same market prices as those used to value post-consumer food waste; the total costs to society associated with food waste in South Africa can be expected to exceed the estimates provided in Table 6. There is therefore a need for further research to quantify and value food waste along the food supply chain in South Africa and other developing countries; in order to raise awareness regarding the associated losses to society.

Acknowledgements

This study was funded by the CSIR through the Parliamentary Grant budget. Linda Godfrey and xx anonymous reviewers provided invaluable comments on an early draft of the paper

Bibliography

Arcus Gibb (Pty) Ltd (2008). A study on waste categorisation for solid waste services in the City of Cape Town, Final report, 18 December 2008, Issue 1.0.

De Wit, M.P. (2010) Personal Communication

De Wit, M.P., Nahman, A. (2009). Costing the integrated waste management bylaw with specific reference to airspace. Draft report (Phase II), De Wit Sustainable Options Pty (Ltd), Brackenfell.

Department of Environmental Affairs (2009). Greenhouse gas inventory South Africa 1990-2000: National Inventory report. Compilation under the United Nations Framework Convention on Climate Change (UNFCCC), Department of Environmental Affairs, Pretoria.

Department of Environmental Affairs (2010). National waste management strategy - First draft for public comments, Department of Environmental Affairs, Pretoria.

Department of Environmental Affairs and Tourism (1999). State of Environment: Cape Metro: Waste.

El-Fadel, M., Findikakis, A.N., Leckie, J.O. (1997) Environmental impacts of solid waste landfilling. Journal of Environmental Management, 50, 1-25.

Eshet, T., Ayalon, O., Shechter, M. (2005) A critical review of economic valuation studies of externalities from incineration and landfilling. Waste Management and research, 23, 487-504.

Eshet, T., Ayalon, O., Shechter, M. (2006) Valuation of externalities of selected waste management alternatives: A comparative review and analysis. Resources, Conservation and Recycling, 46, 335-364.

European Commission (2000). A study on the economic valuation of environmental externalities from landfill disposal and incineration of waste: Final main report, European Commission: DG Environment.

European Commission (2010). Preparatory study on food waste across EU 27, Technical Report 2010-054. ISBN 978-92-79-22138-5, European Commission.
Fiehn, H., Ball, J. (2005). Integrated waste management: Background research paper produced for the South Africa Environment Outlook report on behalf of the Department of Environmental Affairs and Tourism, Jarrod Ball and Associates.
Food and Agriculture Organisation (2011). Hunger statistics for 2006-2008, http://www.fao.org/hunger/en/, 7 December 2011.
Grolleaud, M. (2002). Post-harvest losses: Discovering the full story. Overview of the phenomenon of losses during the Post-harvest System, Food and Agriculture Organisation: Agricultural Support Systems Division, Rome.
Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., Meybeck, A. (2011). Global food losses and food waste: Extent, Causes and Prevention. Study conducted for the International Congress SAVE FOOD! At Interpack 2011, Düsseldorf, Germany, Food and Agriculture Organisation of the United Nations, Rome.
Hartmann, H., Ahring, B.K. (2006) Strategies for the anaerobic digestion of the organic fraction of municipal solid waste: An overview Water Scence and Technology, 53, 7-22.
Jarrod Ball and Associates (2001). Current waste management in the City of Johannesburg: A waste stream analysis of the general waste stream, DANCED Environmental capacity building project, Johannesburg. Mini-project WM4 on metro-wide waste management planning – phase 1. Report No. 1A, Danish Cooperation for Environment and Development (DANCED) / City of Johannesburg, Johannesburg.
Lundqvist, J., de Fraiture, C., Molden, D. (2008). Saving water: From field to fork – Curbing losses and wastage in the food chain, SIWI Policy Brief, Stockholm International Water Institute (SIWI), Stockholm, Sweden.
Marais, M. (2011) Personal communication.
Mata-Alvarez, J., Mace, S., Llabres, P. (2000) Anaerobic digestion of organic solid wastes. An overview of research achievements and perspectives. Bioresource Technology, 74, 3-16.
Nahman, A. (2011) Pricing landfill externalities: Emissions and disamenity costs in Cape Town, South Africa. Waste Management, 31, 2046-2056.
Parfitt, J., Barthel, M., Macnaughton, S. (2010) Food waste within food supply chains: Quantification and potential for change to 2050. Philosophical Transactions of the Royal Society: Biological Sciences, 365, 3065-3081.
Republic of South Africa (2008). National Environmental Management: Waste Act, No. 59 of 2008, The Presidency, Pretoria.
Sakai, S., Sawell, S.E., Chandler, A.J., Eighmy, T.T., Kosson, D.S., Vehlow, J., Van der Sloot, H.A., Hartlén, J., Hjelmar, O. (1996) World trends in municipal solid waste management. Waste Management, 16.
Silbernagl, P. (2011) What's the composition of your domestic waste stream? Is there value in recycling? The Waste Revolution Handbook, 1, 136-141.
Statistics South Africa (2011a). Consumer Price Index: October 2011, Statistical Release P0141, Statistics South Africa, Pretoria.
Statistics South Africa (2011b). Gross Domestic Product: 3rd Quarter 2011, Statistical Release P0441, Statistics South Africa, Pretoria.
Statistics South Africa (2011c). Mid-year population estimates - 2011, Statistical release P0302, Statistics South Africa, Pretoria.
Steyn, N.P., Nel, J.H., Casey, A. (2003) Secondary data analyses of dietary surveys undertaken in South Africa to determine usual food consumption of the population. Public Health Nutrition, 6, 361-644.
Van Nes, W.J. (2006) Asia hits the gas: Biogas from anaerobic digestion rolls out across Asia. Renewable Energy World, January/February 2006, 102-111.

Waste Resources and Action Programme (2008). The food we waste, ISBN 1-84405-383-0, Waste Resources and Action Programme (WRAP), Banbury, UK.