Title:

Costs of food waste in South Africa: Incorporating inedible food waste

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Abstract

This is the third in a series of papers examining the costs of food waste throughout the value chain in South Africa. The previous papers focused on the edible portion of food waste, the costs of which were estimated in terms of the market prices associated with the wasted food. The inedible portion (peelings, bones etc.), the costs of which require quantification using a different approach, was ignored. In this paper, opportunity costs associated with the inedible portion of the food waste stream in South Africa are estimated, in terms of the value foregone by not recovering this waste for use in downstream applications, such as energy generation or composting. In this way, costs of inedible food waste in South Africa are estimated at R6.9 billion per annum, or R2,863 per tonne. Adding this to the previous estimate for edible food waste of R61.5 billion per annum (in 2012 prices; equivalent to R65 billion in 2013 prices) results in a total opportunity cost of food waste in South Africa (in terms of loss of a potentially valuable food source or resource) of R71.9 billion per annum, or R5,708 per tonne. Thereafter, estimates of the costs associated with disposal of this food waste to landfill, including both financial costs and externalities (social and environmental costs), are taken into account. These costs amount to R255 per tonne, giving rise to a total cost of food waste in South Africa of R75 billion (approximately $7.5 billion) per annum, or R5,963 ($596) per tonne. This is equivalent to 2.2% of South Africa's 2013 GDP.

Keywords

Inedible food waste

Composting

Anaerobic digestion

Opportunity costs

Externalities

Landfilling

1. Introduction

Food waste can be defined as food losses throughout the food supply chain, including during production, storage, transportation, and processing; as well as food that is discarded at retailers and in the kitchens of restaurants and households (Lundqvist et al., 2008). As such, it includes food losses that arise before food reaches the end-user (pre-consumer food losses), as well as food that is discarded by consumers (post-consumer food waste). This definition includes both the edible and inedible (peelings, bones, etc.) portions of the food waste stream;

although the current paper focuses specifically on the inedible portion. Globally, it is estimated that food waste throughout the food supply chain (including both pre- and post-consumer food waste) amounts to 50% of all food that is produced for human consumption (Lundqvist et al., 2008).

Food waste, particularly if disposed of (e.g. to landfill) rather than recovered, is problematic for a number of reasons. These include wasted resources and emissions in the food supply chain, opportunity costs associated with loss of a potentially valuable food source or resource for use in other processes (e.g. energy generation or composting), and costs (financial costs, as well as negative social and environmental impacts or 'externalities'[1]) associated with the disposal of organic waste to landfill. The 2012 National Waste Information Baseline Report (Department of Environmental Affairs, 2012) estimates that organic waste (comprising mainly garden waste and food waste) contributes about 13% (by weight) of the South African general waste stream, and that approximately 65% of this organic waste is disposed of to landfill.

In previous papers (Nahman et al., 2012; Nahman and De Lange, 2013), the authors estimated the costs of food waste across the value chain in South Africa, in terms of the loss of a potentially valuable food source, and in terms of the financial and external costs (externalities) associated with disposing of food waste to landfill. Firstly, Nahman et al. (2012) estimated the cost of post-consumer food waste in South Africa at approximately

[1] 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).

R21.7 billion (approximately $2.7 billion at prevailing exchange rates) per annum[2], or 0.7% of South Africa's 2011 gross domestic product (GDP)[3]. This included the costs of wasted edible food, valued according to weighted market prices for income group-specific food baskets[4] (obtained from the South African Consumer Price Index for Food (Statistics South Africa, 2011); as well as both the financial and external costs of disposal to landfill (based on Nahman (2011)).

Thereafter, Nahman and De Lange (2013) extended the analysis by assessing the costs of edible food waste throughout the entire food value chain, from agricultural production through to consumption at the household level. First, food waste at each stage of the value chain was quantified in physical units (tonnes) for various food commodity groups. Then, weighted average representative prices (per tonne) were estimated for each commodity group at each stage of the value chain, based on market prices at each stage of the chain for a range of representative commodities within each group. Finally, prices were multiplied by the food waste quantities, and the resulting values were aggregated across the value chain for all commodity groups. In this way, the total cost of food waste across the food value chain in South Africa was estimated at R61.5 billion per annum (approximately $7.7 billion at prevailing exchange rates); equivalent to 2.1% of South Africa's 2011 GDP.

However, both of those papers focused specifically on the edible portion of food waste, and ignored the inedible portion, the costs of which cannot be estimated using the same methods

[2] R = South African Rands. In the previous papers, an exchange rate of R8 to the US$ was assumed (average over January-October 2012). In the current paper, a rate of R10 per $ will be used, based on the average between March 2013 and March 2014.

[3] In the previous papers, we used the nominal 2011 GDP for South Africa of R2.96 trillion at current prices (Statistics South Africa, 2012). In the current paper, we use the nominal 2013 GDP of R3.4 trillion at current prices (Statistics South Africa, 2014).

[4] Obtained from the South African Consumer Price Index for Food (Statistics South Africa, 2011)

as for the edible portion. In this paper, the costs of the inedible portion of the food waste stream in South Africa are estimated; based on opportunity costs (i.e. the potential value that is foregone by not recovering this waste for use in downstream applications, such as energy generation or composting). We then synthesise the results from the previous two papers with the results from the current paper (updating all values to 2013 prices), accounting also for the financial and external (social and environmental) costs of disposing of food waste to landfill. In this way, it is possible to provide a more complete assessment of the costs of food waste in South Africa.

2. Methods

In previous research on the costs of food waste in South Africa, costs were estimated largely on the basis of food commodity prices, with the rationale that the 'costs' of discarded food can be equated to the potential value of that food if it could have been saved and used to feed those in need. Food commodity prices were used to derive representative prices per tonne for a range of food commodity groups, which were multiplied by the quantities of edible food waste currently being generated, to estimate the total costs of edible food waste in South Africa.

In the case of inedible food waste, however, food commodity prices cannot be used, since inedible food waste by definition cannot be used to feed the hungry. Nevertheless, inedible food waste can be used as an input into other processes, such as composting, bio-energy generation, or the production of animal feed; and therefore has value in its own right. As such, to the extent that inedible food waste is discarded (e.g. to landfill) rather than used as an input into other processes, there are opportunity costs associated with the loss of a potentially valuable resource.

In this paper, we develop a methodology for estimating the opportunity costs of inedible food waste that is disposed of to landfill, in terms of the foregone value that could have been derived had the food been used as an input into two such beneficiation processes, namely biogas production through anaerobic digestion, and composting. We use this method to derive a unit cost per tonne of inedible food waste, which is multiplied by the quantities of inedible food waste currently being generated, to provide an estimate of the opportunity costs associated with inedible food waste in South Africa. The following sub-sections provide more detail on the data and methods.

2.1 Quantity of inedible food waste generated in South Africa

Nahman et al. (2012), which focused on household food waste, cited data from the United Kingdom indicating that 19% of food thrown away by consumers is inedible, with the remainder (81%) still being edible (Waste Resources and Action Programme, 2008). In the absence of more specific information for the South African context, it was assumed that a similar ratio between edible and inedible food waste applies, and the analysis was therefore based only on 81% of the total quantity of household food waste generated in South Africa.

In Nahman and De Lange (2013), where the analysis was extended to food losses and waste throughout the value chain, this assumption was maintained, although in that paper the data used on waste generation quantities pertained only to the edible portion of food waste. A total of 10.2 million tonnes of edible food waste throughout the value chain per annum was estimated. Thus, assuming that this quantity represents 81% of total (edible plus inedible) food waste generated throughout the value chain in South Africa, total food waste generated can be calculated at 12.6 million tonnes per annum, of which 10.2 million tonnes is edible, and 2.4 million tonnes is inedible.

The current paper will therefore focus only on the 19% (2.4 million tonnes per annum) of food waste generated throughout the value chain which can be classified as inedible. The previous papers dealt with the edible portion (10.2 million tonnes per annum). Data from all three papers will be synthesised in Section 3 to provide a full account of the costs of all food waste (both edible and inedible) generated throughout the value chain in South Africa.

2.2 Unit costs per tonne of inedible food waste

Unit costs per tonne of inedible food waste were estimated on the basis of the potential value of this waste as an input to biogas production or composting, using the rationale that this value is lost when the waste is disposed of to landfill rather than recovered, and therefore represents an ‘opportunity cost.’ Note that we use the term ‘unit value’ to describe the value per tonne of inedible food waste that could be derived if the waste was used in one or other of these processes; which in turn translates into a ‘unit cost’ per tonne of inedible food waste that is, instead, discarded to landfill.

In general, unit values are estimated based on the market prices of the end-product, adjusting for the ratio between the quantity of the input feedstock, and of the end-product generated. Note that we do not take the costs of the beneficiation processes into account, since these are likely to differ significantly between different operators, and information on these costs was not readily obtainable. The process followed in deriving unit values associated with each technology is described in the following sub-sections.

2.2.1 Biogas production

There are a currently 38 biogas production operations registered with the National Energy Regulator of South Africa (NERSA) (NERSA, 2013), although these are mostly operated at a small scale, generating only enough biogas for use by the owners. The financial and economic feasibility of biogas production for commercial applications is currently limited in South Africa, such that no biogas is currently sold commercially in the country (Smith et al., 2014). Therefore, since there is no 'market price' for biogas in South Africa, it was necessary to estimate a representative 'price' at which the product would potentially be sold, if such a market were to exist.

In order to do this, we took the price of liquefied petroleum gas (LPG), which is widely sold in South Africa, and adjusted this based on differences in heating value (at standard temperature and pressure, STP) to derive a representative price for biogas. LPG is compressed and sold in liquid form at around R21.74 per kg. With a density of 0.541kg/litres (Department of Energy, 2009), this works out to R11.76 per litre (in compressed liquid form). In order to estimate a price for biogas on the basis of the price for LPG based on differences in heating value at STP, it is first necessary to account for the fact that compressed LPG expands approximately 250 times from liquid to gaseous form at STP when the gas is used. Thus, R11.76 per litre of LPG in liquid form is equivalent to approximately R0.047 per litre of LPG in gaseous form at STP. Given that the heating value of LPG at STP is equal to 94 MJ/m^3, while the heating value of biogas at STP is only 38 MJ/m3 (i.e. LPG holds approximately 2.4 times the heating value of biogas), a ‘price’ for biogas can be calculated at approximately R0.019 per litre at STP, or R19 per m^3.

The production of biogas (methane) is proportional to the feeding rate of the feedstock (which can include food waste as well as other materials), and the temperature. In order to estimate the value of food waste as an input to the process, on the basis of the derived ‘price’ of the end product (biogas), it is necessary to make some assumptions regarding the ratio of food waste used to biogas produced. However, there is no simple answer here, as this ratio can vary depending on the composition of the total feedstock (i.e. the proportion of food waste relative to other materials used as feedstock), temperature and pressure differentials, moisture content, etc. It is theoretically possible to standardise the feedstock to the anaerobic digestion process to improve its digestibility, as long as the pre-processing (milling or heat treatment such as pasteurisation) is carefully controlled. As a rule, cellulosic and lignin-rich materials will largely remain undigested (or rather slowly digested) by anaerobic digestion, and should be minimised to the extent possible in the feedstock. However, since this was not an optimisation exercise, we assumed that the feedstock would consist only of the food waste stream as is (although even here there is a significant amount of variation), with no blending with sewage, straw, grass, wastewater, etc.

Estimates from the literature of biogas yield per kg of food waste used as a feedstock (no blending with other materials) are presented in Table 1. The variances between the studies cited arise due to differences in the composition of the food waste used as feedstock, temperature, and moisture content. Taking an average across the studies, it can be assumed that 1kg of food waste will produce approximately 0.296 m^3 of biogas. Based on the price estimated above of R19 per m^3 of biogas, this works out to a value (before costs) of R5.63 per kg (or R5,634 per tonne) of food waste used as a feedstock.

Table 1: Estimates of biogas yield per kg of food waste used as a feedstock under different conditions

m^3 of biogas per kg food waste	Source
0.642	Banks et al. (2011)
0.111	Curry and Pillay (2012)
0.367	Curry and Pillay (2012)
0.200	ADIAC (2009)
0.153	Wilkie (2013)
0.304	Zhang et al. (2007)
0.296	Average

2.2.2 Composting

Good quality compost requires a carbon-nitrogen (C:N) ratio of around 25-30:1. Food waste is lower in cellulosic and lignin-rich materials as compared to other compostable materials such as garden waste, while it is generally higher in nitrogen content; although the exact C:N ratio differs markedly between different types of food waste. As a result, compost cannot generally be produced using food waste alone; a balance between food waste and other types of organic material (e.g. garden waste) is generally required in order to obtain the correct C:N ratio.

The density of compost ranges between 415kg/m^3 and 711kg/m^3, depending on the moisture content, with an average of 548kg/ m^3 (US Composting Council, 2001). Bulk compost prices in South Africa vary depending on the grade and product, with an average price of approximately of R200/m^3. Based on a density of 548kg/m^3, this implies a price of R365 per tonne.

According to Kim et al. (2011), only 250kg of compost can be obtained from a tonne of food waste, owing to evaporation, chemical decomposition, etc., which lead to a reduction in the mass of the material. Thus, the value (before costs) of one tonne of food waste as an input to composting is equivalent to the price of a quarter of a tonne of compost, or R91 per tonne.

2.2.3 Weighted average unit cost of inedible food waste

In sections 2.2.1 and 2.2.2, we derived the unit value (before costs) per tonne of food waste as an input into biogas production and composting. In order to establish a weighted average unit cost per tonne of inedible food waste generated in South Africa, an assumption needs to be made regarding the proportion of this waste stream that is likely to be directed towards each process. It must be borne in mind that the focus here is on the opportunity costs of the inedible food waste that is discarded, in terms of the potential value that is foregone by *not* recovering this waste stream for beneficiation. As such, the current proportion of the food waste stream that is directed towards each process is of no relevance (indeed, very little food waste in South Africa is currently used in either of these processes). Instead, for the purposes of this exercise, it is necessary to assume that all inedible food waste generated in South Africa (2.4 million tonnes per annum, see Section 2.1) could potentially be beneficiated through one or the other process; and then to make a further assumption regarding what proportion of this total would likely be directed towards each process. In the absence of reliable information on which to base such an assumption (e.g. information regarding how much inedible food waste is currently utilised in each process, or regarding the financial and economic viability of each process); a 50/50 split is assumed. In other words, since there is no justification for assuming otherwise, it is assumed that 1.2 million tonnes per annum of inedible food waste (50% of the total inedible food waste stream) per annum would be used as a feedstock in each process.

The weighted average unit cost per tonne of inedible food waste in South Africa can therefore be calculated as the simple average of the value per tonne of food waste in each process, namely R5,634 per tonne (biogas production) and R91 per tonne (composting), giving rise to a value of R2,863 per tonne.

3. **Results and synthesis**

Based on the data, methods and assumptions described in Section 2, the total opportunity cost of inedible food waste in South Africa can be estimated, by multiplying the quantity of inedible food waste generated (2.4 million tonnes per annum, as per Section 2.1) by the weighted average unit cost per tonne (R2,863 per tonne, as per Section 2.2.3), giving rise to a cost of R6.9 billion per annum.

This can be added to the cost per tonne of edible food waste generated throughout the value chain (R61.5 billion per annum in 2012 prices, as per Nahman and De Lange (2013), equivalent to R65 billion in 2013 prices), to give rise to a total cost of R71.9 billion per annum. Given that 12.6 million tonnes of food waste (edible and inedible) is generated per annum in South Africa, this works out to a weighted average opportunity cost of R5,708 per tonne of food waste in South Africa. These costs are summarised in Table 2.

Table 2: Opportunity costs of food waste in South Africa (in terms of loss of a potentially valuable resource or food source)

	Edible	Inedible	Weighted average	Total
Quantity (1000 t/yr)	10 205	2 394		12 599
Opportunity cost (R/t)	6 375	2 863	5 708	
Opportunity cost (R'million/yr)	65 055	6 853		71 908

Aside from the issue of opportunity costs in terms 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, the disposal of waste to landfill (particularly in the case of organic waste) gives rise to a number of ‘external’ (social and environmental) costs (or ‘negative externalities’) (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 leachate can lead to contamination of ground water. 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 the external costs associated with landfill sites in the City of Cape Town, including emissions of LFG and leachate, transport externalities, and disamenities. Costs associated with LFG and leachate emissions were estimated using the benefits transfer method, which involves drawing on existing valuation estimates from other studies, and applying them to the study site in question, making appropriate adjustments for differences between the original study site(s) and the new study site. Costs associated with transport emissions were estimated based on average external costs per tonne-km associated with freight transport in South Africa as estimated by Jorgensen (2009). Finally, costs associated with disamenities were estimated using the hedonic pricing method, a statistical technique through which the effect of environmental quality variables (such as proximity to a landfill site) on property prices can be isolated from all other characteristics affecting property prices, based on data on house prices and characteristics for a large number of properties, using multiple regression. In this way, external costs per tonne of municipal solid waste entering landfill sites in the City of Cape Town were estimated at approximately R111 (Nahman, 2011) in 2010 prices; equivalent to R130 at 2013 prices.

In applying this estimate to the current study, it could be argued that externalities associated with transport should be excluded, since alternatives to landfilling will also require transport. However, it should be borne in mind that the objective here is to estimate the externalities specifically associated with the disposal of food waste to landfill. The idea is not to conduct a full evaluation of landfilling as compared to other options. As part of such a comparison, the full costs (including externalities) associated with alternatives would need to be estimated, and compared with those of landfilling; however, this was beyond the scope of the current study.

Furthermore, it could also be argued that R130 per tonne is an underestimate of the externalities associated specifically with food waste, since the former 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 (odours, leachate, landfill gas (including methane) emissions, etc). Costs per tonne of food waste disposed of to landfill can therefore be expected to be higher than for general municipal solid waste. Nevertheless, in the absence of information specifically pertaining to the externalities associated with organic waste, or of data on externalities for other areas of South Africa; and given that there are arguments for adjusting the value in both an upward and downward direction; it was deemed necessary to assume that the estimate of R130 per tonne for landfilling in Cape Town should be used in the current study.

In terms of financial (capital and operating) costs for landfill disposal, current tipping fees are generally in the range of R100 to R150 per tonne of waste, varying widely between different municipalities in South Africa. Although these fees are not generally based on full cost accounting (e.g. they don’t generally reflect the costs associated with landfill closure), such that they are likely to underestimate the full financial costs of landfill disposal, this was the best available data on which to base the financial costs associated with landfill disposal at a national level.

As such, assuming external costs of R130 per tonne, and financial costs of R125 per tonne (mid-point in the range of current tipping fees of R100 – R150 per tonne), the total cost of municipal solid waste to landfill is approximately R255 per tonne. As such, costs associated with disposal of food waste to landfill (based on the above estimate of 12.6 million tonnes of food waste per annum, including both edible and inedible food waste) are in the order of R3.2 billion per annum. These costs are summarised in Table 3.

Table 3: Costs of food waste in South Africa in terms of disposal (financial costs and externalities)

	Edible	Inedible	Weighted average	Total
Quantity (1000 t/yr)	10 205	2 394		12 599
Financial costs (R/t)	125	125	125	
Financial costs (R'million/yr)	1 276	299		1 575
Externalities (R/t)	130	130	130	
Externalities (R'million/yr)	1 331	312		1 643
Total (R/t)	255	255	255	
Total (R'million/yr)	2 606	611		3 218

As such, adding the opportunity costs (Table 2) to the disposal costs (Table 3), the total cost of food waste (both edible and inedible) across the value chain in South Africa amounts to R75 billion (approximately $7.5 billion) per annum, equivalent to 2.2% of South Africa's 2013 GDP. On a per tonne basis, the costs of food waste amount to R5,963 (approximately $596) per tonne. These costs are summarised in Table 4.

Table 4: Summary of costs of food waste in South Africa

	Edible	Inedible	Weighted average	Total
Quantity (1000 t/yr)	10 205	2 394		12 599
Opportunity cost (R/t)	6 375	2 863	5 708	
Opportunity cost (R'million/yr)	65 055	6 853		71 908
Disposal cost (R/t)	255	255	255	

Disposal cost (R'million/yr)	2 606	611		3 218
Total cost (R/t)	6 630	3 118	5 963	
Total cost (R'million/yr)	67 661	7 464		75 125

Note: Opportunity costs refer to the costs associated with loss of a potentially valuable resource or food source; while disposal costs refer to both financial costs and externalities associated with disposal

4. Conclusions and recommendations

Landfilling remains the predominant method of waste management in South Africa, accounting for approximately 90% of all waste generated. While the policy environment is in place for moving waste up the waste management hierarchy, away from landfilling towards reuse, recycling and recovery; alternatives to landfilling are generally considered more expensive, at least in purely financial terms. However, if a broader range of economic, social and environmental costs and benefits are taken into account, it is likely that alternatives to landfilling will become more attractive.

For example, this study shows that the ‘full’ costs of disposing of food waste to landfill, in terms of both opportunity costs (i.e. loss of a potentially valuable resource or food source) and costs associated with disposal (financial costs, as well as social and environmental externalities), amount to R5,963 per tonne. These costs should likewise be compared with the ‘full’ costs of alternatives to landfilling, in order to inform decision making regarding waste management alternatives.

More generally, there is a need to assess the full range of economic, social and environmental costs and benefits of various waste management alternatives across different waste streams and municipalities in South Africa. Such an assessment would be an important way of motivating for increased investment in moving South Africa up the waste management hierarchy.

With the recent changes in waste management regulation in South Africa, and the associated increased costs of landfill design and construction, in line with the new legislated requirements (Oelofse, 2013), alternative technologies are likely to gain momentum. The National Organic Waste Composting Strategy (NOWCS) was developed in support of the National Waste Management Strategy (NMWS), which targets a of 25% diversion of municipal waste from landfill (Department of Environmental Affairs, 2011). This NWMS diversion target is envisaged to be achieved largely through the diversion of organic waste, construction waste, paper and packaging waste (Department of Environmental Affairs, 2011).

Goal 2 of the NOWCS is to understand and facilitate feedstock sources and opportunities for composting (Department of Environmental Affairs, 2013). In line with this goal for composting, there is also a need to understand and facilitate feedstock sources and opportunities for other organic waste treatment technologies, such as biogas digesters, in order to ensure that the full opportunities associated with the potential beneficiation of organic waste, particularly food waste, can be realised. It is therefore recommended that an integrated organic waste management strategy be developed to address organic waste in a holistic manner. It is envisaged that such an approach will go a long way towards minimising the costs and realising the opportunities associated with the management of organic waste, including food waste.

Acknowledgements

This study was funded by the CSIR through the Parliamentary Grant budget. Suzan Oelofse and Linda Godfrey provided useful comments on an earlier draft.

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