A NATIONAL WASTE RESEARCH, DEVELOPMENT (R&D) AND INNOVATION ROADMAP FOR SOUTH AFRICA: PHASE 2 WASTE RDI ROADMAP

The economic benefits of moving up the waste management hierarchy in South Africa: The value of resources lost through landfilling

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CSIR/NRE/PW/ER/ 2012/0052/A	Phase 1 - HCD: Current waste HCD initiatives in South Africa	Lombard, J., Lombard, R.K. Godfrey, L. and Roman, H.
CSIR/NRE/SUSET/ER/ 2012/0053/A	Phase 1 - HCD: Core waste management skills and implementation modalities	Lombard, J., Lombard, R.K., Godfrey, L. and Roman, H.
CSIR/NRE/SUSET/ER/ 2012/0063/A	Phase 1 - Institutional framework: Current and required institutional mechanisms to support waste innovation	Schoeman, C., Mapako, M., Kalan, S., Godfrey, L. and Roman, H.

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1 INTRODUCTION

1.1 Background

The most recent waste baseline study shows that South Africa landfills approximately 90% of all waste generated (as at 2011) (DEA, 2012). While the policy environment exists for moving waste up the hierarchy away from landfilling towards reuse, recycling and recovery (Figure 1), landfilling remains the predominant method of waste management.

Discussions around moving away from landfilling towards alternative technology solutions are usually stalled by the perceived higher cost of alternatives relative to landfilling. Typical landfilling disposal fees range from R100-R150/T for general waste, up to R600-R800/T for hazardous waste (DST, 2013). However, these tipping fees, especially for general waste, are thought to be artificially low, since many municipal landfill sites are not designed and operated according to sanitary engineered landfill standards which would drive up costs (through higher CAPEX and OPEX costs). New norms and standards for disposal of waste to landfill (DEA, 2013) are expected to assist in correcting these price 'distortions' by significantly increasing waste disposal costs at new landfills, or where new cells are developed at existing landfills (DEA, 2013; DST, 2013).

Therefore, with the perceived higher cost of alternatives being a constraint to their implementation in South Africa, the question arises as to how one can drive waste management towards alternative technology solutions which appear to be more 'expensive' than simply disposing of waste to landfill? This report turns the argument around by looking at the value of resources which are currently lost to the South African economy by disposing of them as waste to landfill[1]. By understanding the value of resources lost to the South African economy, an informed discussion can be had between stakeholders (government and industry) on the economic (as opposed to the financial) benefits of moving waste up the hierarchy.

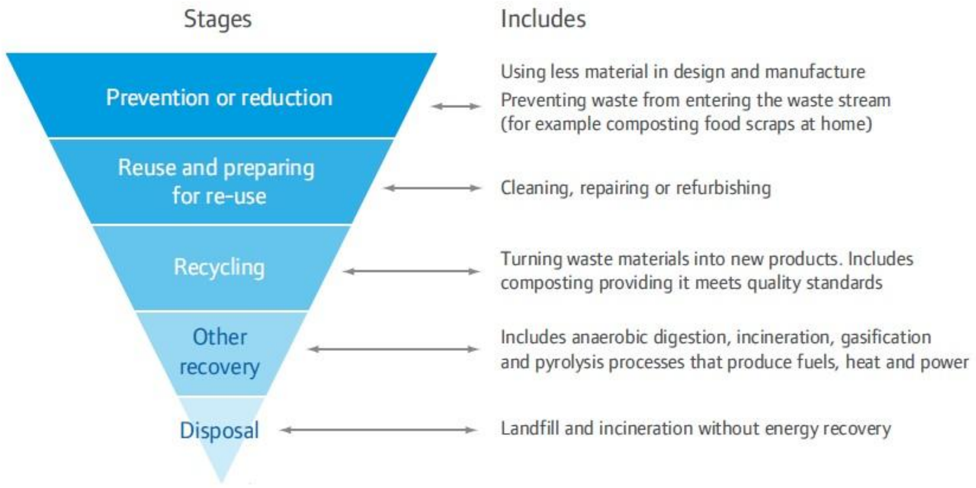

Figure 1: Waste hierarchy

1 From an economic perspective, the value of these resources can be seen as additional 'costs' associated with landfilling (or 'benefits' associated with alternatives) that are currently not being accounted for in decision-making processes.

The aim of this research is therefore to determine the monetary value of resources potentially available to the South African economy by recovering them from our waste streams. Specifically, the focus is on the economic *benefits* of recovery[2]

The term 'recovered' is used throughout the report in reference to the recovery of materials from the waste. These resources are then available for diversion into waste reuse, recycling or recovery (including energy recovery) activities. The assumption is made that all reasonable measures have been taken to first reduce the amount of waste generated, and where waste cannot be reduced, alternatives to landfilling are maximised.

1.2 Benefits of moving up the waste hierarchy

Moving waste up the hierarchy towards reuse, recycling and recovery contributes to the principles of a 'green economy' in a number of ways:

- Re-introduction of resources back into the economy
- Contribution to economic growth and job creation, and
- Reducing social and environmental costs

Each of these benefits is discussed briefly in Annexure 1.

The focus of this research is on the first benefit of moving waste up the hierarchy – "*Re-introduction of resources back into the economy*" – which we quantify in terms of a 'resource value.' In other words, we estimate the monetary value of the resources that can potentially be recovered from the waste stream. Importantly, this implies that the values reported in this study are likely to under-estimate the full benefits of moving waste up the hierarchy, as the benefits associated with job creation and economic growth, as well as the avoided costs and externalities associated with virgin material extraction, are not taken into account. In Section 5.2, we bring in estimates from previous research regarding the financial costs and externalities associated with landfill disposal, to supplement the estimates from the current study regarding the potential value of recovered resources, in order to provide a more comprehensive picture of the benefits of moving waste up the hierarchy.

The focus of this research is on the "*Re-introduction of resources back into the economy*" – which we quantify in terms of a 'resource value' – the monetary value of the resources that can potentially be recovered from the waste stream

[2] An economic evaluation of waste management options requires assessment of both the costs and benefits of each option. Such an evaluation is beyond the scope of this report, which aims to provide a preliminary assessment of the benefits (not accounting for costs) of moving up the waste management hierarchy, based on the value of resources lost through landfilling.

3 METHODOLOGY FOR ESTIMATING THE RESOURCE VALUE OF WASTE

The aim of this study is to assess the benefits of increased recovery of resources from waste.

The focus is therefore on the potential value of the materials that *could* be recycled; rather than the value of materials *currently* being recycled.

All economic activities (including waste management activities, such as landfilling or recycling) incur both benefits and costs. However, certain of these benefits and costs, such as environmental or social externalities[3], are intangible or difficult to quantify, and are therefore not typically accounted for in policy and decision making, which can in turn lead to incorrect decisions being made. Economic valuation refers to the process by which economists quantify (in monetary terms) the unaccounted for benefits and/or costs of economic activities or policy actions. The information generated through this process can then be used to contribute towards improved decision making, in conjunction with other relevant information.

In this study, the aim is to quantify the economic benefits of moving waste up the hierarchy in South Africa, based on the potential value of the resources that could be recovered. Note that the *costs* of recovery are not taken into account; such that the results of this study cannot, on their own, be used to justify the choice of one waste management option over another (in other words, a full cost-benefit analysis of waste management options is not conducted). Instead, the information presented in this report should be seen as one further source of information that can be used in the decision making process, alongside other information.

Previous studies on the economic benefits of moving waste up the hierarchy have tended to focus either on the cost savings of waste minimisation, or on the contribution of existing recycling activities to GDP (or gross value added, GVA). For example, a study of the value of recycling in the EU focuses on the value (calculated as price multiplied by quantity) of materials that are currently being recycled (ETC/SCP 2011). However, a distinction needs to be drawn between the 'current' value of recycling (i.e. the value of materials currently being recycled), and the 'potential' value of recycling (the value of materials currently being landfilled that *could* be recycled). If the aim is to assess the benefits of increased recovery of resources from waste, as in the current study, then the focus should be on the potential value of the materials that *could* be recycled; rather than the value of materials *currently* being recycled.

According to the EEA (2011:18), while estimates of turnover from recycling in the EU study referred to above are based on the amount of material currently being recycled, "*data on… waste generation signal the maximum amount that could be recycled. Assuming that all waste is recycled provides an indication of the maximum potential for recyclables to meet… material consumption needs. Of*

[3] Externalities can be defined as the positive or negative side effects (external benefits or costs) of a particular economic activity (e.g. landfilling) that do not enter into formal markets associated with the activity in question (and are therefore not incorporated in market prices for the activity); but are instead borne by other groups in society and/or by future generations; or are dispersed throughout society as a whole. Examples include the impacts of landfill gas or leachate on the environment, or the impacts of odours on residents living in the vicinity of a landfill site.

course, this upper limit is theoretical because in reality not all waste can be recycled." [4] This insight suggests a potential methodology for providing an indicative assessment of the value of resources that *could* potentially be recovered from the waste stream and re-introduced into the economy. This methodology involves quantifying (in tonnes) the resources (waste) available, and multiplying this quantity by a representative unit value (in R/tonne).

$$Resource\ value_n = (Q_1\ x\ UV_1) + (Q_2\ x\ UV_2) + \cdots (Q_n\ x\ UV_n)$$

Where: Q = quantity of a waste stream available to the economy (tonnes)
UV = unit value (R/tonne)

This method of determining resource value will therefore be used to estimate the economic benefits of moving up the waste hierarchy in South Africa, in terms of the value of the resources that could potentially be recovered. The following sub-sections present more detail on the approach used in the study.

3.1 Quantity

While it would be ideal to assume that 100% of all waste generated could be recovered, and to base the resource value on this quantity, this may not be realistic, particularly in the short- to medium-term, given current physical or economic limitations to recycling and recovery.

As such, four scenarios have been modelled based on proposed increases in recovery rates of waste streams for the short-, medium- and long-term, i.e. as more resources are recovered from the waste stream and made available to the economy.

1. **Scenario 1:** Baseline (2011) waste quantities and recycling rates, as per the National Waste Information Baseline (DEA 2012); reflecting the tonnages of materials that were being recycled as at 2011.
2. **Scenario 2:** Short-term scenario (2017) based on targets in Industry Waste Management Plans (IndWMP) and targeted recycling rates for 2017 (BMI Research 2013). Where a short-term target was not available for a particular waste stream, a middle point between Scenario 1 and Scenario 3 was adopted.
3. **Scenario 3:** A medium-term scenario (2022), based on the goal of the DST's Waste Research, Development and Innovation (RDI) Roadmap (DST, 2012), to reduce industrial waste[5] by 20% and domestic waste[6] by 60% by 2022, from the 2011 baseline. This goal of reducing waste to landfill was translated to recycling/recovery targets for the individual waste streams.
4. **Scenario 4:** A hypothetical long-term scenario of 100% recycling/recovery, reflecting the tonnages that could be recovered if all waste was diverted from landfill.[7]

[4] For some materials, there are (currently) technical limits to recycling

[5] For the purposes of this study, industrial waste has been interpreted to include hazardous and unclassified waste as per the National Waste Information Baseline (DEA, 2012).

[6] For the purposes of this study, domestic waste has been interpreted to include general waste as per the National Waste Information Baseline (DEA, 2012).

[7] While a recovery rate of 100% is not necessarily realistic, given that some portion of the waste stream will inevitably be landfilled, the intention of this scenario is to provide an indication of the total resource value of all waste generated in South Africa.

It must be emphasized that the recovery rates outlined in the scenarios are in no way legal targets, and have only been set for the purposes of determining the value of resources available in South Africa's waste stream, and for prompting innovation.

3.2 Unit value

We use the term 'unit value' rather than 'price' to represent the value per tonne; since in economic terms the value per unit of a good or service is not necessarily equal to its market price. Generally speaking, economic value refers to the maximum amount that users of a good or service are willing to pay for the good or service. The decision to purchase a unit of the good or service implies that the user places a higher value on the good or service than its market price. Nevertheless, in the absence of costly and time-consuming valuation studies in which a large number of surveys are conducted with users regarding their maximum willingness to pay per unit of a specific good or service, market prices must often suffice as a proxy of unit values.

In determining the unit value per tonne of recyclable materials, it is important to note that "*a recycled product does not always replace a resource of equal value. The level of processing of the recycled product or virgin product determines its value*" (ETC/SCP 2011:25). As such, "*the unit price of the recyclables is usually lower than the corresponding price for virgin material. This is due to the fact that the recyclable would require some further processing before it has the form required to enter the production chain (de-inking and re-pulping for paper or melting for metal scrap). The difference in unit prices represents the level of processing required. The required processing depends on the suitability for recycling of the material itself and the level of purity of the material (in terms of amount of foreign materials mixed with the recyclables)*" (ETC/SCP 2011:28). In turn, the level of processing required (and therefore the unit value of the recyclable material relative to the value of the corresponding virgin material) varies for different types of recyclable materials.

Since unit prices increase along the recycling value chain, it is necessary to choose a specific point along the chain where unit values will be determined. Figure 2 illustrates a simple schematic of the recycling value chain. The arrows represent exchanges of materials, each of which also entails monetary exchanges (in the opposite direction). For example, collectors purchase waste materials from individuals or waste pickers, and in turn sell the collected materials to recyclers. In turn, the recyclers undertake processing of the waste materials, and sell the recycled materials to downstream industries for further processing and ultimately for use as a raw material in production processes. Importantly, at each point along the value chain, value is added to the waste materials. This implies that the 'value' (and the price) per tonne of the material increases along the chain.

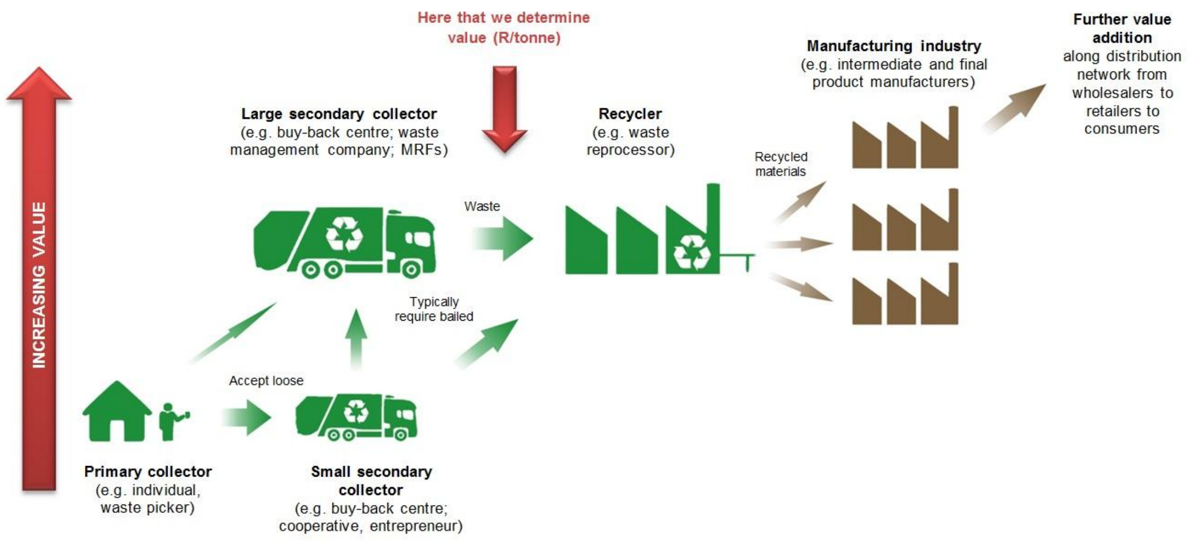

Figure 2: Simple schematic of the recycling value chain showing value addition at each point along the chain

Unit values should ideally be based on the point along the value chain where comparisons with other options would generally be made. In this case, the comparison is with landfilling, and unit values for alternative recycling options should therefore be chosen that are as close as possible to the landfilling option in the value chain, that is, based on the willingness-to-pay by recyclers for collected waste. We therefore generally use the prices paid by recyclers to collectors as a proxy of the unit value[8]. Exceptions occur in the case of wastes for which there is currently no significant recycling market (e.g. because recycling is either technically or economically infeasible), in which case potential unit values were estimated by other means, such as in terms of a Waste-to-Energy (WtE) potential.

> "The price paid by recyclers to collectors is used as a proxy of the unit value."
>
> "Where no significant recycling market exists, unit value is estimated by other means, e.g. Waste-to-energy (WtE) potential."

It is important to note that in basing our assessment on the prices paid by recyclers for waste material before any value has been added in terms of processing of the materials, the values estimated in this study should be seen as a minimum or lower-bound estimate of the full potential benefits of recovery to the economy. Introducing these materials into the economy creates opportunity for further value-add as part of a growing manufacturing sector.

8 Strictly speaking, since markets for waste and waste products do not function freely, a number of corrections should be made to these prices, such as taking into account implicit municipal subsidies for bringing collected waste to private recyclers. Nevertheless, estimation of accurate "shadow unit values" was beyond the scope of this report. The limitations of using unit values based on uncorrected market prices should be borne in mind in interpreting the results presented in this report.

3.3 Waste streams

A very simplistic approach towards valuing the resources available for recycling and recovery in South Africa would involve multiplying the total tonnage of waste generated by a single, average unit price. However, the intention of this research is to support specific interventions with regards to research, development and innovation for targeted waste streams which have high potential for re-introduction into the South African economy. Specific values per waste stream are therefore required. Using the waste categories outlined in the Waste Information Regulations (DEA, 2012a), specific waste streams were targeted for valuation, based on the following criteria –

i. The perceived moderate to high potential for recycling and recovery (global trends)
ii. The magnitude of waste generated (high tonnage waste streams)
iii. The availability and accuracy of data

The methodology has been applied to thirteen key waste streams in South Africa, as follows:

- General waste
    - Municipal waste (non-recyclable portion)
    - Organic waste (component of municipal waste)
    - Other (industrial and agricultural biomass waste)
    - Construction and demolition waste
    - Paper
    - Glass
    - Plastic
    - Metals
    - Tyres
- Unclassified waste
    - Waste electric and electronic equipment (WEEE)
    - Slag (from mineral processing)
    - Ash (from power generation)
- Hazardous waste
    - Waste oils

As further data becomes available, additional waste streams can be included in the valuation, thereby building a more comprehensive picture of the value of resources available to the South African economy.

4 INPUT DATA

The following section presents the quantity and unit value data used as inputs into the model. Data regarding the quantities of waste was obtained largely from the National Waste Information Baseline Report (DEA 2012), supported by data available in the general literature. Data pertaining to unit values was obtained largely from discussions with various collectors, recycling companies, sector associations, and waste management companies.

It is noted that data pertaining to the economic value of recycling is limited, even in developed countries (ETC/SCP 2011). These data constraints are even more apparent in developing country contexts. Nevertheless, sections 4.1 and 4.2 provide information on how quantities and unit values for the various waste streams were established for this study.

4.1 Quantities

For each of the 13 waste streams included in this report, quantities of waste (in tonnes per year) being generated in South Africa (as at 2011)[9], as well as the proportions currently being recycled and landfilled, were obtained from the National Waste Information Baseline (DEA 2012). These quantities are summarised in Table 1.

Table 1 also presents the proposed recycling/recovery rates for each of the four scenarios, on which the resource valuation modelling has been conducted:

1. **Scenario 1:** Baseline (2011) reflecting the tonnages of materials that were being recycled as at 2011 (DEA 2012)
2. **Scenario 2:** Short-term scenario (2017) based on targets in Industry Waste Management Plans (IndWMP) and targeted recycling rates for 2017 (BMI Research 2013)
3. **Scenario 3:** A medium-term scenario (2022), based on the goal of the DST's Waste RDI Roadmap (DST, 2012)
4. **Scenario 4:** A hypothetical long-term scenario of 100% recycling/recovery, reflecting the tonnages that could be recovered if all waste was diverted from landfill.

[9] The DEA baseline waste information for 2011 (DEA, 2012) represents the most recent national overview of waste generation, landfilling and recycling tonnages for South Africa. While regulations are in place to give effect to a national waste information system, routine, annual waste tonnage data for South Africa is not yet available.

Table 1: Waste quantities and assumed recycling/recovery rates under various scenarios (tonnes per year)

Stream	BASELINE (2011)		SCENARIO 1		SCENARIO 2		SCENARIO 3		SCENARIO 4	
	Generated (t/yr)	Landfilled (t/yr)	Recycled (t/yr)	Recycled (%)	Recycled / recovered (t/yr)	Recycled / recovered (%)	Recycled / recovered (t/yr)	Recycled / recovered (%)	Recycled / recovered (t/yr)	Recycled / recovered (%)
Municipal waste (non-recyclable portion)	8 062 934	8 062 934	0	0	2 015 734	25	4 031 467	50	8 062 934	100
Organic component of municipal waste	3 023 600	1 965 340	1 058 260	35	1 587 390	53	2 116 520	70	3 023 600	100
Biomass waste from industry	36 171 127	36 171 127	0	0	10 851 338	30	21 702 676	60	36 171 127	100
Construction and demolition waste	4 725 542	3 969 455	756 087	16	1 559 429	33	2 362 771	50	4 725 542	100
Paper	1 734 411	745 797	988 614	57	1 087 476	63	1 387 529	80	1 734 411	100
Plastic	1 308 637	1 073 082	235 555	18	537 850	41	785 182	60	1 308 637	100
Glass	959 816	652 675	307 141	32	417 520	44	575 890	60	959 816	100
Metals	3 121 203	624 241	2 496 962	80	2 653 022	85	2 809 083	90	3 121 203	100
Tyres	246 631	236 766	9 865	4	103 585	42	197 305	80	246 631	100
WEEE	64 045	57 161	6 884	11	19 453	30	32 023	50	64 045	100
Slag (from mineral processing)	5 370 968	2 685 484	2 685 484	50	3 356 855	63	4 028 226	75	5 370 968	100
Ash (from power generation)	36 220 000	33 930 896	2 289 104	6	4 766 552	13	7 244 000	20	36 220 000	100
Waste oils	120 000	67 200	52 800	44	69 600	58	86 400	72	120 000	100
TOTAL	**101 128 914**	**90 242 158**	**10 886 756**	**11**	**29 025 804**	**29**	**47 359 071**	**47**	**101 128 914**	**100**

Notes:

- Figures for 'slag' based on ferrous metal slag from steel, manganese, chrome, vanadium etc. processing and non-ferrous metal slag from aluminium etc. processing
- Figures for 'ash' based on fly ash and bottom ash from Eskom's coal-fired power stations

4.2 Unit values

For each of the 13 waste streams included in this report, unit values were calculated based on prices paid by recyclers to collectors. Where no significant recycling market exists, unit value was calculated by other means, e.g. waste-to-energy (WtE) potential. Annexure 2 provides a detailed explanation on the calculation of unit value for each waste stream. The final results are presented in Table 2.

Table 2: Unit values (R/tonne) for the 13 selected waste streams (2013)

Stream	Range in prices (R/t)	Unit value (R/t)
Municipal waste (non-recyclable portion)	N/A (own calculations)	367.38
Organic component of municipal waste	N/A (own calculations)	188.63
Biomass waste from industry	N/A (own calculations)	188.63
Construction and demolition waste	85 - 90	87.50
Paper[10]	200 - 2000	744.47
Plastic[11]	1900 - 3960	3119.54
Glass	450 - 500	490.00
Metals[12]	1000 - 7000	2270.00
Tyres	N/A (own calculations)	367.00
WEEE	1000	1000.00
Slag	170 - 180	175.00
Ash	0 - 5	3.00
Waste oils	2777.78	2777.78

Disclaimer:

All prices quoted in the report are average prices based on data from multiple sources, multiple geographic regions, and for a period of time (2013), and as such should not be seen as the current (January 2014) market price that could be obtained for a waste.

Prices paid by recyclers vary greatly, depending on the company, geographic region, quality of recyclables, markets, whether recyclables are received loose or baled, etc. In addition, the wide ranges seen in the middle column of Table 2 reflects the range of prices associated with different materials within each stream, such as ferrous vs. non-ferrous metals, different grades of paper, different polymers of plastic, etc. This implies that presenting minimum and maximum values based on the range in prices for each waste stream is not appropriate; since doing so would ignore the heterogeneity of materials included within each waste stream. As such, the unit values presented in the last column of Table 2, and which are used in the analysis to follow, were calculated as 'representative values' for each waste stream, taking all of these factors into consideration. For example, the unit value of metals was calculated taking into account the relative contribution of ferrous vs non-ferrous metals to the total metal waste stream in South Africa.

[10] The wide variation occurs due to different grades (R200 for mixed up to R2000 for white)
[11] The wide variation occurs due to different types of plastics (PE-LD – PET)
[12] Wide range from ferrous to non-ferrous

4.3 Assumptions and limitations

A number of assumptions and limitations associated with the study should be borne in mind before drawing conclusions on the basis of the results presented in this report. These include the following:

- Only the *benefits* of moving up the waste hierarchy have been estimated; *costs* of recovery are not taken into account. These could include, for example, additional costs of collection, transport and processing to deal with different waste streams; as well as the decrease in revenue from disposal. All of these factors need to be brought into a financial and economic evaluation of waste management options. Therefore, the results of this study cannot, on their own, be used to justify the choice of one waste management option over another, which would require a rigorous assessment of both benefits and costs, as well as other information.
- Estimation of accurate “shadow unit values”, based on corrections to market prices (e.g. by taking into account implicit municipal subsidies for bringing collected waste to private recyclers) was beyond the scope of this report.
- The unit values used to value recyclable materials are based on prices at a point in the value chain where a comparison can be made with landfilling. . However, in the case of recovery, there are opportunities for further value addition along the value chain, while in the case of landfilling, such opportunities are lost. It could therefore be argued that, at an economy-wide level, if opportunities for further value addition are taken into account, the full benefits of recovery to the economy exceed the values estimated in this report.
- The report focuses specifically on 13 waste streams. Other waste streams, some of which may also have recycling potential, are excluded from the analysis. For example, although we include slag from mineral processing, we exclude other mining waste (amounting to 510,000,000 tonnes per year, according to Purnell 2009), for which there may also be recycling potential, but for which insufficient data exists relating to the composition (and therefore value).
- Some materials can be recycled a number of times; whereas in this study we only consider the resource values associated with one round of recycling. For example, paper can be recycled up to seven times (PAMSA 2013), whilst glass is in principle infinitely recyclable (GRC 2008). In this study we are only considering the resource values associated with one round of recycling.
- The study focuses on the benefits of recycling in terms of resource value only. There are multiple economic benefits associated with moving up the waste hierarchy, particularly from a green economy perspective. Although the report provides an indication of the additional benefits associated with avoided disposal costs, the benefits associated with job creation and economic growth, as well as the avoided costs and externalities associated with virgin material extraction, are still not taken into account.
- The study uses waste quantities (as at 2011) and unit values (as at 2013) on which to calculate resource value, and has not included the likely growth in the generation of waste due to economic development. For general waste this growth rate is in the region of 2-4% per annum (Fiehn & Ball, 2005; DEA, 2012), which will further add to the quantity of resources available and the resultant resource value.

Furthermore, it is acknowledged that –

- Prices paid for recyclables are often influenced by factors external to the South African economy, e.g. demand for resources by emerging markets can drive up prices; oil price fluctuations, etc. Changes within the external environment, over which South Africa has little control, could therefore influence local recycling prices and therefore unit value.
- Increased recovery of recyclables can cause prices to decrease, especially if supply exceeds demand. This has not been taken into account in the model, since market stimulation (local and international) is critical to maximising recycling and recovery.

5 RESULTS

In this section, we bring together the data on quantities of waste recovered (Section 4.1) and the unit values of the materials (Section 4.2), to obtain an estimate of the resource value of waste recovery in South Africa, both currently and under a number of scenarios as they relate to increased recovery rates.

For the sake of convenience, the scenarios are repeated here:

1. **Scenario 1:** Baseline (2011) reflecting the tonnages of materials that were being recycled and recovered as at 2011
2. **Scenario 2:** Short-term scenario (2017) based on targets in Industry Waste Management Plans (IndWMP) and targeted recycling rates (BMI Research 2013)
3. **Scenario 3:** A medium-term scenario (2022), based on the goal of the DST's Waste RDI Roadmap (DST, 2012)
4. **Scenario 4:** A hypothetical long-term scenario of 100% recycling/recovery, reflecting the tonnages that could be recovered if all waste was diverted from landfill

5.1 Resource value from increased recycling/recovery

The values across all four scenarios are summarised in Table 3. The results of the modelling show that the value of resources currently being recycled/recovered from the 13 waste streams is R8.2 billion/year (Baseline Scenario). However, with increased recovery of resources from the waste stream, the resource value can increase to R12.8 billion/year under Scenario 2; R17.4 billion/year under Scenario 3; to R25.2 billion/year under Scenario 4. Achieving the goal of the DST Waste RDI Roadmap could therefore potentially unlock R17.4 billion/year worth of resources into the economy, which otherwise would have been lost through disposal to landfill.

The benefits of increased recycling/recovery can be calculated as the difference between the current resource values (baseline) and the potential higher resource values associated with the various increased recovery scenarios. The benefits of increased recycling/recovery (relative to the baseline) range from R4.6 billion/year under Scenario 2, R9.2 billion/year under Scenario 3, to R17.0 billion/year under Scenario 4 (Table 3). Achieving the goal of the Waste RDI Roadmap could therefore unlock an additional R9.2 billion worth of resources (at current prices and tonnages).

It must be re-emphasised that these estimates are likely to underestimate the full benefits of resource recovery to the South African economy; for a number of reasons (see Section 4.3).

Table 3: Potential resource value (per year) under different scenarios of resource recovery

	Quantity recycled / recovered (t/year)				Unit value (R/t)	Value (Rand/year)			
Stream	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**		**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Municipal waste (non-recyclable portion)	0	2 015 734	4 031 467	8 062 934	367.38	0	740 547 527	1 481 095 054	2 962 190 108
Organic component of municipal waste	1 058 260	1 587 390	2 116 520	3 023 600	188.63	199 624 053	299 436 079	399 248 106	570 354 437
Biomass waste from industry	0	10 851 338	21 702 676	36 171 127	188.63	0	2 046 933 732	4 093 867 465	6 823 112 441
Construction and demolition waste	756 087	1 559 429	2 362 771	4 725 542	87.50	66 157 613	136 450 038	206 742 463	413 484 925
Paper	988 614	1 087 476	1 387 529	1 734 411	744.47	735 995 662	809 595 449	1 032 976 649	1 291 220 811
Plastic	235 555	537 850	785 182	1 308 637	3119.54	734 824 361	1 677 846 536	2 449 411 002	4 082 351 670
Glass	307 141	417 520	575 890	959 816	490.00	150 499 090	204 584 780	282 185 904	470 309 840
Metals	2 496 962	2 653 022	2 809 083	3 121 203	2270.00	5 668 103 740	6 022 360 735	6 376 617 729	7 085 130 810
Tyres	9 865	103 585	197 305	246 631	367.00	3 620 455	38 015 658	72 410 862	90 513 577
WEEE	6 884	19 453	32 023	64 045	1000.00	6 884 000	19 453 250	32 022 500	64 045 000
Slag	2 685 484	3 356 855	4 028 226	5 370 968	175.00	469 959 700	587 449 625	704 939 550	939 919 400
Ash	2 289 104	4 766 552	7 244 000	36 220 000	3.00	6 867 312	14 299 656	21 732 000	108 660 000
Waste oils	52 800	69 600	86 400	120 000	2777.78	146 666 667	193 333 333	240 000 000	333 333 333
Total	**10 886 756**	**29 025 804**	**47 359 071**	**101 128 914**		**8 189 202 652**	**12 790 306 399**	**17 393 249 283**	**25 234 626 353**
Benefit of increased recycling relative to baseline (Scenario 1)							4 601 103 747	9 204 046 631	17 045 423 701

5.2 Additional economic benefits

It is important to emphasise that the value estimates in Table 3 are calculated in terms of resource value only. Recall from Section 1.2 that there are multiple economic benefits from moving up the waste hierarchy, particularly from a green economy perspective. The values reported in Table 3 exclude the benefits associated with job creation and enterprise development; the indirect ‘multiplier’ (knock-on) effects on the macro-economy; the avoided financial costs and externalities associated with disposal; and the avoided financial costs and externalities associated with virgin material production.

In terms of the avoided costs of disposal, current disposal (tipping) fees are generally in the range of R100 to R150 per tonne. It is acknowledged that these do not necessarily reflect full financial costs of landfilling, which would include capital, operating and closure costs over the lifetime of a landfill. Estimates from some municipalities suggest that full financial costs are likely to be much higher than the range of tipping fees reported here; nevertheless, in the absence of sufficient data on true landfill costs, these tipping fees will be used as a conservative estimate of avoided financial costs. Furthermore, a study by Nahman *et al*. (2011) estimated externalities (social and environmental costs) associated with landfilling in the City of Cape Town at approximately R111 per tonne. Assuming that the latter can be extrapolated to other areas of South Africa, we can use these figures to supplement our estimated resource values with the benefits in terms of the avoided financial costs and externalities associated with landfill disposal, to give a more comprehensive estimate of the benefits of recycling. The results are summarised in Table 4.

It can be seen that, in terms of the resource value of recovered materials plus the avoided financial costs and externalities associated with landfill disposal, the current value of recycling/recovery is in the order of R10.5 billion/year; which could increase to R18.9 billion/year under Scenario 2, to R27.4 billion/year under Scenario 3, and to as much as R46.5 billion/year under Scenario 4. Achieving the goal of the DST Waste RDI Roadmap, taking into account avoided financial costs and externalities associated with landfill disposal, could therefore potentially unlock R27.4 billion/year worth of resources into the economy, which otherwise would have been lost through disposal to landfill.

The benefits of increased recycling/recovery relative to the baseline (difference between current value and potential value under each scenario), in terms of resource values and avoided disposal costs, range from R8.4 billion/year under Scenario 2, R16.9 billion/year under Scenario 3, to R36.0 billion/year under the 100% recycling Scenario 4 (Table 4).

Of course, even these values are likely to represent an under-estimate of the full benefits of moving waste up the hierarchy. Although we have now incorporated the benefits associated with avoided disposal costs; the benefits associated with job creation and economic growth, as well as the avoided costs and externalities associated with virgin material extraction, are still not taken into account.

Table 4: Benefits of waste recovery in terms of resource value and avoided disposal costs (per year)

	Quantity Recycled / recovered (t/year)				Unit value (R/tonne)	Value (Rand/year)			
	Baseline	Scenario 2	Scenario 3	Scenario 4		Baseline	Scenario 2	Scenario 3	Scenario 4
Resource value	10 886 756	29 025 804	47 359 071	101 128 914	*varies by waste stream	8 189 202 652	12 790 306 399	17 393 249 283	25 234 626 353
Avoided financial costs of landfilling	10 886 756	29 025 804	47 359 071	101 128 914	100	1 088 675 600	2 902 580 356	4 735 907 080	10 112 891 400
Avoided externalities of landfilling	10 886 756	29 025 804	47 359 071	101 128 914	111	1 203 966 346	3 209 963 616	5 237 439 640	11 183 846 599
Total						**10 481 844 598**	**18 902 850 372**	**27 366 596 003**	**46 531 364 353**
Benefit of increased recycling relative to baseline							8 421 005 774	16 884 751 405	36 049 519 755

5.3 Unit benefits of recycling/recovery

The values estimated in this report can be translated into benefits per tonne of waste recycled (i.e. the 'unit benefits' of recycling); which can be compared with the costs per tonne (unit costs) of recycling (not estimated in this report) for policy and decision-making purposes. The value estimates in Table 4 were therefore divided by the quantities recycled in each scenario, to provide an estimate of the benefits of recycling per tonne (including the benefits associated with the resource value of recyclables, as well as the avoided financial costs and externalities associated with landfilling) (see Table 5).

Table 5: Benefits of recycling/recovery per tonne of waste (in terms of resource value and avoided disposal costs)

	BENEFIT PER TONNE (R/t):			
	Baseline	Scenario 2	Scenario 3	Scenario 4
Resource value	752	441	367	250
Avoided financial costs of landfilling	100	100	100	100
Avoided Externalities of landfilling	111	111	111	111
Total	**963**	**651**	**578**	**460**

Furthermore, the benefits per tonne illustrated in Table 5 pertain only to the resource value of recycling and the avoided financial and external costs of landfilling; they exclude other benefits such as the avoided financial and external costs of virgin material extraction, benefits in terms of job creation and economic growth, etc. As such, the estimates provided in this report are likely to underestimate the full benefits associated with moving up the waste management hierarchy; although the *costs* of moving up the hierarchy will also need to be taken into account.

6 DISCUSSIONS

While this research is based on limited data and has provided a simplified model of a complex socio-economic system, the results do highlight some key points which require further discussion.

Based on the results of this research and the apparent considerable value of resources 'locked-up' in South Africa's waste stream, one must question why South Africa currently only experiences a national recycling rate of ± 10% (DEA, 2012). While disposal costs, especially for general waste, are particularly low, the value of recyclables alone should drive a more aggressive recovery of these resources, especially waste streams with high unit benefits of recovery (i.e. where the benefits of recovery are high on a per tonne basis). In Table 6, we summarise the unit benefits per waste stream (in terms of resource value only, in column 2; and including the additional benefits associated with avoided disposal costs of R211 per tonne, in column 3); as well as the current recycling rates (as at 2011).

Table 6: Unit benefits (excluding/including avoided disposal costs) of recovery for 13 selected waste streams

Stream	Unit benefit (in terms of resource value only) (R/t)	Unit benefit (in terms of resource value plus avoided disposal costs) (R/t)	Current recycling rate (%)
Plastic	3119.54	3330.54	18
Waste oils	2777.78	2988.78	44
Metals	2270.00	2481.00	80
WEEE	1000.00	1211.00	11
Paper	744.47	955.47	57
Glass	490.00	701.00	32
Tyres	367.00	578.00	4
Municipal waste (non-recyclable portion)	367.38	578.00	0
Organic component of municipal waste	188.63	399.63	35
Biomass waste from industry	188.63	399.63	0
Slag	175.00	386.00	50
Construction and demolition waste	87.50	298.50	16
Ash	3.00	214.00	6

Possible reasons for the lower than expected recycling rate for certain waste streams, given the available resource value, include –

1. Unit costs of recovery exceed benefits
2. Costs and benefits are not borne by the same parties
3. Lack of access to waste streams (limited recovery)
4. Lack of markets for recovered resources
5. Lack of infrastructure/technology to recover resources
6. Recyclate more expensive than virgin materials

6.1 Benefits versus costs

With information now available on the unit benefit of recovery per waste stream (Table 6), the sector must compare these benefits with the unit costs of recycling/recovery of each waste stream, to assess the economic viability of alternatives (based on a rigorous cost-benefit analysis approach), and to identify where economic opportunities exist.

Assessment of the costs of recycling/recovery was beyond the scope of this report. This requires empirical data based on actual waste management projects, pilot projects, or, at the very least, the advanced stages of engineering analysis. Such information is currently lacking in South Africa, and, the data that is available tends to provide conflicting results, given the wide range in cost estimates for different technologies in different contexts. Much work is therefore required in assessing the costs and benefits (including external costs and benefits) of alternative waste management options in South Africa, in order to provide reliable information for decision making.

6.2 Sharing of cost and benefit

While preliminary evidence suggests that for many waste streams, the benefits of recovery and recycling exceed the costs, the benefits and costs are typically not shared by the same party. In the case of domestic waste, municipalities typically bear the cost of collection, separation and disposal, while the private sector realises the financial benefit of recycling, with access to the resource. In other words, there is no real incentive for municipalities to spend more on putting source separation measures in place to maximise collection of recyclables (increased management costs), when they realise none of the resource value opportunities. This may be different for industrial waste, where the private sector may have more control over costs and benefits.

In economic terminology, recycling is a good example of an activity with positive externalities - costs are borne by one party to undertake the activity, but the benefits are realised by another party. In such cases, the usual recommendation from an economic perspective (aside from mandatory regulations, etc.) would be to ensure that financial incentives are provided to those bearing the costs, through some form of transfer from the beneficiaries to the providers, e.g. by means of subsidies or some form of trading or compensation scheme. In principle, given the large difference between the benefits and costs, there should be some opportunity for win-win compensation.

Alternatively, in some countries there is more use of voluntary mechanisms, whereby industry itself recognises the benefits of investing more heavily in recycling (including collection, separation). Possible reasons why this hasn't taken off in South Africa may be that (i) virgin materials are relatively cheap, so there is no incentive for industry to switch towards greater use of recycled materials, and (ii) municipalities act as gatekeepers to the waste, particularly domestic waste, which increases the risk of investment by the private sector.

Industrial waste may be more accessible to increased recycling/recovery, and this must be supported. Furthermore, mechanisms should be put in place to facilitate greater ease of access by the private sector to municipal waste, without compromising the municipality's constitutional responsibility to ensure the safe management of domestic waste, or which will result in increased environmental or social risk.

6.3 Adding value along the recycling value chain

As discussed in Section 4.2, the unit values used in the calculations are based on the prices paid by recyclers to collectors. As such, value added further along the recycling value chain (e.g. in re-processing the waste materials into recycled materials, the production of new products, the distribution of these products to end-users, etc.) is excluded from the analysis presented above. At each stage along the value chain, value is added to the recycled materials.

As an indication of the extent to which the unit values used in this study are conservative as a result, it is worth noting the following. In the case of plastics, we use a unit value of R3,119 per tonne, based on prices paid by recyclers to collectors. However, recyclers add value to the waste materials and can sell these to downstream industries at an average price of R7,740 per tonne. This represents an increase in value of 150%, associated with one step further along the value chain (further value is added thereafter). This concept is shown graphically in Figure 3, for the case of plastic.

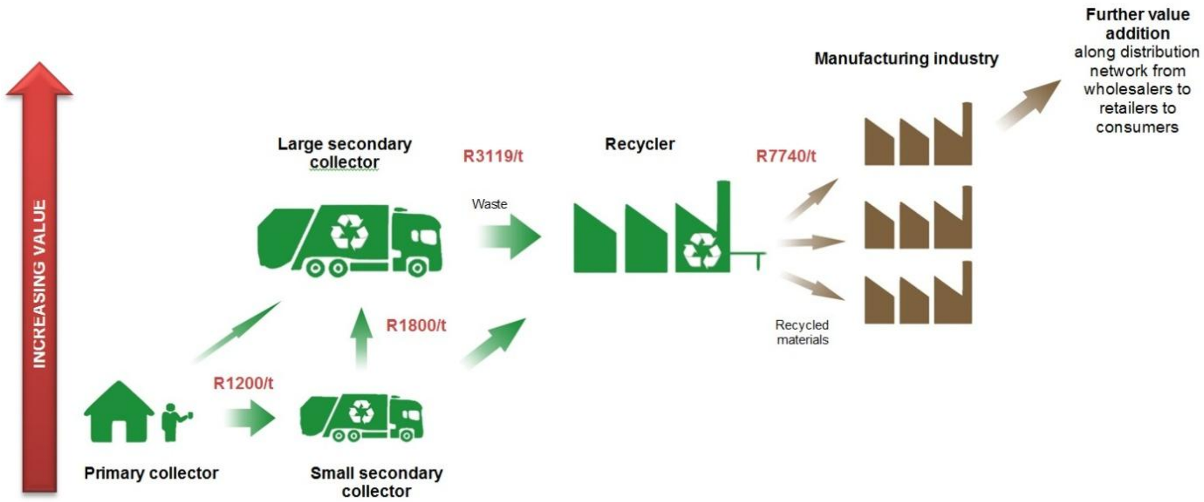

Figure 3: Example of value addition along the value chain, the case of plastics

Similarly, for metals and WEEE, while prices paid by recyclers to collectors are on average R2,270 and R1,000 per tonne respectively; our own calculations (based on scrap metal prices and the metal, plastic and glass content of WEEE respectively) indicate that the values could increase to an average of R6,126 and R7,424 respectively further along the value chain.

The diagram also shows the benefits, in terms of increased resource value, by recovering recyclables close to the point of generation (separation at source providing 'clean' waste), and supporting primary and secondary collectors to increase tonnages and benefit from economies of scale.

7 CONCLUSIONS AND RECOMMENDATIONS

This report estimates the potential benefits of recycling in terms of the resource value of the materials that could be recovered and recycled back into the economy. The results of the modelling show that –

- Recycling at ±10% (as at 2011 baseline) unlocked R8.2 billion/year worth of resources into the South African economy
- Achieving the DST target (Scenario 3) would unlock R17.4 billion/year worth of resources
- Achieving 100% recycling and recovery targets (Scenario 4) would unlock R25.2 billion/year worth of resources into the South African economy, which would have been lost to landfill.

It is found that, purely in terms of resource value, the benefits of additional recycling/recovery, over and above the value of resources currently being recycled, range between R4.6 - R17.0 billion/year. If benefits in terms of avoided financial and external costs associated with landfill disposal are taken into account, the benefits increase to between R8.4 - R36.0 billion/year.

On a per tonnage basis, the benefits of recycling (in terms of resource value and avoided disposal costs) range between R460 and R963 per tonne, which in many cases exceeds current estimates of the cost per tonne of recycling.

It is recommended that the methodology and data inputs be tested with the sector to fine-tune the research findings, to test the main findings, and to evaluate where opportunity waste streams exist for increased recycling or recovery. It is reiterated that the estimates of the benefits of recycling/recovery should be treated as under-estimates of the full potential benefits of moving waste up the hierarchy in South Africa; although the costs of moving up the hierarchy also need to be taken into account.

KEY HIGHLIGHTS:

- Considerable value (not only resource value but broader economic value) is locked-up in waste that is currently being disposed of to landfill in South Africa
- Waste disposal costs (tipping fees) in South Africa are particularly low, however, the value of recyclables alone should drive a more aggressive recovery of these resources than what we currently see (especially waste streams with high unit values)
- We need to actively investigate ways of overcoming the financial, bureaucratic and technological constraints restricting waste recovery in South Africa
- The annual resource value of waste (R25.2b) represents ~0.86% of South Africa's GDP (2011)

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Annexure 1: Benefits of moving up the waste hierarchy

Re-introduction of resources back into the economy

The recovery of resources from waste, through recycling and recovery activities, allows for valuable materials or energy to be re-introduced into the economy, while also reducing the costs and externalities associated with virgin material extraction.

Recycling helps to ensure secure supplies of essential resources, and reduces the need for extracting and refining (or importing) virgin materials. This means that both the financial costs, as well as the externalities (social and environmental costs) associated with virgin material extraction can be avoided. Similarly, the recovery of, for example energy, from waste (a renewable source) reduces the need to generate energy using fossil fuels (non-renewable), thereby contributing towards energy security and avoiding the negative environmental impacts associated with burning fossil fuels, such as greenhouse gas emissions.

Recycling and recovery therefore contribute to resource and energy efficiency, and the decoupling of economic development from resource use and environmental impact (EEA 2011). As such, waste is increasingly seen as a valuable resource (UNEP 2013). Indeed, according to UNEP (2013:29), "*'Waste' is first of all an economic concept – implicit in the word is the fact that resources are not being used efficiently. There is an economic loss every time resources (assuming they have some other potential use) are utilized in a way that results in being discarded as waste. Raw materials entering a production chain and ending as waste also represent a loss of energy and water. Industrial waste reflects inefficiencies in production processes. If resources can be saved, recovered, or used more efficiently, there is a net economic gain*."

In the European Union (EU) recycling meets a substantial proportion of the demand for resources such as paper and cardboard, as well as iron and steel. The EU has identified 14 critical materials, many of them metals, which show a high supply risk and which could constrain future economic and technological development within the region. The recovery of these materials through, for example, the recycling of electronic and electrical equipment (WEEE), or through urban mining, is seen as a means of securing supplies of rare metals and other critical resources (EEA 2011).

Contribution to economic growth and job creation

Recycling and recovery contribute to economic growth and job creation, and can also foster innovation and create new business opportunities (EEA 2011, UNEP 2013).

According to a report by the European Environment Agency, recycling and recovery "*create more jobs at higher income levels than landfilling or incinerating waste*" (EEA 2011:7). In other words, not only does moving waste up the hierarchy result in a net increase in employment levels[13]; but the resulting jobs are also higher paid and more 'decent.' In addition, "*numerous opportunities exist for eco-innovation and development of new technologies in the recycling sector, potentially creating markets for new products and services*" (EEA 2011:11). The EEA also argues that the recycling sub-

[13] Net increase in employment, where job losses in landfilling are outweighed by the creation of 'green' jobs in recycling and recovery.

sector is becoming an increasingly significant contributor to GDP and trade in the EU. While South Africa's waste sector is estimated to contribute 0.51% to GDP, Australia has been able to create a recycling industry contributing 1.2% to the country's GDP (ACR, 2008), and a recent publication by the European Parliament shows the European eco-innovation industry (which includes the waste sector) to have grown to 2.5% of the EU's GDP, during a time when other sectors have been severely affected by the recession (EP, 2013).

In the United Kingdom (UK), a study revealed that only 11% of employment in the waste management sector is related to disposal activities (including disposal to landfill and by incineration); with the vast majority of employment in activities related to recycling and recovery (Figure 1-1) (Aulakh and Thorpe 2011).

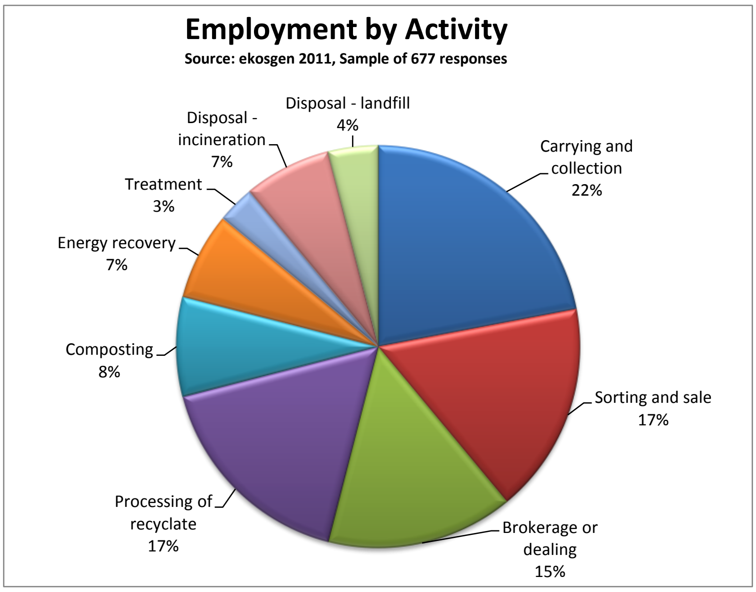

Figure 1-1: Employment by activity in the UK waste sector (adapted from: Aulakh and Thorpe 2011).

Reducing social and environmental costs

Waste recycling and recovery also reduces the social and environmental costs (externalities) associated with landfill disposal. Externalities associated with landfill disposal include, e.g. health hazards, odours, visual impacts, contamination of soil and water resources, emissions of greenhouse gases, reduced land availability and value.

Whilst recycling and recovery are often perceived to be more expensive than landfilling from a purely financial perspective, this is not necessarily the case from a 'true cost' or 'full cost' perspective, when external costs are taken into account. For example, according to UNEP (2013:30), "*good waste management provides direct economic benefits through improving human health and the environment, including higher productivity, lower medical costs, better environmental quality and the maintenance of ecosystem services. It is the community at large, and often its poorest members, that reap the largest share of these benefits. By proper pricing of raw materials, water, energy and waste management, costs can be shifted away from the poor and the general community to those manufacturing the products or generating the waste. This is more equitable and also more effective, as it provides an incentive to reduce waste generation*." The economic assessment of costs and benefits (including externalities) of different waste management options is still in its infancy in South Africa, such that it is not yet possible to make general statements in support of one option or another. Much work remains to be done in this area.

Annexure 2: Calculation of value per selected waste stream

The following sub-sections describe the determination of unit values for each of the recyclable materials included in this assessment. Note that, in some cases (depending on data availability), in addition to the unit values used in the calculation of resource values in the report; we also provide indicative estimates of higher resource values associated with value addition further along the value chain, to illustrate the concept of value addition (See Section 6.3), and to give an indication of the extent to which the estimates provided in the report are conservative.

1. Municipal waste (non-recyclable portion); organic component of municipal waste, and biomass waste from industry

In the case of the non-recyclable portion of municipal waste, the organic waste fraction within municipal waste, and biomass waste from industry, significant recycling markets do not currently exist, since unit values are relatively low, given limited downstream applications. Nevertheless, these streams have Waste-to-Energy (WtE) potential, and can also be used to a certain extent in composting and in the production of animal feed, etc. Thus, for these streams, unit values were determined in terms of WtE potential, rather than in terms of the prices paid by recyclers. This was done by determining how much energy (in kWh) could be obtained per tonne of each stream, and then by applying the average price of electricity per kWh.

A report by Agama Biogas for the South African Cities Network (Austin and Gets 2009) estimates the total electricity generation potential of solid waste conversion in six Metros in South Africa at 6,000 GWh/a (based on a projected MSW quantity of 9,906,810 tonnes of waste in these Metros in 2010); of which 1,500 GWh/a is derived from the organic fraction (4,823,621 t/a). This implies a WtE potential of 605.64 kWh/t of waste from general MSW, and 310.97 kWh/t from organic waste. Given the average electricity price in South Africa for 2012/13 of 60.66 c/kWh (Eskom 2012), this works out to a value of R367.38 per tonne for the non-recyclable portion of MSW, and R188.63 per tonne for the organic component of municipal waste and for biomass waste from industry.

2. Paper

According to DEAT (2005), the prices paid by recyclers for waste paper ranged from R600-R1800 per tonne (DEAT 2005 report). More recently; according to information from various collectors, recycling companies, pulp and paper companies and paper mills; the prices paid to collectors for various types of waste paper in South Africa range from R200 to R2,000 per tonne, depending on the grade. Based on the data obtained from these various sources, pertaining to prices across the various grades, an average price (paid by recyclers and paper mills to collectors) of R744.47 per tonne was calculated. This will be used as an estimate of the unit value of paper per tonne.

Looking further along the value chain, an international packaging manufacturing company claimed that over the period January to December 2013, the price they paid to recyclers for waste paper was in the range of R1,000 to R1,500 per tonne. This gives an indication of the extent to which value is added one step further along the value chain.

However, even this is an underestimate of the full potential benefits of the recycling of waste paper. For example, another way to calculate the unit value of recycled paper is based on the use of waste paper as a raw material in paper mills, as an alternative source of fibre to virgin wood pulp. 65% of recovered paper in South Africa is used for this purpose (PAMSA, 2013). Paper is recyclable up to seven times before the fibres become too short for use in new paper production (PAMSA, 2013). According to ETC/SCP (2011:29), recycled paper "*can be assumed as the equivalent product of pulp, as an input to paper mills*." The international pulp price (6 month average from May 2013 to November 2013) was obtained from Indexmundi (www.indexmundi.com), at R8,293 per tonne.

However, the value per ton of recycled paper is lower than the price of pulp (ETC/SCP 2011), both because of the costs of de-inking and processing, and because of efficiency losses between the quantity of recycled paper used in the process and the quantity of pulp that can be produced as a result. This was reflected by determining the quantity of pulp that can be obtained per tonne of waste paper. According to Kinsella (2012), the production of 1 tonne of Kraft pulp requires 1.4 tonnes of recovered paper, implying a 71% level of efficiency. However, according to SAPPI (2011), its Cape Kraft Mill is able to produce 60,000 tonnes of paper a year from just 67,000 tonnes of waste paper, implying an efficiency of 89.5%. We therefore assumed an average efficiency of 80% for South Africa (i.e. for every tonne of waste paper, 0.8 tonnes of pulp can be produced. This gives rise to a value of R6,634.55 per tonne of waste paper, in terms of the pulp that could potentially be produced.

Although this value does not include the cost of de-inking and of the process to convert the material into pulp (ETC/SCP 2011), it gives an indication of the extent to which value is added along the value chain, and therefore serves as an important reminder that the values provided in this report are very much minimum estimates of the full potential benefits of resource recovery.

3. Glass

In the case of glass, there is generally a relatively high difference between the unit price of waste glass and that of glass products, since glass waste generally takes the form of glass cullet, and requires significant further processing (ETC/SCP 2011). Unlike the case of plastics, paper and metals, where there is a wide diversity of different types and associated prices, prices for waste glass cullet are relatively standardised. Data from both collectors of various types, and from recycling companies, suggests an average price paid by recyclers to collectors for waste glass of R490/tonne.

4. Plastics

In the case of plastics, "*the importance of sorting and cleaning of the waste materials becomes evident. In order to increase the value of a recyclable, all foreign material should be removed. This is… very difficult in the case of plastics, since the separation of mixed plastics into plastic types is technologically difficult and, thus, costly… The low price of plastic wastes, which is caused by the limited applicability of plastic recyclables and the high cost of reprocessing, does not allow for a safe comparison of the wastes to primary production*" (ETC/SCP 2011:28-29). In turn, the low unit prices of plastic wastes relative to the price of virgin materials result in relatively low recycling rates for plastic (e.g. 18% in South Africa) as compared to other materials; implying a particular need for intervention in this waste stream in order to incentivise recycling. Given the level (and costs) of sorting and processing required to render plastic wastes suitable for manufacturing of new plastic products, it can be expected that the difference between the lower bound and higher unit values for plastics is relatively high.

Given the different types of plastics recycled in South Africa, each with different prices, it was necessary to determine the composition of the plastic waste stream, in order to estimate an average weighted price per tonne of plastic wastes. For this purpose, we used data from the 2012 Plastics SA recycling survey (Plastics SA 2013) regarding the tonnages recovered for different plastic materials (in 2011, excluding exports); as shown in the first five columns of Table 2.1.

Table 2.1: Composition of recovered plastics in South Africa

Type	Packaging	Non-packaging	Total	Proportion of total	Proportion of PE-LD, PE-HD, PP and PET	Price paid by recyclers, R/tonne, 2013)
PE-LD/LLD	89,493	6,359	95,852	39.01	43.30%	3 080.00
PE-HD	27,108	11,871	38,979	15.86	17.61%	2 740.00
PP	21,549	18,734	40,283	16.39	18.20%	3 230.00
PET	46,276		46,276	18.83	20.90%	3 425.00
PVC	587	16,117	16,704	6.79		
PS and PS-E	1,636	1,578	3,214	1.31		
ABS	550	605	1,155	0.47		
Other	1,267	1967	3,234	1.32		
Total	188,466	57,231	245,697	100	100	3 119.54

Average 2013 prices (paid by recyclers to collectors, per kg) for PE-LD, PE-HD and PP were obtained from a survey of numerous recycling companies published by Plastics SA (2013). These prices roughly corresponded with data received pertaining to the selling prices of both small buy-back centres and large collection companies, and were therefore seen as representative (see last column of Table 2.1, where prices have been converted to a per tonne basis). For PET, an average of R3,425 per tonne was calculated based on information from both recyclers and collectors.

Prices for the other plastic types were not as readily available. However, given that PE-LD, PE-HD, PP and PET make up 90% of total plastics recovery in South Africa, it was deemed sufficient to extrapolate the data and base the valuation only on these four types. We extrapolated the tonnages recovered of these four types (from the Plastics SA data) to the total quantity of plastics recycled in SA (as per DEA 2012). These proportions (Table 2.1, column 6) were then used to weight the prices (for 2013) of the four representative materials, and thereby to obtain a weighted average representative unit value for plastic waste, calculated at R3,119.54 per tonne.

Over the same period, recyclers sold the recycled materials to downstream industries at prices averaging R7,740.37 per tonne (more than double what they pay) for PE-LD, PE-HD and PP. This gives an indication of the extent to which value is added along the value chain.

However, it should be borne in mind that even this higher value is an underestimate of the full potential benefit of the plastics that could be recovered, but rather presents the value at one step further along the chain. Nevertheless, this is indicative of the extent to which value is added at each stage along the chain, and therefore of the extent to which the values provided in this report are very much a minimum estimate of the of the potential benefits of recycling to the South African economy.

5. Metals

Relative to other waste types, metals such as iron, steel and aluminium are characterised by a "*high unit price of scrap, which is comparable to the price of virgin material, since the scrap does not require particular processing before it can be used in metal production*" (ETC/SCP 2011: 29-30). These high unit prices relative to the price of virgin materials explains the relatively high recycling rate for metals (e.g. 80% in South Africa) compared to other waste types. In addition, in South Africa, collectors of used beverage cans, for example, are paid a flat rate, ensuring a stable supply (DEAT 2005).

Prices for scrap metals vary significantly between different types of metals, particularly between ferrous (iron and steel) and non-ferrous metals. According to the Metal Recyclers Association (in DEA 2012), 86% (2,640,000 t/yr) of total metal scrap recycled in South Africa is ferrous scrap (iron, steel etc.) and the remaining 14% (420,000 t/yr) is non-ferrous scrap (aluminium, copper etc.). Unfortunately, a more detailed breakdown of specific metals within these categories could not be ascertained. It was therefore necessary to determine a weighted average unit value for metals based simply on the breakdown between ferrous and non-ferrous metals recycled in South Africa.

As a unit value to be used in the analysis, we use prices paid by recyclers to collectors for scrap metals. Most collectors provided prices for used beverage cans (UBCs) only; however, UBCs make up only a small proportion of total metal recovery and recycling in South Africa; where the bulk of scrap metal arises from industrial sources rather than packaging. We were able to obtain prices from a large waste management company regarding the average prices paid by recyclers for ferrous and non-ferrous scrap metals more generally (rather than simply for UBCs). Based on this information, prices paid are in the range of R1,500 per tonne for ferrous scrap, and R7,000 per tonne for non-ferrous scrap (mainly aluminium). Taking into account the proportions of ferrous (86%) and non-ferrous (14%) scrap recycled in South Africa referred to above, this results in a weighted average unit value of R2,270 per tonne, which will be used as an estimate of the unit value of scrap metals.

To give an indication of the extent to which this value is conservative, we can look at international scrap metal spot trading prices; since a relatively large proportion of scrap metal in South Africa is destined for export, and local prices are generally influenced by international market prices. However, according to a new set of scrap metal export guidelines (Department of Trade and Industry (DTI) 2013); scrap metals intended for export must first be offered to domestic users (e.g. foundries, mills and smelters) at 20% lower than international prices. For December 2013 and January 2014, prices have effectively been fixed by a price preference system managed by the International Trade Administration Commission of South Africa (ITAC 2013). These prices were therefore used to determine a higher estimate of the unit value for scrap metal in South Africa. An average unit value for ferrous metals was calculated based on the average prices of various grades of steel and iron scrap; while an average for non-ferrous metals was calculated based on the average prices of various grades of aluminium, copper, brass, bronze, zinc, lead and tin. In this way, a unit value for ferrous metals was calculated at R3,029.35 per tonne, and for non-ferrous metals at R25,145.83 per tonne. This works out to a weighted average of R6125.66 per tonne, based on the proportions of ferrous and non-ferrous metals recycled in South Africa (86% ferrous scrap and 14% non-ferrous scrap).

It is worth noting that, as expected, these prices are lower than international spot prices against which scrap metal prices in South Africa are benchmarked. For example, average international spot prices over November-December 2013 for ferrous scrap according to the Metal Bulletin (http://www.metalbulletin.com/My-price-book.html) were R4,199 per tonne; and R45,556 per tonne for non-ferrous metals (based on aluminium, copper and brass and non-ferrous alloys only); giving a weighted average of R9,989 per tonne. However, given both the 20% discount for local recyclers, as well as the costs associated with transport etc., local prices can be expected to be somewhat lower than the international prices. The preference prices from ITAC can therefore be seen as indicative of the prices received for scrap metals locally, and are therefore used as a higher estimate of the unit values for metals.

It is also worth noting that the resulting values based on a price of R6,125.66 per tonne correspond with data reported by the Metals Recycling Association (in Botes 2012), which shows that between 2.5 – 3 million tonnes of scrap metal is recycled every year in South Africa, and that the scrap metal industry is worth between R15 million and R20 million a year (employing 15,000 people in the formal sector and approximately 440,000 people in the informal sector). As mentioned above, high recycling rates for metals relative to other materials are attributed to the relatively high value per tonne of metal compared to other recyclable materials (Botes 2012).

6. Waste electric and electronic equipment (WEEE)

An important constraint to the recovery of rare and precious metals from WEEE is the fact that electronic and electrical products tend to be composed of a large number of different materials, each of which is only present in small quantities, but across a multitude of applications and products ('dissipative use') (EEA 2011). As such, in the case of WEEE, "*a comparison with a resource has no meaning at all, since the raw material for electronic and electrical equipment production consists mostly of metal, glass and plastic. A comparison of the WEEE economy with these raw materials would be invalid since the added value of the processing of these materials into complex electric and electronic equipment by far supersedes the cost of the raw materials*." (ETC/SCP 2011:28-29). Furthermore, recovery of such metals therefore requires the development of specialised recycling infrastructure. As such, global recycling rates of rare metals for which demand is projected to increase in future (due to their use in emerging technologies such as renewable energy and ICT) are low – e.g. 1% for gallium, germanium, indium, neodymium and tantalum, and 15% for ruthenium. For cobalt, palladium and platinum, recycling rates are higher (60-70%). These factors explain the relatively low recycling rate of WEEE in South Africa (11%).

Prices paid by recyclers to collectors for WEEE could only be obtained from one waste management company, who indicated a price of R1,000/tonne across all types of WEEE. This will be used as an estimate of the unit value per tonne of WEEE.

To give an indication of the extent to which this unit value is conservative, we attempt to derive a weighted average value per tonne of WEEE, based on the values of the contents of which WEEE is composed. According to DEA (2012), typical material fractions in WEEE are as follows:

- Printed circuit boards (2%)
- CRT & LCD screens (12%)
- Cables (2%)

- Metal-plastic mixture (5%)
- Plastics (15%)
- Metals (60%)
- Pollutants (3%)
- Others (1%).

In the case of metals and plastics, it is necessary to obtain a more refined breakdown, given the variation in prices between different types of metals and plastics respectively.

The metals fraction within WEEE (60%) consists of a range of different metals, including ferrous, non-ferrous and precious metals, with a wide variation in prices. According to a study in the UK (WRAP, 2012), the average concentration of precious metals in the WEEE stream is estimated at 30g/tonne (0.003%), of which

- 21.41g/tonne consists of silver,
- 6.45g/tonne gold and
- 2.14g/tonne Platinum Group Metals (PGMs), such as palladium and platinum.

These precious metals are typically found in ICT equipment, such as printed circuit boards. In comparison, these materials are commercially mined at concentrations of 850g/tonne (silver), 5g/tonne (gold) and <2g/tonne (PGMs). Other metals found in WEEE include lead, aluminium, iron and copper; as well as metals such as cadmium, antimony, tantalum, gallium and indium. Based on WRAP (2012) and Robinson (2009), the concentrations of various metals in WEEE can be estimated as in Table 2.2.

Table 2.2: Assumed concentration of various metals in WEEE based on WRAP (2012) and Robinson (2009)

Metal	Typical concentration in WEEE (%)
Silver	0.002141
Gold	0.000645
PGMs	0.000214
Antimony	0.17
Cadmium	0.018
Copper	4.1
Lead	0.29
Tin	0.24
Zinc	0.51
Aluminium	13.7425
Iron	36.415
Total	55.49

For the other metals, reliable information regarding typical concentrations could not be obtained. Nevertheless, since the typical total metal fraction in WEEE is 60%, the metals listed in the table (with a total concentration in WEEE of 55.49%) can be seen as representative.

Unit values for most of the metals in Table 2.2 were calculated based on the relevant scrap metal prices, as an average for each metal across the various grades; as per ITAC (2013) – see above. For precious metals, we used the scrap metal price calculator at http://www.silverrecyclers.com, which calculates scrap prices at various purities based on current spot prices. To account for the costs associated with extracting and refining precious metals from WEEE, we assumed the lowest possible levels of purity (i.e. 0.292 (7 karats) for gold, 0.925 for silver, and 0.800 for PGMs). For PGMs, we took an average across the scrap prices for platinum and palladium, since prices of the former are roughly double that of the latter, and no reliable indication could be found of the breakdown specifically of platinum, palladium and other PGM's within WEEE.

Similarly, the plastics fraction within WEEE (15% of total WEEE) consists of a range of different polymers, including PE, PP, PS, PVC, PET, etc (Goosey 2013). However, no reliable information could be found regarding the breakdown of the plastic content of WEEE into different types of plastics. We therefore used a weighted average unit value for general plastic waste as determined above as an estimate of the value per tonne of the plastic content within WEEE. Since we are here focused on establishing an indicative higher value estimate, we used the higher estimate of the weighted average unit value of plastic waste (associated with the prices at which recyclers sell recycled plastic to downstream industries), namely R7,740.37 per tonne.

Finally, CRT and LCD screens are composed largely of glass. For example, according to Goosey (2013), 83% of LCD screens is composed of glass. Assuming a similar proportion for CRT screens, and considering that CRT and LCD screens typically make up 12% of WEEE (see above), it can be assumed that glass makes up approximately 10% (83% of 12%) of WEEE. Again, we use the average unit value of glass (R490/tonne) calculated above as an estimate of the unit value of the glass content in WEEE.

Taking into account the material fractions and unit values of the various types of metals, plastics and glass found in WEEE, an indicative higher weighted average unit value per tonne of WEEE can be calculated (based only on the metal, plastic and glass content for which unit values could be estimated, representing approximately 80% of the total weight of WEEE), as in Table 2.3.

Table 2.3: Composition and unit values of potentially recoverable metals, plastics and glass in WEEE

	g/t WEEE	% of total WEE	Price [R/T]	Unit value [R/T] of WEEE
Silver	21.41	0.002141%	6 263 164.25	134.09
Gold	6.45	0.000645%	124 289 678.11	801.67
PGMs	2.14	0.000214%	297 618 239.52	636.90
Antimony	1700	0.170000%	24 740.00	42.06
Cadmium	180	0.018000%	7 560.00	1.36
Copper	41000	4.100000%	44 067.27	1 806.76
Lead	2900	0.290000%	9 918.23	28.76
Tin	2400	0.240000%	139 858.65	335.66
Zinc	5100	0.510000%	10 237.24	52.21
Aluminium		13.74%	9 251.46	1 271.38
Iron		36.42%	3 029.35	1 103.14
TOTAL METALS		55.49%		
PLASTICS		15.00%	7 740.37	1 161.06
GLASS		9.96%	490.00	48.80
Total		**80.45%**		**7 423.86**

In this way, an indicative higher estimate of the weighted average unit value of one tonne of WEEE (based on potentially recoverable metals, plastics and glass, accounting for 80% of the total weight of WEEE) can be calculated at R7,423.86 per tonne (see Table 2.3). While this value seems high, it is in fact low relative to figures from WRAP (2012), which estimated a replacement value of the materials in an average tonne of WEEE items at approximately £825, equivalent to almost R15,000 per tonne at current exchange rates.

7. Tyres

Information obtained from the recycling sector showed that waste tyres can be recycled to produce rubber crumb, which can be sold for approximately R3,000 per tonne to road builders. However, collection and transport of waste tyres from tyre dealers costs between R700 and R1,900 per tonne, while processing to produce rubber crumb costs another R2,000 per tonne, excluding overhead costs. It is therefore clear that recycling of tyres to produce rubber crumb is currently not economically viable. The new tyre levy of R2.30/kg may partially address this. In the meantime, a more viable option may simply be to recover energy by using tyres in cement kilns or brick making plants, where waste tyres can replace up to 15% of the coal currently being used to produce energy (Groundwork 2014). With a calorific value similar to that of coal (Harley 2006), the WtE potential of tyres is relatively high, and has been valued at R367 per tonne. This figure will therefore be used as an indicative unit value for waste tyres.

8. Slag

According to Purnell (2009), approximately 510,000,000 tonnes of mining waste is generated per year in South Africa. This mining waste consists of a variety of materials, some of which may have significant recycling potential. However, owing to a lack of data regarding the composition of this waste stream, we focus here specifically on the more limited category ‘slag’ used in DEA (2012), quantified at 5,370,968 tonnes per year. This category consists of ferrous metal slag from steel, manganese, chrome, vanadium etc. processing, and non-ferrous metal slag from aluminium etc. processing (DEA 2012). This slag (aggregate) can be used as a building material in the construction of roads and buildings. According to the Aggregate and Sand Producers Association of South Africa (ASPASA 2014), for many purposes, recycled aggregate can substitute for primary aggregates. However, prices for recycled aggregate are likely to be lower than those for virgin aggregates (Purnell 2009). The CSIR’s Built Environment Unit estimates a price for recycled aggregate in the construction industry at between R170 per R180 per tonne. A unit value of R175 per tonne will therefore be used in this study.

9. Ash

Ash produced by Eskom’s power plants, approximately 90% of which is in the form of “fly ash” (Purnell 2009), can potentially be sold and used in the cement industry. Eskom sells this ash at low prices (on a sliding scale ranging between R0 and R5 per tonne, depending on whether the ash is collected on-site or off-site, and by Eskom or by the users themselves), in order to make it attractive to customers. Taking a straight average over the range of prices yields a unit value of R3 per tonne, which will be used in our calculations.

10. Construction and demolition waste

Construction and demolition waste consists of a range of materials, including concrete, bricks, masonry, ceramics, metals, plastic, paper, cardboard, gypsum drywall, timber, insulation, asphalt, glass, carpeting, roofing, and excavation materials (DEA 2012). A study in the Western Cape estimated that concrete and masonry together make up about 33.3% of this waste, followed by wood (25%) and drywall (12.5%) (Viljoen 2010, in DEA 2012). Some of this waste can be crushed to produce recycled aggregate, although currently the majority is used as backfill in construction. For slag from mineral processing (see above), we used a unit value of R175 per tonne for aggregate. However, since not all of the construction and demolition waste can be used to produce recycled aggregate, and since the current practice is for construction and demolition waste to be used simply as backfill (which can be assumed to have a lower value as compare to the value of aggregate), we will assume a unit value equal to half of the unit value for aggregate, i.e. R87.50 per tonne.

11. Waste oils

Information from the recycling sector revealed that a value of R2.50 per litre can be used for waste oil. Based on an assumed density of 0.9 kg/L (in the case of used lubricating oil) (ROSE Foundation 2014), this works out to a unit value of R2,778 per tonne.