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Acronyms

AD	Anaerobic Digestion
AISWM	Advanced Integrated Solid Waste Management
ATT	Advanced Thermal Treatment
AWT	Advanced Waste Treatment
BAU	Business As Usual
C&D	Construction and Demolition
CAPEX	Capital Expenditure
CDM	Clean Development Mechanism
CHP	Combined Heat and Power
CPI	Consumer Price Index
CSIR	Council for Scientific and Industrial Research, South Africa
DEA	Department of Environmental Affairs
DEFRA	Department for Environmental, Food & Rural Affairs, United Kingdom
EIA	Environmental Impact Assessment
FGT	Flue Gas Treatment
GHG	Greenhouse Gas
IBA	Incinerator Bottom Ash
ISWA	International Solid Waste Association
ISWM	Integrated Solid Waste Management
IVC	In Vessel Composting
IWMP	Integrated Waste Management Plan
KfW	KfW Development Bank
KP	Knowledge Product
LPG	Liquefied Petroleum Gas
MBT	Mechanical Biological Treatment
MHT	Mechanical Heat Treatment
MRF	Material Recovery Facility
MSA	Municipal System Act
MSW	Municipal Solid Waste
NEMWA	National Environmental Management Waste Act
OPEX	Operational Expenditure
PPP	Public Private Partnership
RDF	Refuse Derived Fuel
RLM	Rustenburg Local Municipality
RSA	Republic of South Africa
SWM	Solid Waste Management
UK	United Kingdom
UMDM	uMgungundlovu District Municipality
WtE	Waste to Energy
ZAR	South African Rand

Glossary

Terminology	Definition
Activity-based accounting	An accounting approach that registers costs attached to each activity in the process flow separately. It enables management to better understand how and where the company is overspending and which areas have the greatest potential for cost reduction.
Cost of financing (cost of capital)	Interest on loan and other charges (front-end fee, commitment fee) involved in borrowing of money for investment.
Economic analysis	The analysis of the economic performance of an investment, taking into account the welfare effects of the investment, results in economic indicators. This type of analysis is usually used by government agencies when spending public funds in choosing among various investment projects.
Environmental costs	Costs connected with the actual or potential deterioration of natural assets due to economic activities. In case of AWT, environmental costs may include the costs of pollution prevention (e.g. filters and odour control measures), pollution remediation measures, etc.
Externality	Effects/impacts cost and benefits of production that are external to the buyer and provider of a service or goods and are not included in the price of the service/goods.
Financial analysis	Assessment of financial (monetary) viability, stability and profitability of a project or business.
Full cost	Total costs including the investment cost and the operating cost. Investment cost allocation within an accounting period is presented by the depreciation expenses and interest on loan (if funded by loan).
Investment cost (capital cost) also called 'capex'	Investment cost (capital cost) also called 'capex': Fixed, one-time expenses incurred for the purchase of land, buildings, construction and equipment (inclues cost of dismantling, removal and restoration). Total cost needed to bring a project to a commercially operable status.
Landfill airspace (void space)	The volume of space on a landfill that is permitted for the disposal of waste.
Net Present Value	The difference between the present value of cash inflows and the present value of cash outflows, used in capital budgeting to analyse the profitability of a projected investment or project.
Operating cost	Running costs, fixed and variable, involved in the daily production/service provision, including costs for maintenance and repair, labour, utilities, consum-ables, etc. Also called 'opex'.
Revenues	Income from sales of services or goods, sourced from gate fees, sale of recovered materials, energy, tariffs or other income.
Ring-fencing	Financial separation of a portion of a municipality's assets or budget in order to safeguard use for the intended purpose.
Specific cost (unit cost)	A cost per unit, e.g. cost per tonne of waste handled (ZAR/tonne). Throughout this document, the following exchange rate is used: 1 EUR = 13 ZAR (corre-sponding to European Central Bank exchange rate April 20th, 2015).

Informal service sector	Entrepreneurs providing small-scale waste collection and cleaning services in rural and poor areas.
Informal valorisation sector	Recovery of recyclables and small-scale manufacturing by the informal sector.
Informal waste sector	An all-encompassing term that captures the totality of informal economic activity in the cleaning, waste management services and recycling sector.
Integrated solid waste management	The coordinated use of a set of waste management approaches and solutions, each of which has a functional role in an overall solid waste management system, and which combine together as a recognisably coherent whole.
Itinerant waste buyers	Recyclers who go door-to-door, collecting, buying or bartering for materials, before they have entered the official waste stream.
Labour force	People who are able and willing to work.
Linear resource economy	An economy where solid waste exits the economic flow of goods once generated.
Material recovery facility	A facility where recyclable materials are recovered and sorted. At a dirty MRF, recyclables are sorted from mixed waste input feedstock; at a clean MRF, recyclables are sorted from a separately collected mixed-dry-recyclable input feedstock.
Mechanical bioloical treatment	A combination of mechanical and biological processes used to pre-treat the input feedstock and produce outputs including recyclables, refuse-derived fuel, and/or biologically stable compost.
Traders	Formal or informal entrepreneurs and companies buying recyclables from individual waste reclaimers or companies and reselling them into the recycling value chain.
Primary collection	The collection of waste from the point of generation (e.g. household or commercial premises) and its transport to community container or other places of secondary collection, or final disposal.
Professionalisation	Imparting professional skills and capacities.
Refuse-derived fuel	Waste fraction with good combustion properties that can be used as fuel.
Secondary collection	The collection of waste from a place of temporary storage that is distant from the point of generation (e.g. community container or other location) and transport to transfer station, treatment or landfill.
Separation at source	Sorting of different materials at the source of generation (households, businesses, etc.) before collection.
Waste management hierarchy	An integrated set of options dealing with waste generation and the disposal thereof in order of preference: Reduce generated waste, reuse, recycle and compost, recovery of energy and disposal.

Chapter 1
INTRODUCTION



1 Introduction

1.1 Background to the AISWM Programme

The South African government in partnership with the German Development Cooperation has embarked upon the implementation of an **advanced integrated solid waste management** (AISWM) Programme for the Republic of South Africa.

The Programme prepares projects in pilot municipalities and disseminates knowledge, experience and the practical application of advanced waste treatment (AWT) and broader AISWM systems in the context of South African municipalities.

AISWM is not a universally known term. The term is used to describe integrated solid waste management (ISWM) making use of systems and technologies, within a framework of policies, legislation and practices, that reduce dependency on landfill for disposal of waste. The Programme defines **AISWM** as *the coherent and sustainable application of approaches and solutions that have the effect of reducing the amount of waste that needs to be landfilled*.

AISWM is the process of advancing waste management practices up the hierarchy away from landfill and towards creating energy, recycling, composting, reuse and reduction. **AISWM** does not necessarily demand the use of sophisticated and expensive technology; rather it involves a blend of management systems and appropriate technologies that succeed in sustainably diverting waste away from landfill.

The Department of Environmental Affairs (DEA) coordinates the Programme at national level, with the Rustenburg Local Municipality (RLM) and uMgungundlovu District Municipality (UMDM) partnering at a local level. Each of the partner municipalities has received tailored consultancy support for the preparation of AISWM projects that may be integrated into, and be sustainable within, their local situation.

The intended results of the Programme are to support the implementation of AISWM systems in municipalities and undertake **knowledge dissemination and training on best practices, examples and lessons learned** from the projects to decision-makers in other municipalities and at national level in South Africa.

A series of five knowledge products (KPs) have been prepared to support capacity building on the subject of AISWM across South Africa. The KPs aim to provide clear, concise and factual information to support decision-making on AISWM and AWT, so that municipalities and their partners can plan and implement the next generation of facilities.

1.2 Relationship between Knowledge Products in this Series

This knowledge product (KP) 4, financial implications of advanced waste treatment, is the fourth KP in the series. It builds on KP1: An Introduction to Advanced Waste Treatment, KP2: Appropriate Technology for Advanced Waste Treatment and KP3: Recognising the Informal Waste Sector in Advanced Waste Treatment.

Knowledge product 4 focuses on the financial aspects of developing and operating different types of advanced waste treatment facilities. This KP provides an overview of the financial implications of moving away from landfill and towards AISWM systems. Benchmark cost ranges and breakdowns are provided for different technologies. The KP further includes guidance on preparing a business case (including planning and financial analysis) for AWT systems. The full suite of KPs is illustrated in Figure 1: Relationship between knowledge products in this series.

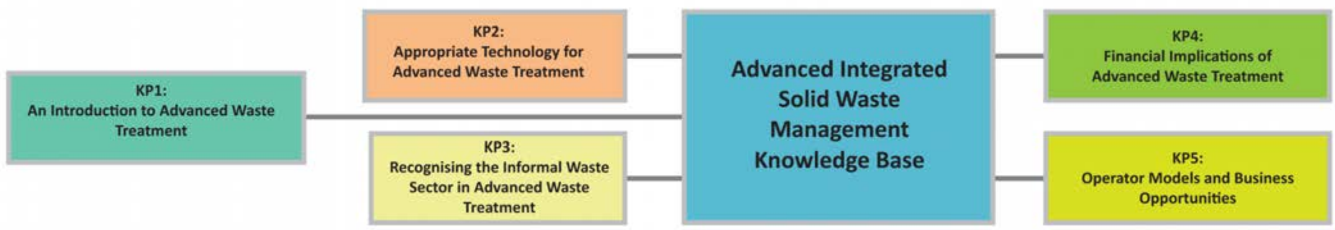


Figure 1: Relationship between knowledge products in this series

1.3 Context of this Knowledge Product

Traditionally, solid waste management (SWM) has been regarded one-dimensionally, with waste being collected and disposed of at 'sinks' better known as landfills. However, since the inception of the *National Environmental Management Waste Act 59 of 2008 (NEMWA)*[1], municipalities have been urged to adopt an integrated multi-dimensional approach to SWM by applying the principles of the waste management hierarchy in the development of their ISWM systems.

The hierarchy includes waste reduction, re-use, recycling and composting, energy creation (via / recovery) and, finally, disposal. Waste reduction is the most desirable outcome and disposal the least. Both the one-dimensional and multi-dimensional approaches are illustrated in Figure 2.

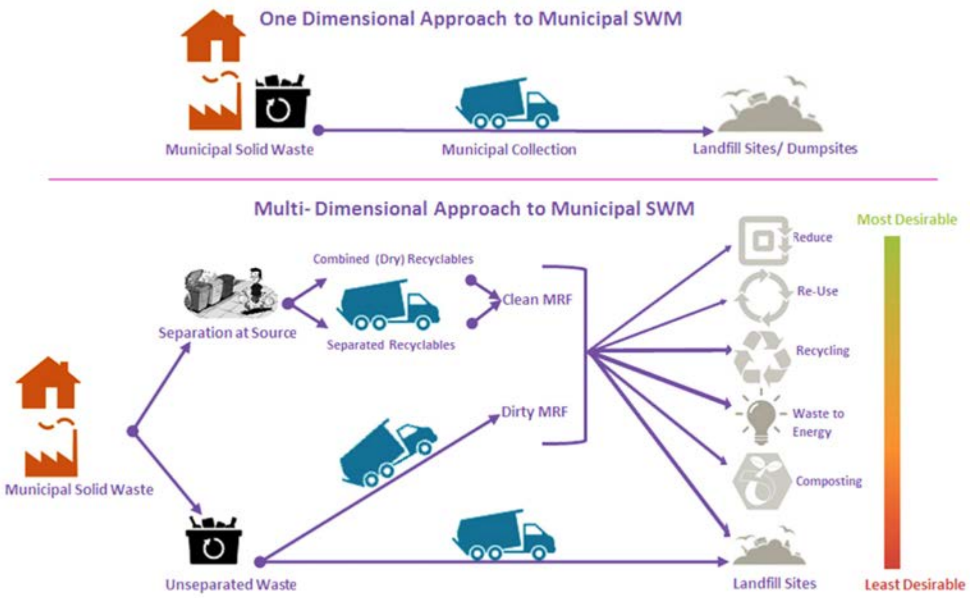


Figure 2: One-dimensional versus multi-dimensional-approach to municipal SWM

(Source: Adapted from DEA 2012:18)

When comparing financial performance, costs and revenues of one-dimensional systems against multi-dimensional systems it should be undertaken with a view to the *long-term* economic implications.

The introduction of advanced waste treatment mechanisms generates repercussions downstream for the collection system with feedstock quality and quantity, and upstream with specific reference to the market for recovered resources. Regardless of the AWT options being pursued, there remains a need for landfill sites in order to manage residual waste and by-products.

The cost of a waste management system is context-dependent. It depends on availability of land, the market demand for secondary resources, the cost of labour and the costs associated with raising capital, amongst other factors. Initially, multi-dimensional AISWM systems will appear more expensive than a one-dimensional system. However, when the economic and social costs (including the otherwise unaccounted externalities) of one-dimensional systems are fully considered, multi-dimensional approaches may become more favourable. The reduced pollution and its associated clean-up costs, more efficient resource use and job creation represent some of the key economic and social benefits of AWT.

Through legislative, financial, institutional, administrative and advisory support by national, provincial and local government, opportunities need to be created ensuring that treatment and recycling of waste becomes more financially viable. Projects of such nature need to consider job creation and wider social impacts, irrespective of the facility being government owned, a public private partnership (PPP) or an entirely privately owned and managed facility.

1 *Available online at https://www.environment.gov.za/sites/default/files/legislations/nema_amendment_act59.pdf, accessed November 2015.*

1.4 Scope of this Knowledge Product

The technologies that are represented in the knowledge products allude to both mainstream and emerging techno- logies that can be applied primarily for the treatment of **municipal solid waste** (MSW). Synergies with other waste streams may exist; however, the intention of this knowledge product is to profile technologies that have a potential mainstream applicability to the diversion of MSW from landfill.

Technologies are divided into three categories: **Promising technologies – short-term**, **potential technologies – medium-term** and **potential technologies – long-term**.

- **Promising technologies – short-term:** (e.g. windrow composting, construction and demolition (C&D) waste recycling and materials recovery facilities (MRF) are assessed as having strong potential for wide scale application for South African municipalities under the current market conditions. A major market-influencing factor is the price of landfill. Municipalities that have succeeded per implementing (and paying for) legally compliant landfill services, will recognise the full cost of these services in their municipal budgets and are likely to find promising technologies to implement under existing budget and price structures. Whether or not this is the case, will depend on the municipality's specific situation.

- **Potential technologies – medium-term:** (e.g. mechanical biological treatment (MBT), anaerobic digestion (AD) and in-vessel composting (IVC), are assessed as being potentially applicable in municipalities where external influencing factors exist that either: a) drive up the cost of landfill, b) where there are synergies in the co-processing of MSW with other waste streams, or c) where there is a particularly strong demand for the outputs from the AWT process. These types of technologies are generally more costly in financial terms than landfill. However, external factors may influence market conditions to an extent that they become financially viable under specific conditions.
- **Potential technologies – long-term:** (e.g. incineration with energy recovery, mechanical heat treatment (MHT), and other advanced thermal treatment (ATT) technologies such as gasification and Pyrolysis, require high capital expenditure. The applicability of these technologies cannot be ruled out; however, their high costs suggest feasibility is improbable in all but the largest metropolitan municipalities. Although the scale of the difference in cost for these technologies when compared to a landfill, or landfill in addition to the lower cost AWT, is significant enough to ensure investment justification it will be difficult unless a very strong case can be presented.

This knowledge product addresses the following questions:

What is the economic rationale for a municipality to invest in AWT? (Chapter 2)

What should municipalities take into consideration whilst preparing a business case for AWT? (Chapter 3)

What are good practices for financial analysis and prioritising investments for municipalities? (Chapter 3)

What are the typical cost structures for different AWT technologies? (Chapter 4)

What are the cost implications for collection and transportation of various AWT technologies? (Chapter 4)

What degree of cost-increase (from the business as usual scenario) should municipalities expect when implementing different AWT facilities? (Chapters 5,6 and 7)

Chapter 2

THE ECONOMIC RATIONALE FOR AISWM

2 The Economic Rationale for AISWM

The economics of waste treatment is influenced by a complex mix of driving forces. On the one hand, waste treatment services are similar to disposal services in that the service is typically 'out of sight and out of mind' to the customers of the service. However, waste treatment can generate revenues, from sale of recovered materials and energy which disposal services may not be able to generate.

Waste treatment facilities must compete with waste disposal facilities in the price of the service; the net costs (costs minus revenues) of AWT need to be equal or similar to the cost of disposal in order for the business case to be compelling. Finding a balance to this equation is key to the widescale adoption of AWT.

2.1 Macro-Economics of Waste Management

Waste management services first arose with the aim of protecting public health. With regard to waste collection, the value of the service is in the removal of the materials from the place of generation. Clients of the service tend to be willing to pay for the removal of their waste. The resulting direct S*ervice → Payment* relationship helps to create a favourable economic environment for the provision and progressive extension/improvement of current services.

Waste treatment and disposal services are, however, different. Service-payment relationships between the client and the service provider is indirect, i.e. the client (waste generator) typically does not 'see' the service that they receive. Furthermore, this has an important effect that the service is often under-valued, and consequently under-provided, unless policy and legislative instruments are in place to drive infrastructure development and service provision.

The quality of disposal services is almost entirely driven by environmental legislation. When left to market forces, the quality of disposal tends to remain very low. This is due to the cost of long-term or cumulative environmental (and indirect health) impacts not being reflected in market prices, unless, there is some form of regulation or policy driver.

The disposal service is a net financial cost activity that the customers of the service often regard as 'out of sight and out of mind'. South African municipalities have made great strides in improving the quality of waste disposal. Legally-compliant landfills are not yet universally provided across the country, although that is the trend. This is driven by the public awareness and environmental enforcement.

2.2 Economics of AWT

Under pure market conditions, the economic viability of recycling and treatment is driven by the market value of the materials extracted from the waste stream; either for re-use, recycling, composting or conversion to energy. The market can be relied upon to deliver a certain level of recycling and treatment, mainly for higher value materials such as ferrous and non-ferrous metals, glass, certain plastics and pure organics/biodegradables.

Experiences from industrialised countries that have succeeded in establishing higher treatment intensity, and diverting larger percentages of municipal waste away from landfill, demonstrate that policy instruments are required to shape the market conditions on the ground. In addition, higher intensity of treatment is driven by a combination of the policy (regulatory, financial, economic) framework, coupled with the specific local market influencing factors.

The basic costs of waste management under the 'business as usual' (BAU) scenario increase as waste collection coverage extends and legally compliant landfill is ensured. Thus, this increase in cost is necessary for alternative treatment to be in a position to try and compete with the BAU scenario.

Once a municipality has secured sufficient landfill airspace to meet its long-term needs, it becomes apparent that a landfill is an 'asset' that should be used prudently. Siting of landfill facilities is a difficult process, and often faces significant public opposition. Every indication suggests that, over time, securing additional permitted landfill airspace will become increasingly difficult.

Given the need to make progress on meeting the *National Waste Management Strategy* targets, municipalities have to consider how best to divert significant quantities of MSW from landfill. With increasing application of policy instruments designed to shape the market over time, the bottom line for introducing AWT will improve. The business and policy drivers in the waste management process flow are conceptually outlined in Figure 3: The business and policy drivers in the waste management process flow.

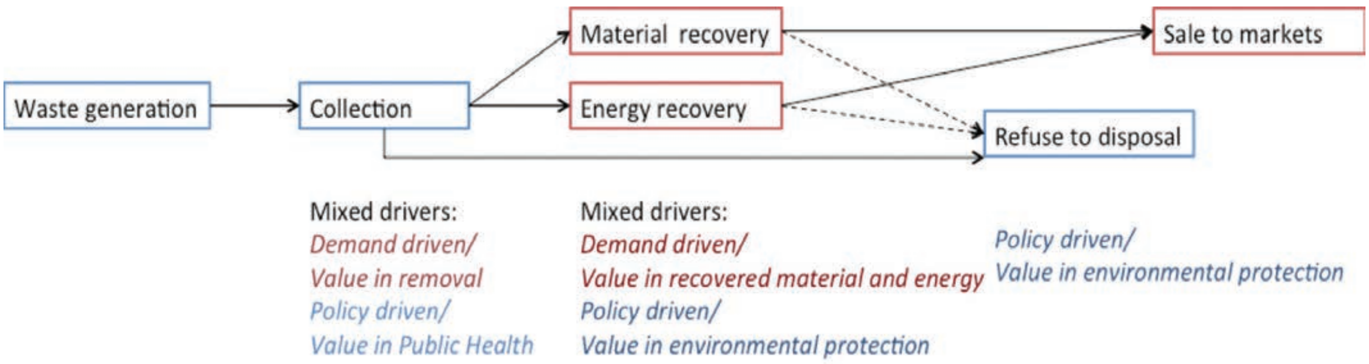


Figure 3: The business and policy drivers in the waste management process flow

Figure 3: The business and policy drivers in the waste management process flow illustrates how revenue streams will vary for the different activities. There is a demand for collection service and usually people are willing to pay a price for removal. Therefore, collecting revenues from the public in the form of user charges and taxes, is possible and sometimes reaches full cost recovery. For low income earning citizens, where affordability is of concern, public funds are allocated due to public health issues that may arise in cases where services may not be available.

There is a demand for recovery that is driven from the intrinsic value of the discarded materials. Revenues for AWT are derived from various sources, including commercial revenues from the sale of recovered materials and energy. Those activities that are not demand driven need an environmental policy push and revenues from subsidies or other public funds. This is the case for the recovery of certain waste streams and for the disposal of such waste streams.

2.3 Economic Costs and Benefits of Waste Management

Advanced waste treatment is generally more expensive than landfilling when only considering the financial costs. However, when considering the wider economic costs and benefits from a societal standpoint, advanced treatment options may become more favourable than that of landfilling, as an option.

The *Global Waste Management, Outlook Report of 2015* concluded that in implementing proper waste management was up to 10-15 times cheaper than the foregone economic costs associated with inaction or insufficient action in waste management.[2]

Internationally, there have been numerous efforts to monetise the negative environmental and health impacts of landfill or dumping. These studies are usually location specific, but typically monetise negative impacts to air, water and soil pollution, health, climate change, nuisance caused by odour and the negative landscape impact. For example, Landfill Tax in the United Kingdom (UK) was originally established based on a monetary calculation of the environmental externalities of landfill. The effect of Landfill Tax is to create a disincentive to landfill and drive market forces towards investing in landfill diversion. Since the introduction of landfill taxes/levies in various forms and at various levels, such policy applications have been taken up in many countries, in order to drive the economics of landfill diversion.

2 *Wilson D.C., Soos R., Simonett O., Chapter 5 Financing Waste Management, Global Waste Management Outlook, UNDP and ISWA (September 2015)*

In South Africa, according to the Council for Scientific and Industrial Research (CSIR) study on *Environmental and disamenity costs associated with landfills: A case study of Cape Town, South Africa,* the **Additional Economic Cost** of landfilling a tonne of waste is estimated to be between **30 ZAR** to **110 ZAR**.[3]

Economic costs are influenced by construction and operation standards, existence of energy recovery and landfill location. Waste treatment is higher in the waste management hierarchy, and as long as pollution control from these facilities is within regulatory norms, they tend to produce fewer negative environmental impacts and generate greater benefits.

Besides pollution control and saving of landfill void space, AWT tends to offer the type of benefits described in the Table 1.

Table 1: Wider benefits to society and the economy from advanced waste treatment4

No	Category of benefit	Explanatory comments
1	Increased resource security	After a century of steady decline, resource prices in real terms doubled between 2000 and 2010[5]. With continued price volatility, developing indigenous supplies of secondary raw materials from recycling makes good sense, particularly in rapidly industrialising countries. For example, e-waste comprises a richer 'ore' for many scarce and critical metals than the natural ores mined for the virgin raw materials.
2	New jobs	Environmentally sound waste management, the recycling of dry and organic materials and energy recovery from wastes all represent 'new' green industrial sectors with the potential for substantial job creation. UK employment in the sector, for example, increased by 50% between 1993 and 2013. The wider 'circular economy' holds further promise: The McKinsey report estimates the potential to create between nine and 25 million new jobs worldwide.[6]
3	Reduction in GHG emissions from waste management	The Intergovernmental Panel for Climate Change reports that MSW accounts for approximately 3% of total greenhouse gas (GHG) emissions, mainly as methane. Efforts in high-income countries to divert biodegradable municipal waste from landfill represent a significant contribution to early progress on GHG mitigation.
4	Energy recovery by using waste to generate energy often together with sparing other precious resources	Through conventional and advanced and waste-to-energy technologies, co-incineration and anaerobic digestion technology. For example, waste to energy plants in China are both reducing fossil fuel use and are known to prevent deforestation, wood being a common source of fuel in rural China.

2.4 Concluding Remarks

When considering all the benefits of AWT holistically, including the wider environmental and social benefits, the attractiveness of AWT increases. Furthermore, AWT is the segment of waste management activities where the private sector can recognise a business interest, and make the best use of the intrinsic and energy values of the various waste streams.

3 *Nahman, A. Rounded figures taken from "Pricing landfill externalities: Emissions and disamenity costs in Cape Town, South Africa", June 2011, Waste Management Journal 31, 2046 – 2056, www.elsevier.com/locate/wasman*
4 *Wilson D.C., Soos R., Simonett O., Chapter 5 Financing Waste Management, Global Waste Management Outlook, UNDP and ISWA (September 2015)*
5 *World Bank Commodity Price Data ('Pink Sheet'), (http://databank.worldbank.org/data/reports.aspx?source=global-economic-monitor-(gem)-commodities)*
6 *http://www.ellenmacarthurfoundation.org/business/reports; McKinsey Global Institute, 2011. Resource revolution: Meeting the world's energy, materials, food, and water needs. Dobbs, R., Oppenheim, J., Thompson, F., Brinkman, M. and Zornes, M http://mckinseyonsociety.com/resource-revolution/*

Chapter 3

PREPARING A BUSINESS CASE

3. Preparing a Business Case

AWT projects need to be thoroughly prepared and analysed. Municipalities should define the role of the AWT in the waste management system as a whole, assessing options, hence ensuring that the final selection meets objectives and is feasible. After understanding the costs and revenues in the baseline, the cost of various AWT options need to be financially analysed. The required level of gate fee for the AWT project needs to be calculated, prior to undertaking final decisions.

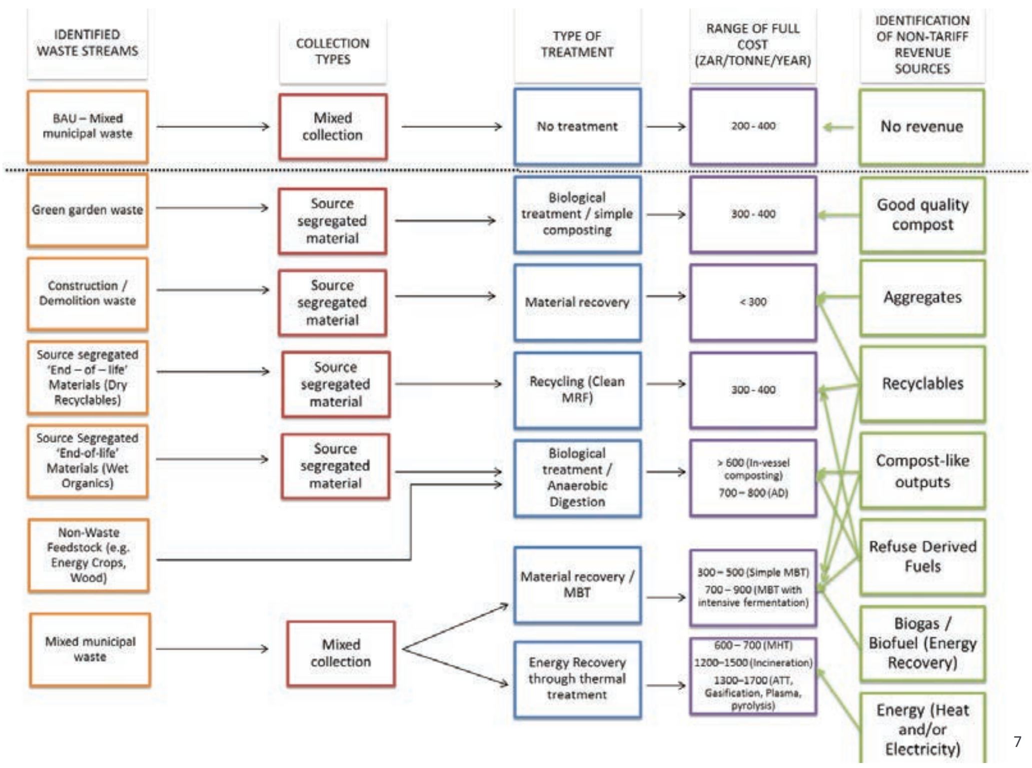
3.1 Analysing Integrated Systems

An integrated 'system' approach is required when weighing the costs and benefits of AWT versus the BAU scenario. This implies taking into consideration the entire waste management system, identifying the changes in the flow of materials, what the implications are in terms of collection, pre-treatment and disposal, and what changes are needed to meet quality and quantity requirements for input materials for any AWT facility.

One simple approach is to draw a **process flow (or mass balance) diagram** for the waste streams to be handled. Process flow charts use arrows for collection and transport steps of waste management and a labelled box for every process where a material transformation happens. These changes, for example, can be in the form of changes to density, moisture, composition or the material quality. Using a process flow diagram will highlight the changes intended in terms of collection and pre-treatment.

Part of an integrated analysis includes the analysis of downstream markets and treatment needs for the residual waste following the various treatment options. The assumption of too optimistic market scenarios for outputs/by-products from AWT or not including cost estimates for treating residual waste can significantly change the financial analysis of a waste management scenario.

Figure 4: Presents an overview of the key waste sources, collection types, typical cost ranges and potential revenue sources for different types of AWT, when compared to the BAU situation of mixed MSW going straight to landfill. Figure 4: May be used as a reference guide to cross-check completeness when preparing a process flow diagram for a proposed AWT system.



[7]

Figure 4: An illustration of AWT options, costs and non – tariff revenues per waste stream and collection types

7 *Note: This is a simplified summary diagram and does not intend to be exhaustive in all technology configurations. The dotted line separates the BAU scenario from AWT technologies.*

3.2 Defining Project Scope

Municipalities often receive unsolicited technology offers from different suppliers and sales agents. Unfortunately, in many cases these offers fail to deliver on promises when they are subjected to due diligence by independent experts. The offers are sometimes unreasonable and/or unfeasible and are often facsimiles from other projects. Consequently, not tailored to the specific needs of a municipality or regional waste management system.

Municipalities need to be cautious when entering into any agreements unless they have a sound understanding of how a particular AWT project will function within the overall waste management system. Key issues to consider in scoping AWT projects include a range of factors; the most important ones are discussed as follows:

- Process flow and material balance in the existing system
- Demand for secondary raw materials or energy
- Economies of scale and availability of feedstock
- Source and availability of capital investment
- Social, environmental and resource efficiency benefits

3.2.1 Process flow and material balance in the existing system

Understanding waste quantities and composition, existing material flows and facilities, and current costs and tariff/price structures is necessary. It is imperative to have a good understanding of the needs of the integrated waste management plan (IWMP) for the municipality.

3.2.2 Demand for secondary raw materials or energy

Assessing markets for the outputs of an AWT process is essential when defining the scope of work to be undertaken. For example, if there is a local demand for very high quality organically certified compost, then the compost derived from mixed municipal waste will not satisfy that market as it will be too contaminated. Similarly, if there is an energy output from a particular AWT process, the feasibility will depend on whether that energy can be utilised in the form of heat or electricity. If the energy can be utilised in the form of heat, the proximity of the customers to the AWT facility needs to be taken into account.

Market considerations have a significant impact on the feasibility of different types of AWT, and the reliability of project cost-benefit estimations.

3.2.3 Economies of scale and availability of feedstock

Economy of scale is a key aspect for analysis. Certain facilities are flexible and may be cost-effective at smaller scales, whilst others only become viable at a larger scale.

If a large facility is planned, this may require regionalisation, which implies that municipalities will need to be prepared to work together in the planning, financing and implementation of such projects. Regionalisation is an option to consider for achieving better economies of scale and reaching feasible input quantities for AWT facilities, but it is not always easy to achieve.

3.2.4 Source and availability of capital investment

Due to the limited potential to publicly finance AWT, attracting private investment is often a key criterion in defining the scope of an AWT project.

3.2.5 Social, environmental and resource efficiency benefits

Other key criteria to consider are job creation and livelihood protection/creation. The environmental and resource recovery benefits of the treatment options also need to be estimated.

National policy goals and local governance objectives converge in the four points, listed earlier and, tend to be the main decision-making factors that surround approval of AWT projects.

3.3 Understanding Existing Costs

To gain an understanding of the existing costs, municipalities need to identify the full costs of waste management services. This is not an easy task when the waste management service related costs have not been 'ring fenced', or at least recorded in a 'cost centre', i.e. a separate inventory of costs and revenues attributable to waste management services.

Understanding the full costs of waste management services involves preparing an asset register, collecting and assimilating data on operating costs (both budgeted and actual), and identifying other 'hidden' costs and revenues. **Full cost accounting, activity-based accounting and revenue sources are discussed at length in the *Solid Waste Tariff Setting Guidelines for Local Authorities*[8].**

The collection of data and subsequent analysis of the 'status quo' should ensure that the existing assets are fully considered. A detailed understanding of the cost components helps to make future cost projections as accurate as possible.

Municipalities and operators regularly maintain an inventory of assets, along with their book value and an estimated remaining useful life. Additional data collection may be required to understand the technical characteristics of the assets, i.e. fuel consumption of vehicles, maintenance needs and availability of spare parts.

In general, the inventories include all fixed and capital assets, such as land, construction, offices and industrial buildings, storage yards, garages, vehicles, waste treatment installations and waste handling equipment.

Major budget line items include waste disposal, collection, cleaning services and remediation/closure of existing landfills/dumpsites. Added to this, is the investment budget allocated for replacement of equipment and/or upgrades.

The cost information as illustrated in Table 2, serves as an example of the type of costs associated with different components of the waste management service.

It should be noted that the costs do not include the cleaning of illegal dumpsites. According to the City of Cape Town (personal communication), the cost for cleaning up illegal dumpsites is one of the city's largest budget items, which in 2015 was estimated at 400 million ZAR/year.

Table 2: Operational costs budget for Johannesburg (2012/2013), Cape Town (2009/2010) and Rustenburg (2012/2013) municipalities[9]

Operation costs	Unit	Johannesburg (2012/2013)[10]	Cape Town (2009/2010)[11]	RLM (2012/2013)[12]
Waste generation	Tonnes	1,775,600	3,030,412	91,793[6]
Operational budget	ZAR	1.3 bn	1.5 bn	0.1 bn
Operation costs as a percentage of budget				
Collection	%	35	40	35
Area cleaning	%	14	31	23
Disposal	%	8	18	16
Administrative	%	1	7	12
Drop offs	%		4	
Overheads	%	21		2
Other cost	%	21		13
Total	%	100	100	100

8 *Republic of South Africa, Department of Environmental Affairs, 'Solid Waste Tariff Setting Guidelines for Local Authorities', May 2012*

9 *The information was sourced from the City of Cape Town Metropolitan Municipality and from Pikitup (Johannesburg's official waste management company), Johannesburg. Given the different timeframes, these costs should be seen as general guideline values and are not directly comparable.*

10 *De Wit Sustainable Options, Sally Anne Käsner Jeffares & Green, 'Pikitup Waste Minimization Startup Info', Annexure A, September 2013*

11 *Akhile Consortium, 'MSA Section 78(3) to Assess Alternative Service Delivery Options', RFP No. 554C/2008/09, Consolidated Report, Solid Waste Management Department, Cape Town Municipality, May 2011*

12 *Rustenburg Local Municipality, Directorate – Technical and Infrastructure Services, Operating Budget 2012/2013*

13 *Infrastrucktur&Umwelt, Professor Bohm und Partner, KfW, 'Draft Feasibility Study Report. Advanced Integrated Solid Waste Management System for Rustenburg Local Municipality', February 2009, pp 17.*

The examples of budget breakdowns presented in Table 2 are from secondary information sources and are therefore different. Some cost categories such as those related to a municipality's role in planning and outsourcing waste management activities have not been elaborated upon further.

3.4 Specific Costs

The costs per tonne of collection services vary widely. These costs depend on the following:

- method of collection chosen (whether door-to-door, communal or block collection, etc.);
- distances within the collection area;
- types of vehicles and containers used;
- infrastructure of the city;
- types of waste collected; and
- types of housing and commercial/industrial premises.

Where the costs of disposal are reflected in the landfill gate fees, they can be easily understood and used as a benchmark against which to assess AWT alternatives. There are differences among fees depending on the type of waste delivered, for example, inert waste disposal in some landfills is at no cost to the generator, while waste generated outside of the municipal territory may be more expensive to dispose of.

Specific full cost of landfilling in Cape Town is estimated at 400 ZAR/tonne based on the 2009/2010 budget information and including capital expenditures; a large proportion of which were allocated for disposal and drop offs.[14] The closure and after-care costs of the landfill and the cost of waste transfer are also included in the gate fee for the City of Cape Town. However, capital expenditures for land purchase and facility have not been included.

Experts estimate that the operating costs of landfills are currently in the range of 150 to 450 ZAR/tonne depending on the management practices and pricing policy at the site.[15]

Waste disposal gate fees are mostly designed to cover the operation costs, and at times may also include capital depreciation and interest costs. The average landfill gate fee, nationwide, is approximately 150 ZAR/tonne. Table 3 provides information on the disposal gate fees that are applicable for Cities of Johannesburg and Cape Town, respectively.

Table 3: Disposal gate fees for Johannesburg and Cape Town

Disposal gate fees	Johannesburg (2013/2014)[16] ZAR/tonne	Cape Town (2014/2015)[17] ZAR/tonne
For general waste excluding VAT	309	317
Rate of cost recovery of disposal cost from gate fee	No information	Estimated at 100% operational cost recovery rate

Sources of revenues for collection are user charges collected from citizens and commercial customers using the service. Payment rates vary. Low-income earning citizens have a right to receive the public service of waste collection free of charge.

14 *Akhile Consortium, 'MSA Section 78(3) to Assess Alternative Service Delivery Options', RFP No. 554C/2008/09, Consolidated Report, Solid Waste Management Department, Cape Town Municipality, Executive Summary, page xxvi, May 2011,*

15 *Bertie Lourens, WastePlan, direct communication 5th of May 2015 and John Coetzee, Jeffares and Green, personal communication 9th of May 2015*

16 *De Wit Sustainable Options, Sally Anne Käsner Jeffares & Green, 'Pikitup Waste Minimization Startup Info', Annexure A, September 2013*

17 *Gate fee as declared by the City of Cape Town, valid until 30th of June 2015*

3.5 Operational Costs

Accounting records and budgets maintain information about operating costs. Some difficulties may arise in discovering these costs as municipal waste budgets may not be clearly demarcated or 'ring fenced'. Furthermore, cost data may only be available to operators who might wish to keep this data confidential.

Costs of different utilities or service elements are often aggregated, recorded in different departments of the municipality. This situation fosters uncertainty in decision-making and sends incoherent signals to the private sector – thus creating a market barrier for the development of AWT.

A typical operating cost structure for waste management services includes direct labour, fuel, utilities, supplies and mechanical maintenance and repair costs. Operation costs include costs that are not always immediately obvious and may be hidden in other budget lines, or may be part of an overall overhead that is not attributed to waste management.

Examples of these costs include: Obtaining permits, planning for waste management, preparing tenders and contracting, management of operators and monitoring and quality control. Customer relations and satisfaction surveys, awareness-raising, insurance, taxes and cost of financing sometimes also fall within this category.

Costs related to *ad-hoc* activities, such as cleaning-up of illegal dumps or debris after a storm or flood, extinguishing landfill fires or closing old landfills sometimes also fall into the category of hidden costs.

It is good practice to calculate costs based on activity, separated for each individual component of the service – such as street sweeping, waste collection, waste transport, recycling and landfill operations.

3.6 Revenues

Revenues may comprise local taxes or fees, revenue from the sale of materials or energy recovered, gate fees, collection from service users/customers or transfers from local or national budgets. Other, less significant, financing sources include income from permits, the occasional renting of assets, profit sharing deals (e.g., concession fees) or littering fines. Where gate fees or user charges are applied, it is important to understand the current payment rates.

Once current costs and revenues are understood, the process of forecasting future revenues and expenditures may commence. Forecasts of future revenues are required to set user fees. *The Solid Waste Tariff Setting Guideline for Local Authorities*[18] allows for different revenue collection mechanisms, including taxes, user charges or a combination of both. The Guideline presents options for introducing targeted subsidies as well as using tariff systems to incentivise source separation and waste minimisation.

The source of financing for the operating costs is also the starting point of analysis for future systems. Changes proposed in the revenue structures usually need to be gradually introduced in order to ensure social acceptance.

3.7 Financial Analysis

Financial analysis is a professional sphere of work and municipalities will require technical expertise to prepare and assess the financial, cash flow and subsidy implications of AWT projects. This section highlights some of the issues that need to be taken into account when financially analysing an AWT project.

Most AWT facilities will require a gate fee to be paid to the operator of the facility in order for the business case to be viable. This gate fee may need to be competitive with the cost of landfill, or the cost of landfill including the calculated environmental and social benefits and externalities. In some cases, an AWT facility may be viable as long as input materials (e.g. green waste or construction and demolition waste) are delivered free of charge to the AWT operator. However, each case is different and needs to be assessed on its merits.

Technology offers for an AWT facility being received from manufacturers, suppliers or sales representatives should be *independently verified* as to their suitability for the applicable situation.

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18 *Republic of South Africa, Department of Environmental Affairs, 'Solid Waste Tariff Setting Guidelines for Local Authorities', May 2012*

3.7.1 Defining key input values to the analysis

The lifetime of the investments and the period for financial analysis need to be defined. The period of analysis is usually 20-30 years or the lifetime of the major asset (e.g. landfill or treatment facility).

The financial analysis uses a set of macro-input indicators and forecasts for key variables. These include forecasts for population growth, waste quantities and composition, interest rates, fuel costs, energy prices, compost prices, refuse-derived fuel (RDF) prices, etc. The financial analysis should usually be carried out in constant (real) prices.

Input data and forecasting needs careful consideration, since slight variations may alter the projected financial outcome. Sensitivity analysis that poses 'what if?' scenarios for waste input rates, costs and revenues is essential to rectify these effects and provides a sound basis for decision-making.

Several of the input indicators are difficult to determine, but the greatest ambiguity usually surrounds the waste quantities and composition. Allocating the budget and taking the time to carry out waste quantity and composition surveys is essential prior to undertaking major AWT investments, especially for those AWT projects that rely on waste input being of a certain calorific (heat) value.

3.7.2 Assessing full cost of treatment options

Future costs need to be estimated with a reasonable degree of confidence.

Capital and investment costs need to be fully considered, and include all costs related to planning, permitting, siting, and construction of the facility. These costs will need to be factored into cash flow calculations as cost of financing (i.e. interest and debt repayment).

Investment costs can include land purchase, site clearance, construction of reception areas and buildings, materials storage areas, mobile plant and vehicles, containers and vessels, mechanical equipment, electrical equipment, pollution control equipment, etc.

For a thorough assessment, the financial outcomes of the project need to be analysed over the lifetime of the investment. The analysis of the BAU scenario should not be limited to the current status and should rather include any changes to the baseline that may be envisaged over time.

It should be borne in mind that most, if not all, AWT facilities have process rejects or by-products that will require landfilling. In some cases, these materials may be hazardous in nature. In all cases, the costs of landfilling these items need to be included in the financial analysis of an AWT project.

3.7.3 Affordability and cost recovery

The challenge of keeping waste management systems affordable and also covering costs is a pressing decision-making issue. Authorities are responsible for ensuring a reliable, quality service that is fully compliant with legal requirements, whilst also ensuring that the costs of, and tariffs for, the services are kept within affordability ranges for the population.

In 2011, the *National Policy for the Provision of Basic Refuse Removal Services to Indigent Households*[19] was tabled, in line with the *Free Basic Services Policy* adopted in 2001.[20]
It aims to provide a basket of free basic services to citizens, including solid waste collection, water, sanitation and electricity.

Under these circumstances, it becomes clear that **achieving full cost recovery** for more advanced treatment options will be challenging. Currently, waste tariffs in many municipalities barely cover collection costs, and do not include costs of disposal.

19 *Republic of South Africa, Department of Environmental Affairs, 'National Policy for the Provision of Basic Refuse Removal Services to Indigent Households', 2011*
20 *Republic of South Africa, 'Free Basic Services Policy', Pretoria: Government Printer, 2001*

The key criterion on which the financial viability of an AWT project must rest, is the comparison of the costs against the cost of landfilling. In addition, the full economic analysis compares the Economic Net Present Value and Economic Internal Rate of Return of the scenarios with and without AWT. The economic indicators together with the financial Net Present Value and Internal Rate of Return indicators serve to assist informed decision-making. Thus, the aim is often to determine the financing gap, and the potential role of grant funds in bridging that gap.

3.7.4 Assessing the non-tariff revenues

Everything but tariff (or tax associated exclusively with the provision of waste management services) is a non-tariff revenue. Revenues from sales of recovered materials or energy are included in this category. Sensitivity analysis to assess the effect of price fluctuations for one or more recovered material, product or energy is important.

There may be extra revenues from the gate fee paid by private users or municipal clients falling outside of the administrative area of the owner of the facility. These should be accounted for as non-tariff revenues.

3.7.5 Establishing revenue requirement

The revenue requirement (or subsidy requirement) is calculated at full cost recovery as follows:

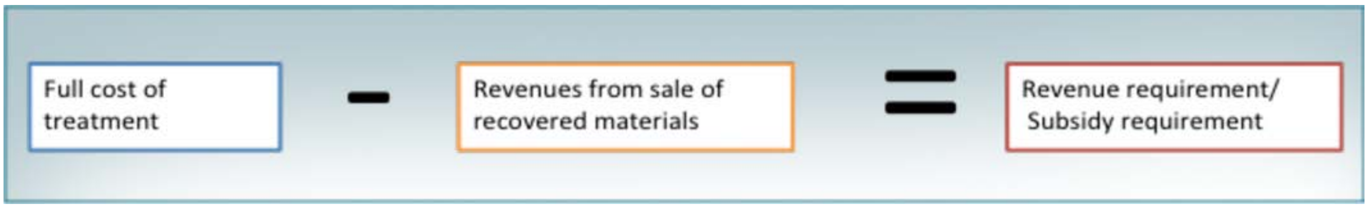


Figure 5: Revenue requirement calculation (ZAR/tonne)

If the revenues from the sale of recovered materials are less than the full cost of treatment, a subsidy or gate fee will be needed to cover the deficit. Where revenues are higher than the treatment costs, a net profit will be generated.

These subsidies or gate fees need to be covered either through budgetary allocations or charged to the end consumer through user charges, tariffs or taxes.

An indicative revenue stream from the users is usually defined based on current practices and a gradual, affordable increase in tariffs. Certain assumptions/decisions need to be made in discussion with stakeholders to establish expected payment rates, level of fees and the rate of yearly increases that may be applied to fees.[21] The assumptions should be clearly stated and sensitivity analysis undertaken, especially on how variations in waste input quantity/quality affects the project viability.

3.7.6 Defining the gate fee

The gate fee at full cost recovery will be the subsidy or revenue requirement.

Figure 6: Gate fee calculation (ZAR/tonne)

21 *Republic of South Africa, Department of Environmental Affairs, 'Solid Waste Tariff Setting Guidelines for Local Authorities', May 2012*

The gate fee or the specific subsidy required will be the single most important indicator for deciding whether or not to invest in a certain technology. For municipal solid waste, regardless of who the operator of the plant is (i.e. whether private or public), a gate fee will need to be paid for every tonne handled.

The information gathering, analysis and interpretation for preparing a business case for the introduction of AWT takes some time. Some of these steps may already be part of the daily financial and operations management of the municipality and information may be readily available regarding the current process flow and financial situation assessment.

The involvement of experts knowledgeable in the different AWT technologies is important in the financial analysis. Expectations and assessment of market demand and policy environment should be well understood. The effort to go through the steps diligently will pay off in decisions that are sustainable and beneficial to the community in the long-term.

3.8 Concluding Remarks

Preparing the business case for investing in AWT has two major parts. The first is the baseline assessment that includes understanding the current process flow, the waste quantities and composition and current costs. The second part includes the financial analysis of the different technical options considered. During the setting of tariffs the double constraint of affordability and cost-recovery requirements need to be considered. The end decision when opting for advanced waste treatment as compared to the business as usual scenario largely depends on the whether the incremental change in the cost to the municipality is acceptable.

Chapter 4

COSTS AND REVENUES OF AWT OPTIONS

4. Costs and Revenues of AWT Options

Key aspects on costs and revenues of AWT options that are generic for all the AWT options is presented in this knowledge product. Collection and transfer also influence the overall cost of the integrated waste management system when an AWT is introduced and a change is made from a linear model to application of a multi-dimensional system.

4.1 Cost Benchmarking

It is challenging to identify meaningful cost benchmarks for implementing AWT in South Africa. Therefore based on a review of international literature, one particular source herein referred to as the *"Pfaff-Simoneit Study"* covers the needs of this KP comprehensively.[22]

The *Pfaff-Simoneit Study* includes estimations of costs for four income categories, including upper middle-income countries (the income category in which South Africa can be placed). Benchmarks for South Africa are comparable to those in upper-middle income countries, but, are adjusted based on the review of South African case and feasibility studies.

The cost benchmarks presented in this KP should be regarded as indicative and not definitive. The purpose of the benchmarks is to aid in the scoping of AWT projects, and to help readers understand the costs (both in terms of magnitude and type) generally associated with different types of AWT facilities.

Cost breakdowns have been presented that show the relative influence of capital and operating costs associated with each technology. In adjusting the international cost benchmarks to South African market conditions, focus has been placed on understanding how the local supply of equipment and spare parts and local maintenance may influence costs, as well as to reflect the costs of labour, fuel and other utilities in the South African context.

4.2 Typical Cost Structure of AWT

AWT technologies present a somewhat similar cost structure in terms of the balance between investment and operational costs, and in terms of equipment required for the actual treatment or pre-processing of waste and operational requirements. Specific cost structures associated with different AWT technology are described, together with case studies from South Africa.

A key component of the methodology used in this KP includes analysing data from feasibility studies developed within the South African context. Although adjustment to costs, expenditure, and revenues to obtain current uniform data does pose a threat.

Considering the earlier-mentioned constraints, unadjusted data has been presented in this knowledge product.

The typical cost structure in the project preparation, investment and operational phase for the AWT technologies is presented in Table 4. The transaction costs are costs that are incurred during preparation and prior to the commencement of the investment phase. If transaction costs are too high, they may impede otherwise viable projects.

22 *Pfaff-Simoneit W., 'Entwicklung eines sektoralen Ansatzes zum Aufbau von nachhaltigen Abfallwirtschaftssystemen in Entwicklungsländern vor dem Hintergrund von Klimawandel und Ressourcenverknappung' [Developing a sectoral approach to establishing sustainable waste management systems in developing countries in the context of climate change and resource scarcity], PhD Thesis, Rostock University, Faculty of Agro-Environmental Sciences, 2012*

Table 4: Transaction cost structure in the project preparation phase

Cost category	Notes
Feasibility study and technical design	5 to 10% of the total investment costs. The most expensive phase is the detailed technical design.
Permitting (including environmental impact assessment (EIA) and technical documentation needed for permitting, site selection and specialist studies)	3 to 5% of the total investment cost, depending on the difficulty of procedures and compliance.
Market research	Regularly part of the feasibility study. This merits special attention. Market research may be omitted at times for waste management tenders by public authorities, but is crucially important for AWT outputs.
Setting up the financing scheme	Often the source of financing is a combination of public and private funds in the case of AWT. Putting together options for the financing scheme becomes part of the feasibility study.
Contracting and negotiations	Since municipal waste is municipally owned, setting up AWTs will almost always involve public tendering procedures. Public procurement (tendering) can be a lengthy and expensive process, as professional advice is likely to be involved. Initiating public private partnerships adds additional complexity to the procedures.
Construction supervision	Along with the construction, contracting a separate construction supervision contract is needed to monitor and control the construction works. This may be tendered and allocated together with the detailed design.

Table 5 and Table 6 provide the typical cost structures for investment and operation respectively. The most important cost categories are listed and may be used as a checklist to verify if all costs were included when considering AWT investments.

Table 5: Typical investment cost structure

Investment phase	Description and notes
Land acquisition	Planning of waste management facilities can be a significant cost. However, industrial land is relatively cheap. The land footprint required for the different facilities is presented in the sub-chapters to follow.
Site infrastructure	• Paved areas, concrete works • Water supply, access to utilities • Effluent disposal/storing facilities • Road infrastructure
Supporting infrastructure	• Buildings • Weighbridges • Offices • Fencing and security systems
Equipment	Equipment needs depend on the type of AWT technology implemented. Typical equipment that will be necessary for most technologies include various vessels, sieves, separators, loaders, conveyors, temperature monitoring and control and in some cases odour control equipment, blowers, fans and filters, etc. Some of the equipment is locally produced and available, whilst other equipment needs to be purchased from outside the country.
Regulatory compliance	Includes all necessary permits and approvals.

Table 6: Typical operation cost structure

Operational phase	Description and notes
• Labour • Fuel • Energy and utilities • Maintenance and repairs • Disposal of rejects • Feedstock costs • Additives and consumables • Overhead (office supply, communication, etc.) • Advertising, promotion, awareness raising • Taxes and insurance • Monitoring and reporting to environmental and public health agencies	Labour costs include normal salaries and wages, bonuses, overtime costs, allowances, fringe benefits and social contributions, etc. Some technologies may have the need for highly specialised personnel; various technologies can include phases/departments that can be either labour intensive or fully mechanised, depending on local factors. Typical labour requirements may include heavy equipment operators, maintenance personnel, instrumentation/computer operators, administrative support and management. Overhead costs and recurring hidden costs are part of operations and often left unaccounted for. This list shows the cost categories and budget lines that belong to operation costs but sometimes get lost in other municipal budget lines. Private operators do not always incur all of these costs. Depending on the service contract between the municipality and operator, these may be with the municipality or the operator[23].

Operation costs are more challenging to estimate than capital costs, but need the same degree of rigour in order to inform decision-making. It is essential to ensure that the chosen technology can be sustained by revenues and gate fees.

4.3 Typical Revenue Structures of AWT

Revenues from AWT have a series of influencing factors, from the types of outputs of different technologies to local policy and market conditions.

The outputs of the AWT technologies described in KP2 and analysed from an economic point of view in this KP include: Compost and compost-like outputs, aggregates, different recyclables, refuse-derived fuel (RDF), biogas/biofuel and energy (heat and/or electricity).

One of the factors that most influences the revenues from AWT is the existence of a market for the outputs and their market prices and fluctuations. Other factors influencing revenues from AWT include: Quality requirements, levels of contamination, additional processing costs for outputs, opportunity for use of by-products (such as residual heat from some AWT options), disposal costs for rejects, distance to market for outputs, the availability of feedstock for technologies and government incentives, as examples.

Some outputs, such as compost of good quality and minimum contamination, can be a turning point in obtaining revenues, as there is a high demand in South Africa for good quality compost for organic crops. Compost and compost-like outputs are a result of composting, anaerobic digestion or MBTs. However, good quality compost is much more likely to be obtained (and at a lower overall cost) from simple composting of source-segregated green garden waste than from other technologies. This is a clear example of how the market conditions may deem a type of AWT as being ‘promising’ over another.

Carbon financing is widely used internationally and is linked to the greenhouse gas (GHG) emissions reduction impact of the investments. Financing is allocated when the GHG emissions reductions are achieved, monitored and verified. South Africa has benefited from carbon financing through project-based initiatives and a Nationally Appropriate Mitigation Action, which may contribute to revenues.

Specific revenue-influencing factors for each type of AWT are provided under the technology subsection of this KP (Chapters 5-7).

23 *Technology Fact Sheet, In-Vessel Composting of Biosolids, EPA 832-F-00-061; Costs for municipal waste management in the EU, Final report to Directorate General Environment, European Commission, Eunomia Research & Consulting Ltd. EPA US, Biosolids*

4.4 Collection and Transfer

Advanced waste treatment technologies have specific feedstock requirements in terms of quantity and quality. As shown in Figure 4: An illustration of AWT options, costs and non – tariff revenues per waste stream and collection types, for example, recycling and composting is best done from source-segregated waste streams, thus separate collection systems need to be in place. For some thermal treatment options, mixed waste is acceptable as feedstock but where economies of scale are required, regionalisation of waste collection and the introduction of transfer stations may be required.

> **Case Study 1: Source segregation and separate collection of recyclables adds costs to the collection system in Cape Town**
>
> The City of Cape Town has drop-off centres that divert recyclables. During 2012, 2 000 t of recyclables were diverted through these centres. The costs of developing new drop-off centres has been estimated at approximately 5 million ZAR as investment costs, and approximately 8 million ZAR per year for operational costs depending on the size of the facility. The example highlights that setting up collection systems for source-separated recyclables will require investment.

The opportunity for collecting dry recyclables separated at source, was studied both in formal and informal settlements in Cape Town and piloted in the city centre. Studies indicated that this type of collection is not easy to implement as a stand alone service, capture rates are low, and the waste streams in the informal settlements do not contain such high amounts of recyclables, and the cost of the collection is high. The conclusion of the study was that outsourcing collection of source-separated recyclables as a single activity is not sustainable as it increases the additional costs to the City for collection significantly, and, does not have a major diversion impact due to the low capture rates. This also may be the reason why Cape Town decided to pilot outsourcing separate collection together with operation of an MRF at Kraaifontein. Other municipalities could also explore such options for implementation, given cost implications.

The Council for Scientific and Industrial Research (CSIR) study on the cost of collection for source-separated materials provides an in-depth study that considers different solutions for collection, taking into account current trucking capacities and actual distances. The preliminary results of the study indicated that the cost of collecting source-separated materials is cost efficient when it is organised through small and medium-sized enterprises, using labour intensive methods[24]. The initial set of results were favourable and added to the financial attractiveness of AWT options. The findings of the study are expected to assist in identifying solutions that are sustainable and the type of conditions needed in place for introducing the collection of source separated waste.

The costs of both direct hauling of waste to landfill and hauling to a transfer station should be compared in determining the feasibility. A site-specific calculation has to be conducted to establish the minimum distance beyond which introducing a transfer station is cost-effective for certain planned/estimated waste quantities. Therefore, the cost of the transfer station, the direct haul payload, the transfer haul payload and the trucking costs need to be known.

Once these values are known, the following formulas can be used to roughly calculate cost at different distances:

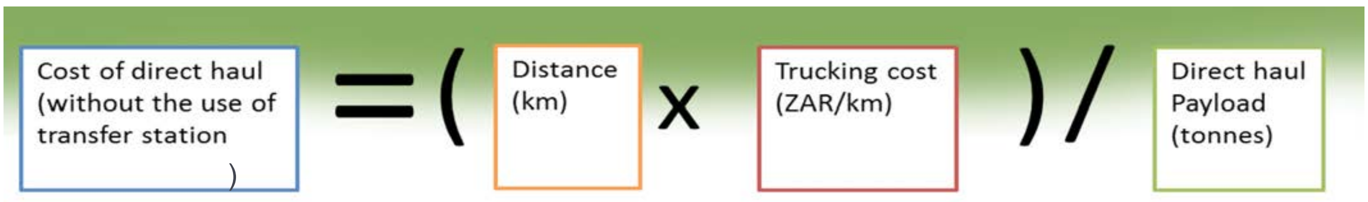


Figure 7: Calculating cost of direct haul

24 *Personal communication between authors and CSIR*

As the calculation in Figure 8 shows, the costs (ZAR/t) of hauling waste to landfill depends on the total distance, costs of transport, and the capacity of the trucks.

Cost of transfer haul = [(Distance (km) x Trucking cost (ZAR/km))/ Transfer haul Payload (tonnes)]+ Transfer station cost (ZAR/t)

Figure 8: Calculating cost of transfer

Once the costs of direct haul and potential economic use of a transfer station are calculated, these can be plotted on a graph to see where the break-even point is and thus what the lowest cost option would be depending on the distances involved. An example is shown in Figure 9.

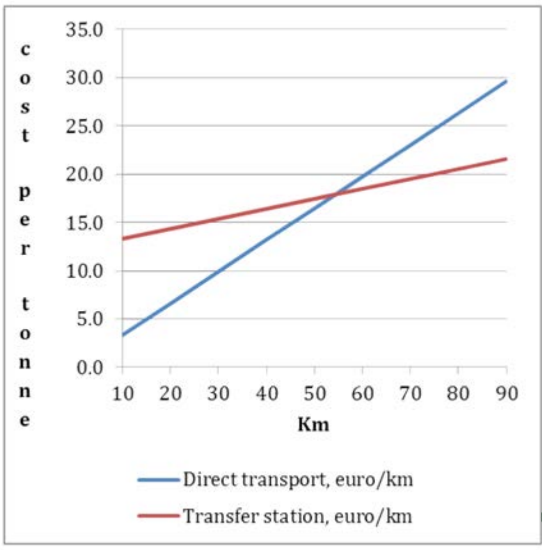


Figure 9: Example break-even point for the necessity of transfer station[25]

Figure 9 illustrates that building a transfer station may be financially justified if the haulage distance is longer than 55 kilometres for the specific case studied and for the amount of waste to be handled in the specific geographical project boundary. In other instances, this may be as low as 15-20 km, depending on the cost efficiency of the collection and transport equipment and the specific costs of the transfer station.

25 Courtesy of RWA Group, 2014 South Region of the Republic of Moldova

Case Study 2: Analysis of the feasibility of a transfer station at Linbro Park, Johannesburg

Table 7: Cost comparison among transfer station technologies[26]

	Unit	Static compactor	Open top	Baling
Specific investment cost	ZAR/tonne	561	480	411
Specific transport cost	ZAR/tonne	86	95	64
Specific Operation & Maintenance cost	ZAR/tonne	87	100	98
Total	**ZAR/tonne**	**734**	**675**	**573**

The conclusion on the preferred method for transfer needs to take into account a variety of significant factors, such as operation, maintenance and capital costs of each option. Also, the impact that the chosen technology may have on landfilling, and the sensitivity of the technology to economies of scale are amongst other considerations. Table 8 summarises the advantages and disadvantages of the solutions considered for the Linbro Park feasibility study.

Table 8. Advantages and disadvantages of the static compactors, open top containers and baling[27]

Technology	Advantages	Disadvantages
Static compators	Lowest operating cost for large quantities of waste Lowest total life cost for haul distances less than 40 km	Highest capital cost Containers need to be replaced Control of payload can be difficult
Open top containers	Rather low operating cost in case low quantities of waste are handled Low capital cost Well suited for smaller volumes No impact on operation of landfill	High operating cost in case large quantity is handled, due to lower payloads Highest total life cost Containers need to be replaced more regularly than reinforced containers More regular repairs required on containers
Baling	Low capital cost Optimised payload Lowest total life cost for haul distances greater than 40 km	High operating cost Changes the way the landfill is operated Difficult to use on existing landfill (i.e. requires dedicated cells) Leachate generation quantities at landfill are unknown; leachate needs to be treated Impact on gas generation likely to be negative

The feasibility study concluded that the further away the destination landfill, the greater the financial savings and shorter the payback period of the capital investment for the Linbro Park regional transfer station. The annual savings on transport costs from the initiative was projected between 30 million ZAR and 60 million ZAR depending on the location of the final disposal landfill, implying a saving of between 170 to 340 ZAR per tonne of waste.

The considerations related to changes in collection and transfer of waste and the cost of these elements are often coupled with the introduction of AWT in the process flow. Cost changes for source-separated collection of waste may not be significant in South Africa and longer hauling for large capacity plants may be optimised through transfer stations.

26 *Calculated from Jeffares & Green Pty (Ltd), 'The Feasibility Study, Project Appraisal and Definition and Preliminary Design of a Waste Transfer Station and Materials Recovery Facility at Linbro Landfill site', for Pikitup Johannesburg Ltd., Contract No. PR114/2011, July 2011 (page 107)*

27 *Idem, page 112*

4.5 Cost Benchmarks for AWT Technologies

Benchmarking costs and revenues can be helpful in assessing AWT projects and guiding the business scoping process. In general, it can be assumed that AWT facilities can be implemented in South Africa at lower costs to those in Europe and other industrialised countries. However the extent to which this is the case depends on the type of technology.

Table 9 summarises expected cost ranges for the AWT options. The information provides an indication for the budgeting requirements of proposed AWT options, and may be helpful in benchmarking tenders and proposals. **The table should, however, be interpreted as indicative rather than definitive.** The costs presented take into account the existing case study experiences, levels of income, wages, availability of equipment, and options for maintenance and repair locally or abroad for the various necessary equipment.

Table 9: Summary of expected cost ranges for treatment options in short, medium and long term

Technology	Range of full specific cost ZAR/t	Investment cost as estimated % of full cost	O&M costs as estimated % of full cost
Business as usual			
Landfilling	200 – 400	67[28]	33
Promising technologies – short-term			
Windrow composting	300 – 400	40	60
Construction and demolition waste recycling	<300	50	50
Materials recovery facilities	300 – 400	50	50
Potential technologies – medium-term			
Simple mechanical biological treatment (MBT)	300 – 500	50	50
MBT with intensive decomposition and fermentation	700 – 900	60	40
Anaerobic digestion	700 – 800	50	50
In-vessel composting	>600	50	50
Potential technologies – long-term			
Incineration with energy recovery	1,200 – 1,500	62	38
Mechanical and heat treatment	600 – 700	55	45
Advanced thermal treatment - gasification	1,300 – 1,700	62	38
Advanced thermal treatment - plasma gasification and pyrolysis	1,300 – 1,700	62	38

Table 9 summarises the benchmarks that are likely to be expected for the different technologies in South Africa. The promising technologies, the potential technologies – medium-and long-term will be discussed each in turn in Chapters 5, 6 and 7. The detailed description will give information on typical capacity, labour intensity, specific costs, cost breakdown and factors influencing revenue for each technology in turn.

Each technology was individually reviewed within a global context and adjusted to the South African situations. In the frame of a Section 78 Assessment Report for Cape Town a range of AWT technologies for the geographic scope of the city were analysed and the results are presented in Table 10.

28 This includes all capital costs of phased site development, closure and aftercare

Table 10: Findings of the MSA Section 78 Assessment Report for the City of Cape Town[29]

▪ Direct and indirect costs per tonne diverted are lowest for the C&D/builders' rubble, net savings of 50 – 75 ZAR/tonne can even be achieved, followed by;
▪ Organic waste management at an additional cost 750 – 960 ZAR/tonne;
▪ Waste recovery 1,380 – 1,470 ZAR/tonne;
▪ Co-mingled waste treatment 1,350 – 1,660 ZAR/tonne,
▪ The most expensive treatment, the household hazardous waste, 2,900 – 3,500 ZAR/tonne.

Table 10 reflects on cost ranges for similar AWTs as those included in the scope of KP4. The lowest cost options include builders rubble (construction and demolition waste) treatment and the treatment of the organic fraction of waste. These are adopted in KP4 as 'Promising technologies for the short-term'. Co-mingled waste treatment (MRF, MBT) are mid-range in terms of cost and may be attractive depending on market conditions and enabling environment are included in this KP4 as 'Potential technologies for the medium-term'. Other, thermal, waste treatment options such as incineration with energy recovery, mechanical heat treatment, pyrolysis and gasification are classified as 'Potential technologies for the long-term'.

The conclusions of the MSA Section 78 Assessment Report for the City of Cape Town presented in Table 10 are similar in terms of cost ranges to the ranges presented in KP4 (Table 9). The findings reinforce each other.

4.6 Concluding Remarks

The chapter has introduced a common language for investment costs, operation costs and revenues in waste management. Some of the costs described are hidden in different departments of a municipality and are not immediately obvious but are going to be important to consider once a service is outsourced or new investments are made. The cost structures presented in this chapter can be followed as a checklist for benchmarking purposes.

The revenues for AWT are diverse, and depend on the specific outputs. Most AWT facilities will need to complement revenue sources from economic incentives, grant financing, public financing or gate fees. Carbon financing is a revenue source that is gaining importance.

Whenever a new technology is introduced, the need to adapt the collection system should also be reviewed at. Organising collection of source-separated materials and/or introducing transfer stations may be required depending on the technology selected.

The cost benchmarks presented are a summary and a guide to reading the following chapters that provides details on costs and revenues of each subgroup of technologies; Promising technologies – short term (*Chapter 5*), Potential technologies – medium-term (Chapter 6) and Potential technologies – long-term (Chapter 7).

29 *Akhile Consortium, MSA Section 78(3) to Assess Alternative Service Delivery Options, RFP No. 554C/2008/09, Consolidated Report, Solid Waste Management Department, Cape Town Municipality, May 2011, Executive Summary*

Chapter 5

PROMOTING TECHNOLOGIES - SHORT TERM

5. Promising Technologies – Short Term

5.1 Introduction

Chapter 5 presents AWT technologies that are assesed as being applicable in the short-term. These technologies have already been identified in KP2 as suitable short-term solutions, and on further review still remain the most price competitive and comparable cost to the business as usual (i.e. BAU landfill) scenario.

This section presents a specific cost structure for investment and operation, the potential revenues, and compares these to net cost of indicative baseline scenarios.

The cost/tonne charts are presented in each sub-section. The costs for a given technology vary depending on the local situation, labour costs, size of the facilities and other related factors. The costs information presented in this section should therefore be interpreted as indicative of the magnitude of costs that can be expected when implementing a certain technology, but should not be assumed as definitive estimates.

Promising technologies in the short-term are those technologies that focus on treating specific waste streams. There are incentives in place in South Africa for a select number of promising technologies. The promising AWT technology options include windrow composting, recycling of construction and demolition (C&D) waste (builders' rubble) and material recovery facility as (MRF) for recyclable fractions of MSW. For a detailed description of each technology, please refer to *Knowledge Product 2*: *Appropriate Technology for Advanced Waste Treatment – Guideline.*

5.2 Windrow Composting

5.2.1 Scale Factors

Composting facilities are generally small scale, and therefore have only limited overhead and maintenance costs. For a facility of approximately 8,000 tonnes per year, a staff of approximately six workers would be sufficient. The situation will vary depending on the local context and level of technology. Key characteristics of windrow composting facilities are presented in Table 11.

Table 11: Key characteristics of windrow composting

Characteristic	Description
Typical capacity	5k – 500k tonnes per annum
Indicative capital cost	A range of 6 to 10 m ZAR for small scale, simple windrow systems
Human resource requirement	Mostly unskilled workers, drivers and mechanics

5.2.2 Cost benchmarks

Specific costs for windrow composting, besides the typical costs mentioned under Section 4.2 (i.e. land acquisition, engineering works and regulatory compliance), arise from the type of equipment used for this AWT technology. Equipment may include: tractors, compost turners, excavators, shredders, sieves, loaders and dumper trucks.

Most of the equipment required for composting is available on the South African market. Only compost turners and chippers need to be procured internationally. Electricity/energy costs will be minimal since the composting is undertaken in open air, and no energy is used in the process itself.

A comparison of indicative costs for windrow composting in South Africa and industrialised countries is illustrated in Figure 10.

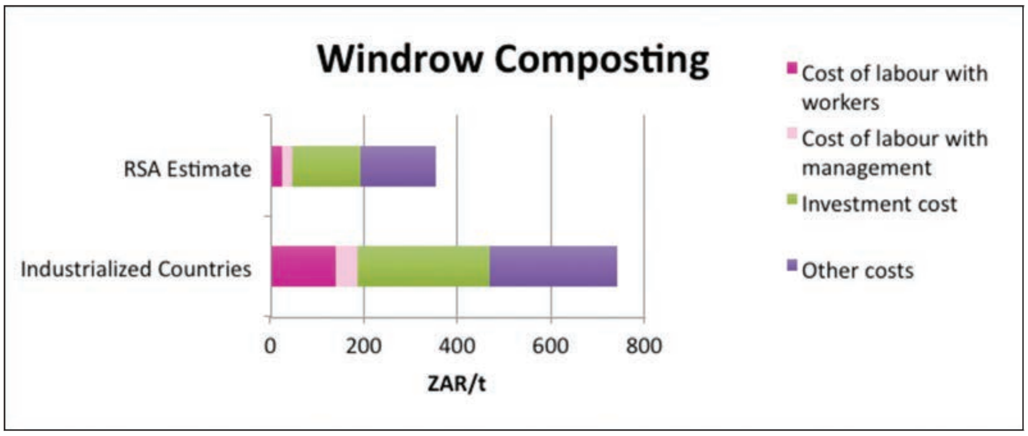


Figure 10: Full cost breakdown for windrow composting[30]

Windrow composting costs are estimated to be in a range of between 300 to 400 ZAR per tonne. Composting is not highly mechanised and not highly labour intensive; as such, the operational costs are relatively low. The cost of repair and maintenance may be relatively high, especially where windrow turners and chippers have been purchased from abroad. Table 12 presents general characteristics of open windrow composting and the main factors influencing revenue.

Table 12: Factors influencing revenues – windrow composting

Technology Heading	Outline Description	Factors Influencing Revenue
Open windrow composting	Garden waste generally has lower moisture content and fewer potentially hazardous elements than mixed organic waste and is therefore best suited to aerobic composting processes.	Revenue/price of compost product in market Distance to outlet for compost Quality requirements/bagging of compost Quantity of contaminants and subsequent screening costs Disposal costs of contaminants

Gate fees for composting will vary depending on the local market demand, logistics and costs for the collection and delivery of source-aggregated green wastes to the facility, and available subsidies.

According to published literature from the UK (hereafter referred to as the *"2014 UK WRAP Report")*[31], composting gate fees in the UK are approximately 24 UK pounds per tonne (430 ZAR per tonne equivalent[32]). In comparison, the approach with the City of Cape Town is somewhat different. The City of Cape Town has contracted collection, chipping and composting of green garden waste and pays a fee to private contractors for the green waste handling service. The fee paid ranges between 500 ZAR to 1,300 ZAR per tonne (100 to 255 ZAR per cubic metre) of green waste handled depending on the distance from the drop-off centre to the composting plant. In both South Africa and the UK, composting requires a gate fee that reflects the net costs of composting after revenues from sale of compost.

The market in South Africa for compost began in the 1990s when the use of organic compost as fertiliser became a criterion for being able to sell table grapes as organic produce. To date, the largest composter in the country is a farmer who started composting to fertilise his own vineyards.

30 Cost information for industrialized countries derived from, and cost ranges for South Africa adapted from, Pfaff-Simoneit, 2013
31 WRAP (Waste Resource Action Programme), "Gates Fees Report", UK, 2014
32 The exchange rate used throughout this document is 1 EUR = 12.97 ZAR (European Central Bank exchange rate April 20th, 2015)

Case Study 3: Reliance Composting Facility in Cape Town

A farmer from the Cape Boland region who needed organic fertiliser for his vineyard started the company Reliance Compost as a side activity in the 1990s. The business gradually grew and today is a multifaceted enterprise. The owner has considered differentiating in to other secondary materials and specific waste stream treatment processes.

The waste treatment activities: The City of Cape Town has 25 drop-off centres in the metropolitan area that receive green garden waste. Reliance Compost Ltd. is contracted to operate 10 of these centres, of which eight are equipped with chippers. The company collects chips and transports the waste to a central composting plant.

At the composting plant, windrow composting is carried out using the Austrian Controlled Compact Microbial method. Compost maturation takes six to eight weeks and does not require the use of additives, with the exception of water and clay.

Input capacity and quality: Approximately 90% of green garden waste generated by households and commercial units in the City of Cape Town is directed to the composting facility. The capacity of the facility has been doubled in recent times, from approximately 500,000 to 1 million cubic metres per annum.

Diversion from the landfill: The volume of green waste diverted from landfill is calculated prior to being chipped; whilst the throughput at the compost facility refers to chipped material (chipping roughly halves the volume of the green waste). The volume of landfill diversion is approximately 2 million cubic meters of green material per annum. Since 2008, approximately 13 million cubic meters of green waste have been diverted from landfill.

Area of land utilised for the licensed composting facility: Approximately 14 ha in total, inclusive of the recent extension that effectively doubled the treatment capacity.

Equipment used: Shredders/chippers and compost turners are imported, whilst trucks, loaders, and other vehicles are sourced locally.

- 35 x trucks, loaders and others, purchased locally;
- turners and chippers are procured from overseas; and
- a workshop for repair and maintenance.

Human resources and labour intensity: There are approximately 220 workers at Reliance Compost, 170 of them at the composting site. The company also has its own in-house maintenance team.

Market for compost: The most important buyers of compost are landscapers and landscape architects. The second most important market is agriculture. 80% of the revenue is generated *via* the price per cubic metre of green waste handled, and paid by the municipality, whilst 20% is generated from the sale of compost and related products. The contract with the City is for a period of three years.

Investment and operation costs: An indicative full specific cost was estimated with an assumption of a 10% profit margin in the range of 800 to 1,000 ZAR/t, inclusive of cost of collection. Investment and operation cost information are captured in the Table 13 for all company activities.

Table 13: Investment and operation costs information for composting case study

Investment cost information	ZAR
Cost of equipment	90 million
Operation costs information	ZAR/annum
Cost of collection	18 million
Cost of composting	5 million
Other operation costs	4 million
Total operation cost	**27 million**

Certification and GHG reduction: The company's organic status is certified annually by an independent certification body. Reliance is also Clean Development Mechanism (CDM)-registered since 2008 (i.e. Reliance Compost is eligible to obtain credits for CO_2 reduction under the (CDM) of the Kyoto Protocol); revenue has been dropping in time, as the international market for certified CDM credits has been reduced substantively the company's revenue from CO_2 credits has subsequently dropped to approximately 1 – 2 million ZAR/year.

The Reliance case study illustrates that the market demand in agriculture for organic compost has driven the implementation of composting in Cape Town. The municipality is reallocating saved costs from landfilling to paying for composting. It is unclear from the case study data whether the overall cost to the municipality is higher than business as usual, but benchmark data suggests that composting and landfilling costs are about the same (Table 9). Therefore as soon as there is a market demand for compost, green waste composting has a high probability of being a promising technology for the short-term.

5.3 Construction and demolition waste recycling

5.3.1 Scale factors

In 2011, construction and demolition (C&D) waste amounted to approximately 4.7 million tonnes in South Africa. Approximately 10-15% of the C&D waste can be utilised as coverage material for landfills and could be used for layering works in the construction of new landfill cells; the remainder 90% could be diverted from landfilling by processing it in material recovery facilities (MRF). Currently, 16% of the total quantity of C&D waste is recycled[33].

Table 14 quantifies some of the typical characteristics of such a facility.

Table 14: Key characteristics of construction and demolition waste recycling

Characteristic	Description
Typical capacity	50 k– 500 k tonnes per annum
Indicative capital cost	c. 25-35 million ZAR for a 100 ktpa C&D recycling facility
Human resource requirement	Low and mostly unskilled workers, manual sorters

As can be seen from Table 14, C&D waste is feasible at large scale, the required investments are relatively low and operating the equipment is rather straightforward, low and unskilled workers being required.

33 *Department of Environmental Affairs, South Africa, National Waste Information Baseline Report, pp 15, November 2012*

5.3.2 Cost benchmarks

The C&D waste, or as it is often called 'builders' rubble', can be processed in a MRF type facility by crushing and sorting operations. The resulting crushed aggregates can be used in concrete, as backfill, for land reclamation, and in some instances for road construction. Metals separated in the sorting phase, such as reinforced steel, can be recycled at market price. Other materials separated at the sorting phase, such as wood, paper, cardboard or plastics can be processed at energy recovery plants or other specific facilities.

The C&D waste recycling plants take up a relatively small area and personnel requirements include a plant operator, drivers and labourers. The diversion from landfill for this type of waste in the City of Johannesburg is estimated at 6.5%. For Cape Town the diversion from landfill can be as much as 50% to 60% due to the well-developed rubble/ builders' waste recycling industries being operated by private companies. The technology is well-proven and already applied in South Africa.

The C&D waste has various compositions depending on the source of the waste. Stream management is often lacking and mixed, contaminated, streams are often landfilled. Charging higher gate fees for contaminated builders' rubble is a simple mechanism for increasing the landfill diversion rate.

The C&D waste processing facilities need to have separate storage areas and processing equipment for the various types of waste received, due to their different structure and particle size: waste from road construction/demolition, building construction/demolition, land reclamation, mixed composition waste, materials with high non-mineral content.

Key/primary equipment required in C&D waste processing facilities include waste crushing and sorting equipment such as: excavators for separating large pieces of material, hydraulic hammers for crushing large pieces of materials, ball mill crushers with magnetic separators, a variety sieves for sorting different particle sizes, feed-in equipment and containers for sorted materials.

Maintenance and repair is one of the most important operation costs. Equipment used in the crushing and sorting operations is subject to a high degree of wear and tear. Other significant operation costs for C&D processing facilities include electricity, fuel, labour and the control measures for noise and air pollution. The design of the installation and adjoining spaces should prevent contamination of separated fractions, thus ensuring the quality of output is maintained.

Economies of scale can be achieved in C&D waste recycling facilities in terms of full cost/tonne, as depicted in Figure 11: Economies of scale in recycling facilities for C&D waste34, implying that the larger the capacity of the construction and demolition waste facility, the smaller the unit operation costs.

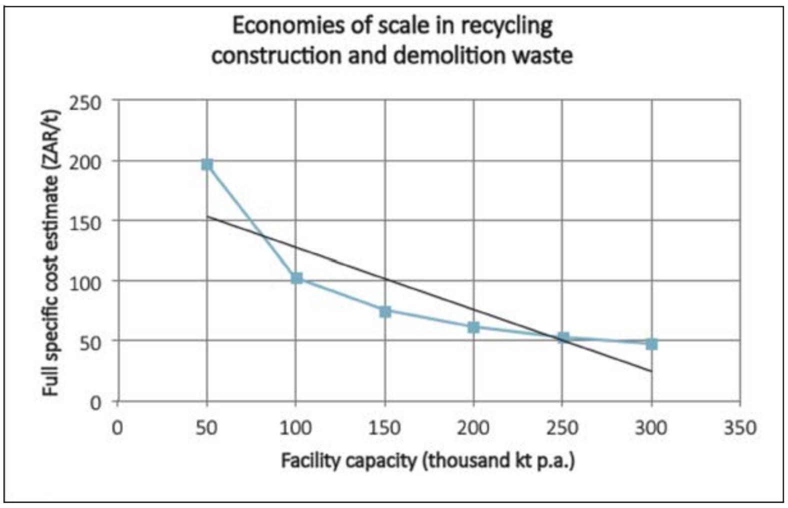


Figure 11: Economies of scale in recycling facilities for C&D waste[34]

Several factors contribute to the success of a C&D waste processing facility, including local market conditions and an enabling policy environment. Measures that promote the recycling of C&D waste in European countries include banning C&D waste from landfill or setting high landfill gate fees for this type of waste (higher than the gate fees of C&D waste processing facilities). Other instruments include taxes on use of virgin aggregates in construction materials, so that construction materials with recycled content have lower market prices than virgin materials.

34 *Brantner GmbH, Feasibility study for Inert Waste Recycling facility, 2008*

As noted from the economic analysis of a C&D recycling facility project from Portugal presented below, revenues from recycled materials need to be supplemented by gate fees in order to have a viable business case for C&D waste processing facilities.

Case study 4: Construction and demolition waste processing facility project in Amadora, Portugal – an economic analysis[35]

The project of the Construction and demolition waste processing facility in Amadora, Portugal is intended to serve Lisbon and its outskirts, a densely populated area. As Portugal has no regulatory or economic instruments for recycling Construction and demolition waste, the economic analysis of this intended project provides a clear view of the economic viability and environmental benefits of the Construction and demolition recycling plant.

Waste treatment activities: Highly mechanised facility, capable of receiving a complete mixture of Construction and demolition waste and separating all the main valuable/marketable materials and rejecting only hazardous materials and wet sludge.

Input capacity and quality: 840,000 tonnes per year input capacity. The intended plant is pre-set for two basic operation modes: when Construction and demolition waste arrives mixed (considered to be the case in approximately 70% of time), and when separate mineral aggregate (ceramic, concrete, rock) is a separate input (approximately 30% of time).

Gate fees: The gate fees taken in consideration for the economic analysis are based on average gate fees charged by Construction and demolition waste recycling companies in the area and amount to 48 EUR/tonne (620 ZAR equivalent) for mixed waste and 8/EUR tonne (100 ZAR equivalent) for source separated material.

Land take of the Construction and demolition waste processing plant: 27,500 m^2.

Equipment: The necessary equipment for the operation of the facility includes weighing devices, excavator, crusher, vibrating feeder, magnet, eddy current generator, vibrating screens and air sifters, horizontal screens, spirals and conveyors. The average service life of the equipment ranges between six and 30 years.

Human resources and labour intensity: Personnel required for the Construction and demolition waste recycling facility include management staff, supervisor, excavator operator and manual sorting workers. 10 un-skilled workers are needed for manual separation. This amounts to 100,000 EUR/year (1.3 mil ZAR equivalent) in labour cost, representing approximately 1.5% of total annual costs.

Market for outputs: The marketable outputs consist of different recyclables, ceramic aggregates and concrete aggregates. Concrete and ceramic aggregates are used in the cement manufacturing industry, as road building base or as fill in material for foundation pits and slab bases in the construction industry, depending on their characteristics.

Investment and operation costs: Investment cost for the 840k tonnes per annum facility is estimated to 4.7 million EUR (approximately 61 million ZAR equivalent).

The structure and percentage of the total for the full specific operation costs of the facility are provided in Table 15 (figures rounded).

35 *André Coelho, Jorge de Brito, Economic viability analysis of a construction and demolition waste recycling plant in Portugal - Part I: Location, materials, technology and economic analysis, Journal of Cleaner Production. 01/2013; 39:338-352. DOI: 10.1016/j.jclepro.2012.08.024*

Table 15: Operation cost structure for a 840 ktpa Construction and demolition waste processing facility in Portugal

Item	% of total cost
Energy, maintenance and labour	4
Transportation of reject materials to landfill or treatment facility	9
Gate fee paid for rejected materials to landfill or treatment facility*	80
Other operational costs	7

*Landfilling gate fee for hazardous or non-treatable materials ranging from 90 to 150 EUR EUR/tonne (1,150 – 2,000 ZAR equivalent).

Specific full cost: The specific full cost per tonne of waste handled is approximately 20 EUR (260 ZAR equivalent).

Conclusion on Feasibility: The operator of the facility is estimated to be able to make a profit margin of approximately 50% with revenues from sales and the gate fee. It should be noted that the gate fee represents 86% of revenues, that means that sales of output products alone is under no circumstances sufficient for a business case for C&D recycling for this facility.

5.3.3 Revenues and gate fees

The general characteristics and main factors influencing revenue for the material recovery of C&D waste are presented in Table 16.

Table 16: Factors influencing revenues – material recovery for C&D waste

Technology Heading	Outline Description	Factors Influencing Revenue
Material recovery for C&D waste	Revenues generated from the sales of mineral aggregates crushed and sorted by particle size and if appropriate by type (i.e. asphalt, concrete, bricks, roof tiles, etc.) and other recovered material (scrap metal, wood, paper and cardboard, plastic, etc.) that can be either recycled or used for energy recovery.	Amount of contamination in recyclate Additional processing costs associated with contaminate Disposal costs for reject material Composition of recyclate Market value of recyclate Distance to market for recyclables Ratio of technology to manual separation

Gate fees for Construction and demolition waste recycling facilities depend on the market for outputs of these facilities and on the type and characteristics of waste accepted. In general, the factors influencing revenues will also influence gate fees.

Case study 5: RamBrick, an innovative recycling initiative for builder's rubble by Use-It

Use-It, a non-profit company based within the eThekwini Metropolitan Municipality (KwaZulu-Natal), produces compressed earth blocks out of recycled builders rubble and soil, called RamBricks. The mission of the company is to offer a four-in-one solution contributing to resolving the problem of landfilling construction and demolition waste and the need for housing, while creating jobs and combating climate change.

In 2013/2014 this project created 84 direct jobs, and 68 indirect jobs, and has saved eThekwini the equivalent of 3.6 million ZAR through diversion of C&D waste from landfill.

Input capacity and quality: The building bricks are manufactured from 95% recycled materials: waste soil, recycled builders' rubble and 5% cement stabilising agent.

Characteristics of outputs: While similar to conventional building materials in appearance, RamBricks are 10 - 43 % cheaper than conventional building materials and offer superior thermal performance and compressive strength[36].

Investment and operation costs: The RamBrick system can be replicated at an investment cost of 540k ZAR for an 1,800 bricks per day capacity or 4.2 million ZAR for a 5,000 brick/day system. This translates into 20 tons/day of waste soil and rubble diverted from landfill for the small scale system and 58 tons/day for the large scale system. Subsequent cost savings from not paying landfill gate fees (estimated at 420 ZAR/tonne for Construction and demolition waste) are 2.2 million ZAR/year for the small scale system and 6.4 million ZAR for the large scale system.

Labour intensity: The operation of the equipment requires eight employees for the small scale system and 11 employees for the larger scale system.

Other costs: Costs of licensing of the RamBrick system include a 3% royalty fee due on revenue, a once-off fee of 65,000 ZAR for training and know-how transfer and once-off handling fee of 2,000 ZAR for procuring the equipment.

The Use-It model presented in the case study, is a successful example of Construction and demolition waste recycling in South Africa. The success of the business model is dependent on the mobile characteristics of the waste processing installation, as transporting the waste soil and builders' rubble to the processing facility is not factored into the operational cost calculations.

5.4 Materials Recovery Facilities (MRF)

5.4.1 Scale factors

The scale of MRF facilities for municipal solid waste depends on the type and volume of processed materials, the collection practices and market for output materials. Labour needs depend on the type of technology chosen. The sorting stage of the MRF process can be either labour intense (with mostly unskilled workers) or automated. The key characteristics of MRFs are presented in Table 17.

Table 17: Key characteristics of clean and dirty MRFs

Characteristic	Description
Typical capacity	1k – 500k tonnes per annum for clean MRF 10k – 500k tonnes per annum for dirty MRF
Indicative capital cost	c. 45 m – 80 m ZAR for a 25 ktpa clean MRF c. 60 m – 110 m ZAR for a 50 ktpa dirty MRF
Human resource requirement	Low and mostly unskilled workers, manual sorters. For example, for a semi-automated MRF processing 50t/day of waste 120 workers are needed[37].

36 *Chris Whyte, Owner of Use-It, Personal communication and RamBrick Business Prospectus, March 2016*
37 *Kraaifontein MRF*

The use of labour-intensive processes with manual sorting is preferred when high quality output is important. Although equipment is able to distinguish between most types of material, experienced personnel are more effective at extracting materials from the waste flow. This has been the case even in highly automated MRFs, resorting to manual picking for the recovery of large objects or non-ferrous metals, such as copper.

Manual sorters in RSA have been found to process 200 to 250 kg of co-mingled recyclables/day, therefore, a 100 tonnes/day facility would require 400 to 500 sorters. An approach adopted by the City of Cape Town is to achieve a balance between mechanical and manual sorting where large bulk throughput is involved.

5.4.2 Cost benchmarks

The choice of technology, the degree of process control and subsequently the investment costs largely depend on what materials are targeted to be recycled and the volume of materials captured, processed and sold. The degree to which materials are co-mingled, collection practices, and market demand for output materials affect investment levels.

Knowledge on the composition and tonnage of residential and commercial and industrial waste should serve as input data in the design of an MRF. Waste audits are recommended to decide if a single stream, dual stream or mixed waste MRF is the most suitable type of facility [38].

The success of MRFs depends on the degree of control regarding waste inputs. Changes in waste feed, for example switching from clean MRF, to dirty MRF, can affect the integrity of the machinery as well as the quality of outputs and subsequently their market value.

An important feature influencing the cost/tonne of waste processed is the flexibility of the facility in terms of output. The fluctuation in recovered material prices determines the need for the degree of separation of materials. For example, if the price of paper rises, then the effort of separating it from cardboard may prove profitable.

Cost-recovery calculations for each material should be performed to ensure that each output generates positive revenue[39]. The MRF, should be equipped based on the available collection practices in the area and the demand in the market for MRF outputs.

Specific equipment in an MRF may include: feed, transfer, sorting and discharge conveyors. This equipment helps to move the waste automatically from the input to the output point of the facility. Other equipment that are required also include: screens, magnetic separators, inclined disk screens to separate fibre from containers, polishing screen and bag splitters. Certain equipment needs to be imported and would also require spare parts from abroad, which may add significant cost and would have to be factored in to ongoing operation costs.

It is possible to increase the level of mechanisation through using drum separators, trommels and/or vibrating screens to separate recyclables from MSW, air classifiers, eddy currents, optical sorters, glass clean-up systems and equipment to prepare the materials for the market (e.g. balers, glass crushers, can flatteners and densifiers, shredders and granulators).

Tendering Considerations:

- Decide on operator model
- Research composition an tonnage of waste streams
- Take into account current collection practices for the design phase
- Estimate material recovery rates for different types of materials

The full cost of building and operating a MRF is estimated to be in the range of 300 to 400 ZAR per tonne. The breakdown of specific costs estimated for MRFs in RSA and industrialised countries is depicted in Figure 12. The feasibility of MRF also depends on the cost of collection of source separated materials, which may be more expensive than collecting co-mingled waste. Labour intensity of both dirty and clean MRF varies across specific cases.

38 *WRAP (Waste and Resource Action Programme), 'MRF Costing model', UK, 2006*
39 *WRAP (Waste and Resource Action Programme), 'MRF Contracts Guidance: Final Report', UK, May 2008*

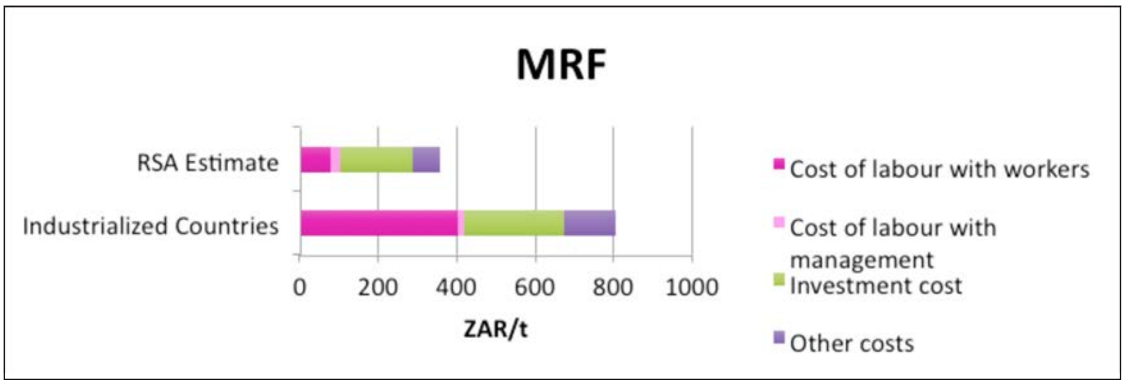


Figure 12: Full specific cost breakdown for Material Recovery Facilities

5.4.3 Revenues and gate fees

Table 18 describes the particularities of clean and dirty MRFs, as well as the factors that influence the revenue of each of the two technologies.

Table 18: Factors influencing revenues - MRFs

Technology Heading	Outline Description	Factors Influencing Revenue
Clean MRF	Mixed dry recyclables are separated into fractions by a mechanical and manual segregation techniques and conveyors. Fractions can be targeted depending on value, with different levels of purity achievable as the end-market dictates.	▫ Amount of contamination in recyclate ▫ Additional processing costs associated with contaminate ▫ Disposal costs for reject material ▫ Composition of recyclate ▫ Market value of recyclate ▫ Distance to market for recyclables ▫ Ratio of technology to manual separation
Dirty MRF	A facility employing a number of separation techniques to recover recyclable materials from mixed waste, usually of a relatively low grade. The remaining residual can be processed into a fuel (refuse-derived fuel (RDF)) for use in cement plants or energy recovery facilities. Small quantities of recyclables may be extracted and sold.	▫ Quality of compost ▫ Cleanliness of recyclables ▫ Disposal costs for reject ▫ Market value of recyclate ▫ Market cost for fuel ▫ Market/facility availability for RDF ▫ Distance to market/outlet for recyclables, fuel and rejects

MRF operators usually require a gate fee to be paid by those delivering waste. The gate fees depend on the market for recyclables, local policy and facility processing conditions. In case of dirty MRFs, it is often difficult for the outputs to comply with the quality requirements of the recycling market. According to the *2014 UK WRAP Report*, gate fees for MRF in the UK are approximately 14 EUR per tonne equivalent (180 ZAR per tonne equivalent).

Case study 6: Kraaifontein clean MRF for Municipal Waste

The Kraaifontein Clean MRF facility was built in 2011 and is owned by the Cape Town Metropolitan Municipality. Operation is contracted out to a private operator known as, Waste Plan. Waste Plan's main line of work has traditionally been cleaner production and assisting companies to reduce their waste.

Waste Plan facilitated the operation of the first large-scale MRF in South Africa for source-separated dry recyclables. Waste Plan was awarded a second three-year contract for the operation of the plant. The lessons learned from the Kraaifontein facility, including cost information, are used in estimating feasibility for establishing MRFs elsewhere in the country.

The waste treatment activities: The company also collects dry recyclables from households and commercial clients and treats these in the MRF. The MRF is partially mechanised, relying on automatic feed in and conveyor belts with manual sorters.

Input capacity and quality: The MRF was built to serve 44,250 households in high-and middle-income areas, where source-separation and collection services are provided. The facility currently serves about 100,000 households and commercial clients, and operates on a two X eight-hour shift basis. The output of the plant is currently 1,800 tonnes/month (80 tonnes/day). The input coming from commercial clients needs little to no sorting.

The material received from households has approximately 15% residual waste. There is no residual waste in the commercially sourced waste stream. Various types of packaging waste is sorted and recovered, except for multi-layer packaging, which is either not collected or returned to landfill as residual waste.

The equipment used: The equipment at the MRF consists of a forklift, feed in conveyor belt, baling equipment, bag-splitter, screen and magnetic separator. Of these, the bag-splitter and screen need spare parts/components from abroad.

Human resources and labour intensity: In MRFs, there is a competing interest between job-creation and mechanising the sorting activity. The technology was scrutinised against labour policy and geared to provide job creation and to promote the transfer of skills. There are 60 workers on site per shift.

Operating costs to the City: Based on the public tender information, the operational cost of the MRF to the City is about 53 ZAR/t, which is well below what the City would be paying for landfilling the same waste. The cost for collection of the recyclables to the City is about 64 ZAR/t. The combined cost of about 120 ZAR/t (rounded) is still cheaper for the City than the gate fee calculated at operational cost recovery at 317 ZAR/t for landfilling.

Market for recyclables: Local prices for materials are currently higher than for export - and have been so for four consecutive years. The major share of income is generated from the price per tonne received from the municipality. An agreements in place to share avoided costs of landfill between the municipality and operator.

Case Study 7: Break-even analysis: Naledi Buy-Back Centre/sorting facility[40]

The Naledi Buy-Back Centre is a Buy-Back/sorting facility (clean MRF) operated in the Zondi Depot area of Johannesburg for the sorting of waste separated at source. The Naledi Buy-Back Centre was envisaged as a replicable project that could be rolled-out citywide. This case study presents information on the current experience and the envisaged upgrade.

The waste treatment activities: The waste treatment activity at the Naledi MRF is 100% manual sorting, carried out on a concrete floor or other suitable platform using manual labour.

Input capacity, costs and revenues are presented for the current scenario "As is" and for the "Full Capacity" scenario in Table 19.

Table 19: Naledi Buy-Back Centre costs information

Input capacity	"As is"	"Full Capacity"
Participation rate	7%	40% (30,000 households)
Quantity of material received	27 t/ month	144 t/month
Amount of recycled material sold to buyers	93% (approx. 25 t/ month)	93% (approx. 134 t/month)
Staffing requirement	26	52
Costs and revenues (ZAR/month)		
Salary costs covered by Co-operative	26,000	52,000
Average revenue from sales	26,525	141,469

All other costs related to the MRF are covered by Pikitup. These include collection of recyclables using six caged trucks, marketing activities, health and safety equipment for the workers, purchasing and maintaining bin liners, storage and processing equipment and facilities, overhead costs and management costs.

From the information presented in Table 19, the present operation at the Naledi Buy-Back Centre has the ability to support a 1,000 ZAR per month wage for 26 people. At full capacity the Centre is estimated to have sufficient profit to enable it to support a wage bill for approximately 52 people.

All other costs, with the exception of salaries, continue to be supported by Pikitup. When taking into account the full cost of MRF operations, including those costs supported by Pikitup, the MRF still functions at a loss in the Full Capacity scenario.

The Kraaifontein MRF is a success both from the point of view of the municipality and the operator, both looking at extending and expanding the experience in the future. Waste quantities captured from households were difficult to estimate in the first phase and the facility is serving more clients than originally planned. Important success factors include the fact that recyclables are sourced from commercial and relatively high-income areas, ensuring a relative high quality of the input material. The municipality pays a fee for collection and treatment of waste but this is below the cost of landfilling, confirming MRF as a cost competitive technology.

The Naledi Buy-Back Centre from the City of Johannesburg is the initiative of the recycling operator, Pikitup, who is subcontracting a co-operative. Pikitup does not receive an additional fee from the municipality for running the MRF. The case study illustrates that at 27 tonnes of waste being recycled per month, the revenues cover only the costs with the manual labour involved in sorting. As tonnes being handled increase, more revenue becomes available to support other related costs. Pikitup operates the MRF at a net loss, as no fee is paid by the municipality for the operation of the manual MRF.

The two case studies illustrate that operating an MRF irrespective of the facility being manual or automated or a combination of both, is a viable alternative when avoided costs of landfill are taken into consideration. To ensure success, the facility should receive a gate fee for operating the MRF, set equal to or below the landfill gate fee, established at operational cost recovery.

40 *Republic of South Africa, Municipal System Act 32 of 2000 (MSA) section 78(3)*

5.5 Concluding Remarks

The generic cost benchmarks and the case studies throughout this chapter indicate that the promising technologies – in the short-term, stand out as possible AWT technologies for which the financial costs are lower or similar to that of the baseline situation of landfilling, i.e. below 400 ZAR/t. These technologies include windrow composting, recycling of construction and demolition waste and material recovery facilities. Adding the wider environmental and social benefits of the AWT solutions increases the attractiveness of these technologies further. Gate fees set at, or close to, the avoided full cost of landfill are an important influencing factor to the business-case for these facilities.

Chapter 6

POTENTIAL TECHNOLOGIES - MEDIUM TERM



6 Potential Technologies – Medium-Term

6.1 Introduction

Potential technologies for the medium-term presented in this section include mechanical biological treatment (MBT), anaerobic digestion (AD) and in-vessel composting (IVC).

These technologies are more costly than the promising technologies presented in Chapter 5. They are more technologically sophisticated, and able to treat complex or contaminated waste streams. There is limited experience with these technologies in South Africa, but several feasibility studies are being conducted and/or have been completed recently.

The technologies presented in this section need a combination of an enabling policy environment, favourable market conditions, economic incentives and/or a share of public financing to facilitate wider implementation. Indeed, these technologies have been widely implemented in other countries where an enabling policy framework is in place.

Examples of enabling conditions that have kick-started markets to implement technologies featured in this chapter are landfill taxes, landfill bans, feed-in tariffs, public co-financing programs, carbon credit schemes adding to operational revenues, extended producer responsibility systems and mandatory recycling targets.

6.2 Mechanical Biological Treatment

6.2.1 Scale factors

Mechanical biological treatment (MBT) combines a series of treatment steps for different waste streams. MBT combines mechanical sorting and biological treatment of the organic fraction, either through windrow composting or aerobic/anaerobic digestion. Key characteristics of MBT are presented in Table 20.

Table 20: Key characteristics of MBT

Characteristic	Description
Typical capacity	50k – 500k tonnes per annum
Indicative capital cost	c. 850 m – 1,160 m ZAR for a 100 ktpa facility
Human resource requirement	Includes engineers, skilled workers, mechanics, unskilled workers and drivers

As can be seen from Table 20 above, MBT facilities are typically large scale, with higher capital costs as compared to the promising technologies for the short-term. MBT is able to handle mixed waste or source separated waste depending on the collection system. The technology is relatively flexible, potentially comprising simple or higher technology solutions, and therefore characterised by relatively wide cost ranges.

6.2.2 Cost Benchmarks

Land acquisition costs depend on the extent and type of treatment technology used for the biological treatment stage. In some cases MBTs are built on old landfills and in such cases, land acquisition costs may not be a significant cost item.

Specific equipment in an MBT facility includes:

- Preparation equipment for reducing the size of waste particles and eliminating some fractions (hammer mills, shredders, rotating drums, wet rotating drums, ball mills, bag splitters). Waste preparation equipment is selected depending on the composition of the waste feedstock.
- Mechanical separation equipment similar to equipment used at dirty MRF facilities.
- Biological treatment equipment, potentially including aerobic bio-drying, windrow composting for biostabilisation, aerobic in-vessel composting or anaerobic digestion.

The operating costs of the mechanical treatment component of MBT are approximately the same as for MRF facilities. The biological treatment costs depend on the type of biological treatment technology chosen.

A crucial determining factor in the business case for MBT is whether there is a market for the process outputs from the facility. For example, if the output is refuse-derived fuel (RDF) the market demand is highly influenced by the relative proximity to facilities that may use this RDF as a fuel source. Internationally, the price varies from minus 45 GB Pounds (Italy) (810 ZAR equivalent) to plus 20 GB Pounds (in some developing countries) (360 ZAR equivalent). The market price for RDF depends heavily on the local market conditions and whether there is any legislation or economic instruments in place that incentivise the use by industry of the RDF material.

Figure 13 and 14 show the specific full costs for a simple MBT and a higher technology MBT. The simple MBT involves sorting, mechanical treatment of the dry fraction and windrow composting of the wet fraction. The higher technology MBT involves the treatment of organic fraction through intensive rotting and fermentation. The difference in cost range shows the cost impact of choosing a more complex technology. The choice of technology, however, also needs to be made depending on the environmental acceptabiltiy of lower cost biological treatment, which may be unacceptable in terms of impact depending on the how close the facility is to environmentally sensitive receivers.

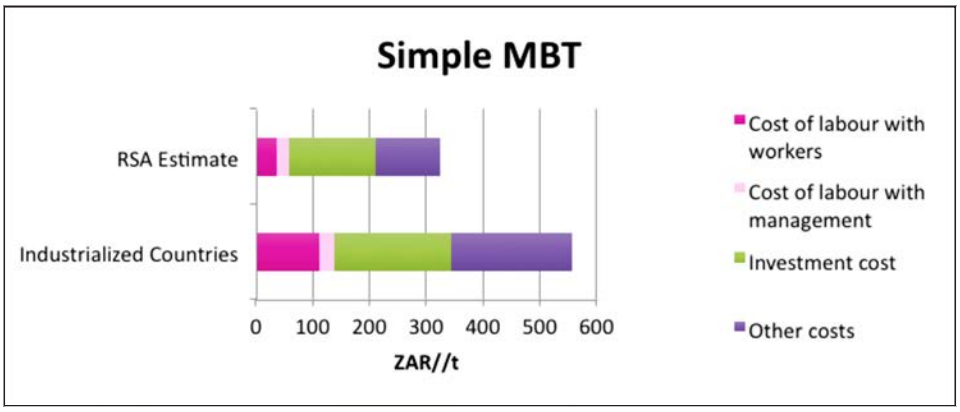


Figure 13: Full cost breakdown for simple MBT with windrow composting

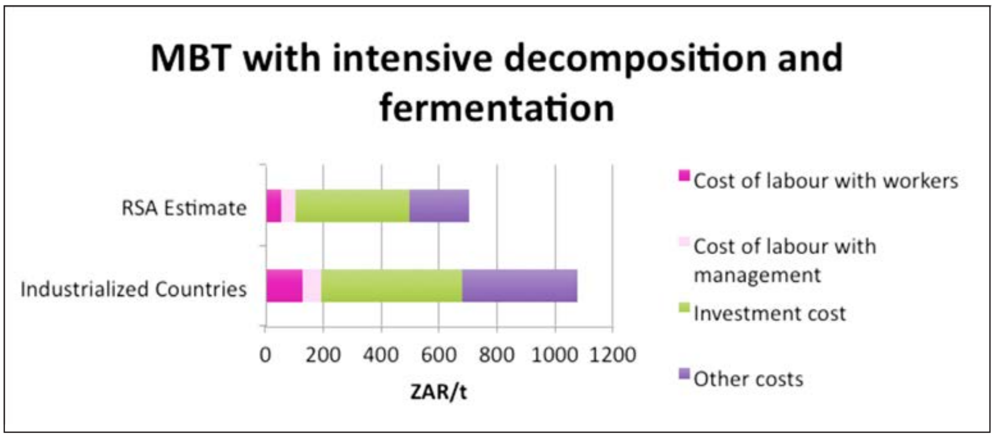


Figure 14: Full cost breakdown for MBT with intensive decomposition and fermentation

The typical costs of a simple MBT, with windrow composting for the treatment of organic matter, and a simple sorting line, as shown in Figure 13 is estimated at between 300 to 400 ZAR per tonne. A more complex technology involving for example intensive decomposition, fermentation and biogas generation may cost up to 800 ZAR per tonne as shown in Figure *14*.

6.2.3 Revenues and gate fees

Table 21 presents a brief description of MBT with composting and with anaerobic digestion, outlining the factors which influence the revenues for each of the technologies.

Table 21: Factors influencing Revenue - MBT

Technology Heading	Outline Description	Factors Influencing Revenue
MBT (with composting/ bio-drying)	A facility combining mechanical separation techniques with biological treatment to either stabilise or dry the organic fraction of the waste. Mechanical separation is used to recover relatively low grade recyclable materials in much the same way as a dirty MRF. The organic fraction can be used as a RDF (bio-drying) or stabilised compost-like output with reduced volume.	▫ Market value of recyclate ▫ Quality requirements of compost like output ▫ Distance to market/outlet for recyclables, RDF, compost-like output and rejects ▫ Quantity of contaminant and subsequent screening costs ▫ Reliability of some technologies/maintenance requirements
MBT (with anaerobic digestion)	A facility combining mechanical separation techniques with biological treatment to derive energy from the organic fraction of the waste. Mechanical separation is used to recover relatively low grade recyclable materials in much the same way as a dirty MRF. The organic fraction can be subject to anaerobic digestion to recover biogas/ generate electricity.	▫ Electricity/bio-methane revenue ▫ Any government incentives for low carbon energy/ other energy recovery incentives ▫ Revenue/cost of digestate product in market ▫ Quality requirements/dewatering of digestate ▫ Quantity of contaminant and subsequent screening costs ▫ Opportunity and value to utilise waste heat from process ▫ Market value of recyclate/fuel ▫ Quality requirements of compost-like output ▫ Distance to market/outlet for recyclables, fuel, digestate and rejects ▫ Quantity of contaminant and subsequent screening costs

Table 21 illustrates the revenue influencing factors that may be essentially divided in three categories of enabling conditions: the uptake markets, the environmental requirements and the economic incentives.

Each potential technology choice will result in different products and by-products that depend on the market conditions, the quality requirements of the market, the distance to the market and the cost of distribution. Economic incentives that influence the uptake by the market, such as a feed-in tariff for energy produced from renewables, a reduced reported GHG emission reduction impact when using RDF as a fuel for the cement industry, or a requirement for using organic fertilisers, will have an impact on the revenue streams of an MBT and influence the choice of the mix of technologies.

Gate fees for MBT technologies should be established taking into consideration the market conditions for the outputs. According to the *2014 UK WRAP Report*, gate fees for MBT plants in Europe are about 116 EUR per tonne (i.e. 1,510 ZAR per tonne equivalent).

Case study 8 with reflects on the costs and revenues of the planned MBT in Rustenburg and how this is not feasible without the availability of grant financing. Case study 7 is included to illustrate the range of differences in cost and labour intensity depending on the choice of technologies in an MBT.

Case Study 8: Rustenburg Local Municipality, feasibility study on intensive decomposition MBT.[41]

In the framework of the DEA/KfW AISWM programme, MBT with intensive bio-drying is proposed for recyclables extraction and Refuse-derived fuel (RDF) production in the Rustenburg Local Municipality.[42] This technology falls in to the more complex/technology intensive category of MBTs, as listed in table 21 as MBT with intensive decomposition or fermentation.

The planned input capacity of the plant is 120,000 t/a. The resulting output is 47,000 t/a RDF and 14,000 t/a recyclables, the balance being water loss and the rejects sent for landfill.

Table 22: Estimated specific investment and operation costs (2015 ZAR)

Costs	ZAR/t	%
Investment cost	246	28%
Estimated operation costs	636	72%
Full specific cost	882	100%

Table 22 illustrates the full specific cost of the envisaged MBT, reflecting the specificities of the selected technologies. The initial financial analysis assumed a mix of potential revenue sources. The sale of recyclables would ensure approximately 12% of the required revenue and the sale of RDF approximately 16%. The price of RDF was assumed at 450 ZAR/t, in 2015.

The gate fee was calculated at 150 ZAR/t, which is comparable to the landfill gate fees and the baseline cost of landfill. The gate fee is also assumed to increase gradually over time, levelling off in 2023 at 400 ZAR/t and later adjusted for inflation.

Approximately 30% of user fees paid are assumed to be allocated to the facility as a revenue stream. The assumption regarding the increase in fees and the increase in collection coverage is that both will increase over time and reach 96% for households and 99% for businesses and institutions, by 2024. With these tariffs and gate fee levels, the revenues from gate fees and user fees were estimated to cover approximately 50% of the total revenue requirements.

A financing gap of approximately 215 ZAR/tonne or 20% of the total revenue requirements of the plant was estimated. The analysis illustrates capital grant funding and a degree of operating subsidy would be essential for the business case to proceed. The project is currently in the market-testing stage.

41 *Infrastrucktur&Umwelt, Professor Bohm und Partner, KfW, 'Draft Feasibility Study Report. Advanced Integrated Solid Waste Management System for Rustenburg Local Municipality', February 2009*

42 *Infrastrucktur&Umwelt, Mott MacDonald, KfW, 'Consultancy Services for Rustenburg Local Municipality (RLM) for Implementation of an Advanced Integrated solid Waste Management System, Quarterly Report No 6', 01 March 2015 – 31 May 2015*

Case Study 9: Comparison of costs across different MBT technologies in Rustenburg[43]

A feasibility study in 2009 compared the costs of a series of different variations of MBT plants.

Table 23 compares a range of technology choices for treating organic fraction in an MBT, including simple windrow composting, in-vessel composting, biological drying and anaerobic wet and dry technologies. The columns address simple to more complex technologies (from left to right).

Table 24 looks at the labour intensity of these same technologies and the number of workers needed in the skilled and non-skilled categories.

Table 23: Specific treatment costs for different MBT options[44]

Option / Item	Open windrows passively aerated ZAR/t	Open/covered windrows actively aerated ZAR/t	In-vessel actively aerated biological decomposition ZAR/t	Aerobic biological drying ZAR/t	Combined anaerobic wet (low solid) digestion for organic waste ZAR/t	Combined anaerobic dry (high solid) digestion ZAR/t
Wages and salaries	22	26	30	17	67	67
Repair and maintenance	26	51	106	145	194	234
Variable cost/consumables	7	20	39	38	60	65
Depreciation of investment	55	131	266	319	453	524
Total costs	**110**	**229**	**441**	**519**	**774**	**890**

As may be observed from Table 23, there is a significant cost increase depending on the biological treatment technology selected. Whilst windrow composting is significantly cheaper than intensive decomposition or digestion variations of MBT, the environmental impacts of these approaches are also markedly different, with windrow composting of mixed municipal waste generating significant potential harmful impacts compared to more advanced technology alternatives.

Table 24: Labour intensity of the different treatment options

Option / Item	Open windrows passively aerated	Open/covered windrows actively aerated	In-vessel actively aerated biological decomposition	Aerobic biological drying	Combined anaerobic wet (low solid) digestion for organic waste	Combined anaerobic dry (high solid) digestion
Number of skilled workers	8	10	12	8	12	12
Number of general workers	15	15	12	6	10	10
Total number of workers	**23**	**25**	**24**	**14**	**22**	**22**

The comparison of the different MBT options according to Table 24, indicates a relatively even labour intensity, with all technologies being labour-intense except for the aerobic biological drying. The more expensive technologies tend to require more staff with appropriate qualifications, skills and/or experience.

In conclusion, MBTs tend to become significantly more costly as the technology for the treatment of the organic fraction becomes more complex, but, are relatively comparable in terms of labour intensity (except for biological drying). Most of the difference in cost towards the higher end technologies is due to a higher capital cost and associated higher costs with maintenance and repair.

43 *Idem 35*

44 *Infrastrucktur&Umwelt, Professor Bohm und Partner, KfW, 'Draft Feasibility Study Report. Advanced Integrated Solid Waste Management System for Rustenburg Local Municipality', February 2009*

6.3 Anaerobic Digestion

6.3.1 Scale factors

Anaerobic digestion (AD) is an emerging technology that is gaining momentum in RSA, with a select number of market players actively considering developing the business.

Anaerobic digestion is commonly used for processing animal waste/manure and sewage sludge. Several AD plants have been commissioned in South Africa, with capacities ranging from very small scale to plants exceeding 10 tonnes/day. There are several companies operating in the market who are looking to develop projects for digesting or co-digesting the organic fraction of municipal solid waste. Key characteristics of AD are presented in Table 25.

Table 25: Key Characteristics of AD

Characteristic	**Description**
Typical capacity	5 k – 150 k tonnes per annum
Indicative capital cost	c. 120 m –220 m ZAR for a 25 ktpa wet AD process c. 300 m – 350 m ZAR for 160 ktpa (620 t/day) (New Horizons Plant)
Human resource requirement	Engineers, chemists, environmental managers, skilled workers, mechanics and drivers

The characteristics of the AD technology featured in Table 25 above show that these facilities can operate at relatively small scales. The technology is, however, relatively capital intensive compared to the promising technologies profiled in Chapter 5, and requires qualified and experienced operators.

6.3.2 Cost benchmarks

Specific costs for AD plants vary according to the type of technology used. The choice of technology (mesophilic, thermophilic, etc.) and the degree of process control may be tuned to the input feedstock, as well as to the desired plant utilisation rate.

Typical equipment for AD includes: digester tanks, combined heat and power (CHP) engines, grid connection equipment, waste processing equipment, dryers, separators, loaders, hoppers, conveyors, temperature monitoring equipment, odour and water control equipment, exhaust gas treatment, digestate storage vessels/bunkers, blowers, fans and vehicles.

The economics of AD are not very sensitive to economies of scale. The average plant size is 1-2 MW installed capacity, with 40 to 80 ktpa waste input. The cost of developing the AD plant will depend on the following variables:

- size of AD digester and associated storage;
- size of energy generation plant (heat only or CHP plant);
- environmental control systems (air, water, noise, etc.);
- grid connection (where applicable); and
- material segregation.

Operational costs depend on the type, quality and availability of the feedstock. A large majority of anaerobic digestion plants utilise agricultural substrates. These can include manures, grasses and energy crops. In general, the materials with the higher gas yields are more expensive.

Manure: In all cases there should be no additional cost (to the waste management system) associated with the use of manure as an input feedstock. For farm scale plants the manure will require storage but in many cases such storage is required as part of the environmental requirements for farming activities in any case, so limited additional costs may be incurred. For centralised plants there will be transport costs associated with delivering the manure from the farms to the facility.

Grass/maize: where grass, maize or other crops are grown for the purpose of energy generation in an AD plant, there will be costs associated with the crop production (ground preparation, sowing, fertilising, harvesting, etc.).

Biodegradable municipal waste: may be used on its own or co-digested with manure or energy crops. Organic municipal waste is typically required to be separately collected, or less often the output from a dirty MRF facility depending on the quality of the material. Securing energy off-take agreements is essential, as is securing the supply of the right quantiy and quality of input feedstock. The availability of bio waste for AD plants depends largely on the collection systems in place. Even where bio waste is available as feedstock to AD facilities at the point of generation, transport costs may need to be covered by the facility operators[45].

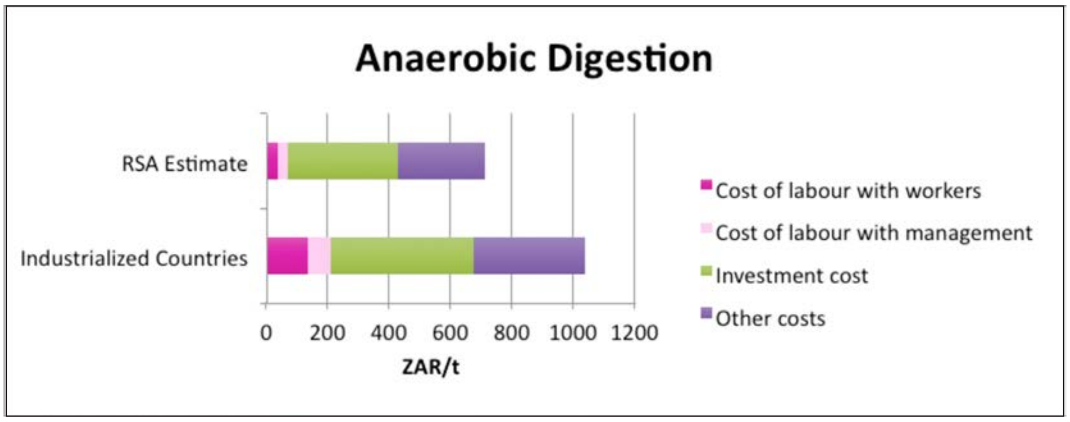


Figure 15: Full cost breakdown for anaerobic digestion

Anaerobic digestion costs are estimated at between 700 to 800 ZAR per tonne as illustrated in Figure 15. The difference in estimated cost for AD facilities in South Africa compared to industrialised countries, shown in Figure 15, is due to a combination of lower labour costs and availabilty of equipment in the South African market.

6.3.3 Revenues and gate fees

Table 26 outlines anaerobic digestion and the factors that influence revenues for this technology.

45 *TEA Ireland, 'BISYPLAN - The Bioenergy System Planners Handbook', BIO-EN-AREA project, INTERREG IVC, 2012, http://bisyplan.bioenarea.eu/ (accessed 10 April 2015)*

Table 26: Factors influencing revenues – AD

Technology Heading	Outline Description	Factors Influencing Revenue
Anaerobic digestion (AD)	Anaerobic digestion utilises natural microbes to digest and decompose food wastes (including animal products) in an anaerobic environment to produce biogas (suitable for use in CHP engines or clean-up for use as a replacement for natural gas) and nutrient rich digestate. The digestate can be spread on the land either in its output state if allowed by regulations, or after dewatering (more suitable if no immediate end user is available). Food waste has higher moisture content than mixed organics and is therefore most suitable for 'wet' AD systems.	- Electricity/bio-methane revenue - Government incentives for low carbon energy or other renewable energy incentives - Revenue/cost of digestate product in market - Distance to outlet for digestate - Quality requirements for dewatering of digestate - Quality requirements for biogas and related treatment costs - Quantity of contaminants and subsequent screening costs - Opportunity and value to utilise waste heat from the process - Appropriate feedstock availability, composition and consistency

The main output of AD is biogas. Biogas may be converted to energy, or may be cleaned for use as natural gas. Securing an off-taker for the energy generated is the key factor influencing revenue as depicted in Table 26. Opportunity to use waste heat from the process adds to the efficiency of the energy generation and use. Valorification of the digestate and related costs of treatment and distribution is also an influencing factor in revenue.

Often, biodegradable municipal waste is co-digested together with other wastes in AD facilities. Ordinarily the materials are either a waste/residue the AD plant can take in for free or potentially charge a gate fee. Gate fees at AD facilities are higher, as much as double, for packaged waste compared to unpackaged waste. The gate fee is related to the gas yield of the material. According to the *2014 UK WRAP Report*, gate fees for AD plants in Europe average around EUR 56 per tonne (i.e. 730 ZAR per tonne equivalent).

In South Africa the biogas industry encounters several challenges.[46] One of the most significant challenges is the low feed-in tariff and the difficulty to gain access to the grid. The available grant subsidies for renewable energy favour larger investments and provide higher prices for energy generated from other sources such as solar and wind. Biogas to energy generation requires an enabling policy environment, coupled with norms and standards. Without tailored policy approaches, it is difficult for AD facilities to compete with other renewables.

The Renewable Energy Independent Power Producers Procurement Programme (REIPPPP), the fund for alternative energy, does not currently favour biogas-based energy generation, regardless of whether the biogas is generated from agricultural biomass, industrial or sewage sludge, green garden waste, organic kitchen waste or a combination of the above. Some of the criteria and the process in the fund are decreasing the chance of biogas based energy generation to succeed.

a. A competitive bidding program, projects need to cooperate with Eskom and to place a tender; transaction costs of preparing a tender are high, about 10 million ZAR. This is too high of a threshold for the relatively smaller AD projects as compared to other renewable energy projects. Transaction costs include financial due diligence, EIA process and securing financial agreements.

b. Biogas plants are usually not larger than 10 MW. However, many of the plants are between 1-2 MW and often as low as 750 kW. A 3-4 MW plant costs approximately 200-300 million ZAR. The requirement for benefiting from the REIPPP is a threshold of minimum 12.5 MW capacity.[47]

c. Caps on electricity price are higher for photo-voltaics than for biomass.

46 *Vulindlela Academy, 2013, "Biogas – Conversations around challenges and opportunities" Conference publication and personal communication with Anaergia, Shmulevich Yoav, May 2015*

47 *REIPPP program description, Department of Energy, http://www.ipprenewables.co.za, website consulted on 13th of March 2016*

d. Biomass-based LPG production is a good way to store energy and helps supply at peak times, other renewable energy sources are not so suitable for this, yet the incentive scheme does not reward or acknowledge this benefit.

As of October 2015, the South African government together with the Netherlands government embarked on the "Development of a Biomass Action Plan for Electricity Generation". The plan will focus on recommendations for creating an enabling environment for large scale uptake of agricultural and forestry uptake for electricity generation. Industry was invited to dialogue and this provided an opportunity to lift existing barriers and give the sector the needed policy push [38].

Case study 10: Saldanha Bay AD for municipal solid waste

A project aiming at the digestion of municipal solid waste was near finalisation in Saldanha Bay at the time of document development. The project is set up entirely as a business initiative. The project developer is West Coast Power Solutions. The technology provider is Anaergia, and the off-taker is ArcelorMittal South Africa. The feedstock provider is a private operator for waste collection services. The project is located at the site of ArcelorMittal, the largest liquefied petroleum gas (LPG) consumer in the country.

Waste treatment activities: The project includes extraction of organic matter from the waste stream with hydraulic pressing. This is followed by AD of organic matter for methane generation and improvement of gas to be suitable as a mix in the LPG supply for the uptake company.

Footprint of the AD facility: approximately 1,000 m^2 of land is required.

Input capacity and quality: The project feedstock of approximately 150 tons/day consists of source-separated organic matter from lightly contaminated organic waste, originating from restaurants, hotels, markets, commercial units and industry provided by the private operator.

The Saldanha Bay Local Municipality expressed interest to providing waste to the facility, the main reason being that the municipality has limited available landfill airspace and can save on waste disposal costs. This is a win-win situation in which the municipality would save money by avoiding cost of landfilling and the private facility operators would benefit from a feedstock available regularly at no fee, having to pay only for the cost of transport to the plant.

Biogas output: approximately 35,000 cubic m/day.

An off-take agreement with ArcelorMittal is in place influencing factors including the realised cost savings with gas consumption.

Investment cost: approximately 80 million ZAR.

48 Information taken from the South African International Renewable Energy Conference (SAIREC) website, http://www.sairec.org.za/title-development-of-a-biomass-action-plan-for-electricity-generation-in-south-africa/, website consulted on the 13th of March, 2016

Case study 11: Anaerobic digestion in Germany

Germany is regarded as the most successful European country in implementing AD for the production of biogas and subsequent electrical energy. The most important driver for the growth of the biogas industry in Germany has been the *Renewable Energy Sources Act (EEG)* through a package of incentives set out to promote AD in Germany since the year 2000.

Legislation introduced by the German government includes:

- a guaranteed fixed fee for the electricity paid by the grid operators for a 20-year period; and
- priority connection, purchase and transmission for electricity from renewable energy sources.

Through these measures, the EEG guaranteed medium-and long-term planning and investment security, reliable cost estimations for consumers, specific fees for different technologies, low bureaucratic barriers and low transaction costs for investors.

The evolution of the EEG and its impact on biogas plans development in Germany has been summarised by the German Biogas Association in Figure 16 below[49]:

Figure 16: Evolution of incentives set by the Renewable Energy Sources Act for anaerobic digestion in Germany

Source: German Biogas Association

The high growth rate was considered unsustainable, and starting with 2012 the feed-in tariffs for electricity have slowly but steadily decreased by 1-2 cents per year through amendments to the EEG.

49 *Clemens Findeisen, Biogas - Trends in Germany, German Biogas Association, available online at http://www.eclareon.com/sites/default/files/clemens_findeisen_-_biogas_-_trends_on_the_german_and_international_market.pdf, accessed March 2016*

Since in August 2014[50], the EEG has been modified for new plants to cut the bonus for energy crops and manure, the bonus for biogas upgrading, the heat utilisation obligation, and cap investments to maximum 100 MW gross additional plants each year. Still, a special higher feed-in-tariff is in place to encourage certain feedstock and technologies:

- Small “manure” plants: 23,73 ct/kWh (ZAR/kWh 3.07 equivalent)
- Waste fermentation plants: 15,26 ct/kWh (ZAR/kWh 1.98 equivalent)

By comparison, the standard tariffs for other biogas technologies are lower:

- ≤ 150 kW 13,66 Cent/kWh (ZAR/kWh 1.77 equivalent)
- ≤ 500 kW 11,78 Cent/kWh (ZAR/kWh 1.53 equivalent)
- ≤ 5 MW 10,55 Cent/kWh (ZAR/kWh 1.37 equivalent)
- ≤ 20 MW 5,85 Cent/kWh (ZAR/kWh 0.75 equivalent)

The strategy of the German government is to maximise the biogas output, not necessarily focusing on increasing also the waste throughput. This led to an increase in the areas cultivated with energy crops. However, the National Non Food Crops Centre (NNFCC)[51] has stated that digesters using high proportions of crops typically require specialist modifications and higher initial investment.

The economics of AD are finely balanced and it is vital to get the feedstock and size of the plant right. A report by the NNFCC[52] revealed that feedstock composition is crucial in determining the most appropriate digester size for maximising yield and income. Supplementing manure and slurry with crops can make all the difference to the profitability of some digesters.

The use of biowaste from municipal solid waste as a feedstock for AD facilities represents a challenge. Digestors require clean biowaste input, and therefore the technology either requires the collection of clean sourced biowaste, or a front-end pre-processing stage that effectively extracts the contaminants from the municipal waste stream.

The economics of the process is highly sensitive to the quality of input material and requires professional operation. Nonetheless Municipality-sourced, the co-digestion of municipally sourced biowaste with manures and crops, offers synergies that can help the business case for these facilities.

6.4 In-vessel composting

6.4.1 Scale factors

In-vessel composting (IVC) is considered a potential technology for the medium-term. Advantages of IVC versus windrow composting are the smaller area of land required and faster process times for producing compost. Table 27 presents key characteristics of in vessel composting.

Table 27: Key characteristics of in-vessel composting

Characteristic	Description
Typical capacity	10 k – 150 k tonnes per annum
Indicative capital cost	c. 60 m – 95 m ZAR for a 30 ktpa facility
Human resource requirement	Low and mostly unskilled workers, drivers and mechanics

IVC is a relatively flexible technology, and can be viable at even at relatively low throughputs. The investment cost, however, is in the order of 10 times higher than for windrow composting. An advantage of in vessel composting is its ability to treat less pure waste fractions. The technology requires mostly low or unskilled labourers.

50 idem

51 NNFCC, 2010, A Detailed Economic Assessment of Anaerobic Digestion Technology and its Suitability to UK Farming and Waste Systems, Report written by The Andersons Centre, 2nd Edition, available online at http://www.organics-recycling.org.uk/uploads/category1060/10-010%20FINAL_Andersons_NNFCC_AD2010.pdf, accessed March 2016

52 idem

6.4.2 Cost benchmarks

Costs for IVC facilities depend on the scale and type of technology employed. Vertical units reduce the land surface requirements and as such reduce land acquisition costs.

Typical equipment for IVC facilities include: composting vessels, shredders, mixers, turning machines, sieves, separators, loaders, hoppers, conveyors, blowers and fans. Temperature monitoring equipment is necessary to ensure a proper composting process. Odour control is an inherent requirement, and the cost associated with this can account for up to 50% of both capital, operational and maintenance costs. Composting facilities usually use either wet scrubbers or bio filters for odour control.

In terms of labour costs, IVC systems can be relatively complex, although the skills required for successful operation are similar to those required for operation of wastewater treatment plants. Typical labour requirements include heavy equipment operators, maintenance personnel, and instrumentation/computer operators. Figure 17 illustrates the estimated IVC costs for South Africa compared to industrialised countries.

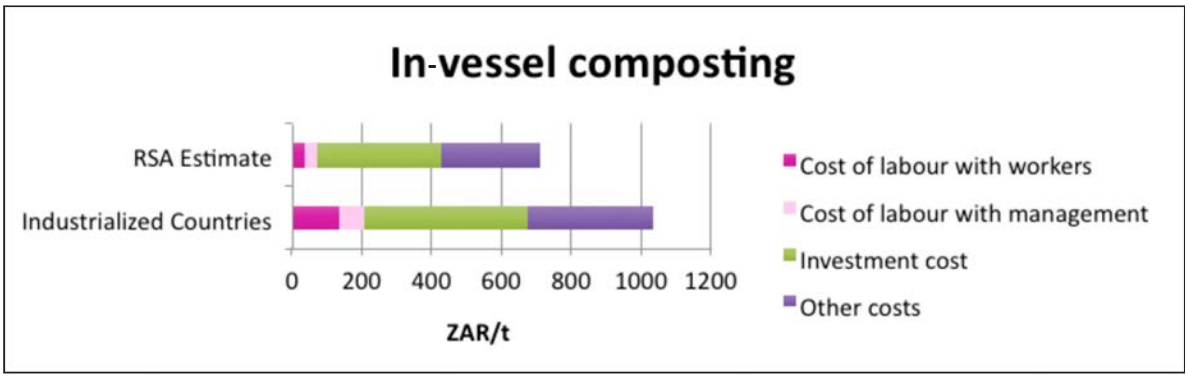


Figure 17: Full cost breakdown for in-vessel composting

IVC costs are estimated at around 700 ZAR/tonne. The major costs arise from investment, maintenance and fuel. Labour intensity and costs are reletively low.

6.4.3 Revenues and gate fees

Table 28 outlines the factors that influence revenue for an IVC facility.

Table 28: Revenue factors for in vessel composting

Technology Heading	Outline Description	Revenue Influencing Factors
In-vessel composting (IVC)	In-vessel composting decomposes the feedstock in an enclosed aerobic environment to produce compost suitable for application to agricultural or horticultural land. Mixed organics containing food (and other potentially hazardous or nuisance materials) require treating in-vessel.	▫ Revenue/cost of compost product in market ▫ Distance to outlet for compost ▫ Quality requirements/bagging of compost ▫ Quantity of contaminant and subsequent screening costs ▫ Disposal costs of contaminant

Table 28 illustrates the importance of quality of compost among the factors influencing revenues. In-vessel composting plants usually charge a gate fee for accepting biodegradable waste at the facility. Gate fees charged for wastes received at the facility depend on the nature of the waste. Gate fees are typically higher for food waste and lower for garden waste. According to the *2014 UK WRAP Report,* gate fees are 64 EUR per tonne (830 ZAR per tonne equivalent) for municipal food and green waste and 71 EUR per tonne (920 ZAR per tonne equivalent) for supermarket waste.

Case Study 12: The Radnor in-vessel composting plant in Cape Town

The Radnor In-Vessel Composting plant was built in the 1960s and remained operational until 2012 when it was closed due to the poor quality of compost being produced, the high capital costs required to repair and upgrade the plant as well as high operational costs. The technology employed was the Buhler In-Vessel System and was used to compost selected municipal general waste and food wastes.

It was estimated at the time the facility was closed down that the cost per ton for producing compost was 482 ZAR excluding overhead and administrative costs compared to the sales price in the private sector ranging between 150-200 ZAR/tonne.

The case study emphasises once again the importance of quality of compost. The production price of the Radnor facility was comparable to the cost benchmarks shown in Figure 17. Nevertheless, the facility was unable to compete with windrow composting in terms of quality of output and cost.

6.5 Concluding Remarks

The feasibility of the potential technologies – medium-term, which includes mechanical biological treatment (MBT), anaerobic digestion (AD) and in-vessel composting (IVC) is heavily dependent on market conditions, feedstock availability, proximity to end-users of process outputs, and the existence and ease of access to policy/economic incentives.

The technologies are not highly labour intensive, but instead offer a technological solution that can significantly decrease reliance on landfill. The costs of these technologies are, however, significanly higher than the prevailing cost of landfill at this present time in South Africa.

The private sector is showing an interest in these technologies. With the emergence of new enabling conditions, such as policies, incentives and administrative procedures, the business case for these technologies may become more attractive. However, at this stage, it seems that the prospects for development of MBT, AD and IVC as waste treatment/landfill diversion technologies will be very location-specific, and limited to specific cases.

Chapter 7

POTENTIAL TECHNOLOGIES - LONG TERM

7 Potential Technologies – Long-Term

7.1 Introduction

This Chapter focuses on long-term, more expensive and advanced solutions, such as incineration with energy recovery, mechanical heat treatment (MHT) and other advanced thermal treatment (ATT) technologies such as gasification and pyrolysis (including plasma processes). To date, there is little to no experience with these technologies in South Africa. Several municipalities have considered the option of introducing ATT technologies in their respective cities. The feasibility studies that are currently available are mostly based on European examples.

Besides the cost factor, from a market view, even potential, ATT technologies are not very favourable. There is no high demand for heat energy in South Africa and coal is still a relatively cheap source of energy. Using waste as fuel, poses challenges due to the naturally less homogenous composition compared to conventional gas, coal and oil. However, in major metropolitan areas, these technologies may become applicable in the future as a major bulk waste treatment and landfill diversion solution.

It is important to note that ATT technologies do not accept mixed municipal waste as feedstock; rather they require an intensive pre-processing step to prepare an RDF input feedstock of sufficient quality.

7.2 Incineration with Energy Recovery

7.2.1 Scale factors

Incineration with energy recovery is a robust technology that can be used to treat, and generate power from a mixed municipal waste feedstock. This can include untreated (raw MSW) and treated (RDF) materials. Incineration facilities have been widely developed globally, with high concentrations of facilities in Europe and China. However, there are only a few facilities developed in other BRICS (Brazil, Russia, India, China, South Africa) countries.

Typically, incineration combustion temperatures are in excess of 850^{o}C. The waste is converted into carbon dioxide (CO_2) and water and contains a wide variety of trace gases and ash residues. Any non-combustible material (e.g. metals and glass) remain as solids. This material is known as bottom ash and contains a small amount of residual carbon. Fly ash is also generated, and typically needs to be treated as hazardous waste.

The capacities of an incineration plant may vary drastically starting at small scale plant handling circa 10,000 tonnes per annum up to large scale facilities capable of handling well over 1 million tonnes per annum with multiple process lines. For example, the Amsterdam Energy Recovery Facility can handle 1.4 million tonnes per annum of mixed domestic and commercial wastes and RDF.

There are two main incineration technologies available on the market; they differ mainly in terms of combustion chamber design; fluidised bed and moving grate. Co-combustion technologies exist to treat waste derived products alongside traditional fuels like coal.

All technology configurations require a relatively homogenous feedstock and will not be able to burn bulky items. Fluidised bed systems require pre-treatment of waste to satisfy the need for greater homogeneity of feedstock, and are reported to have marginally higher capital costs[53]. However, these systems are designed to treat materials with higher calorific values, and therefore recover more energy. Key characteristics of incineration with energy recovery are presented in Table 29.

53 There is little data available to compare the technologies like-for-like

Table 29: Key Characteristics of Incineration with energy recovery

Characteristic	Description
Typical capacity	60 k – 600 k tonnes per annum
Indicative capital cost	c. 1,400 m – 1,900 m ZAR for a 100 ktpa facility.
Human resource requirement	Engineers, chemists, environmental managers, skilled workers, mechanics and drivers

Table 29 illustraes that incineration with energy recovery is typically implemented at a relatively large scale. Co-combustion may become feasible at lower scale but economies of scale are evident. The technology is capital-intensive and needs limited but highly specialised staff and skilled operators.

7.2.2 Cost benchmarks

Incineration with energy recovery technologies are designed to handle a large variety of waste streams. When considering land acquisition and construction of facility buildings for incineration with energy recovery installations, plans should account for the future development and future modifications for the facility. There should be sufficient space for adding new equipment that will enable the facility to respond to the market demand for materials and fuels.

Costs are split between the waste treatment/energy recovery part of the facility, and the gas clean-up equipment at the back end. Combustion of waste materials produces dioxins and greenhouse gases (GHG) which need to be removed from flue gases before emission to the atmosphere. The cost of this clean-up process is a necessary requirement to ensure that all environmental emissions regulations are adhered to.

Investment costs also depend on the capacity of the installation. A rule of thumb for economies of scale is: double the capacity of the plant and multiply the capital cost by 1.6 to 1.8. Estimated costs for incineration with energy recovery in RSA versus industrialised countries are presented in Figure 18.

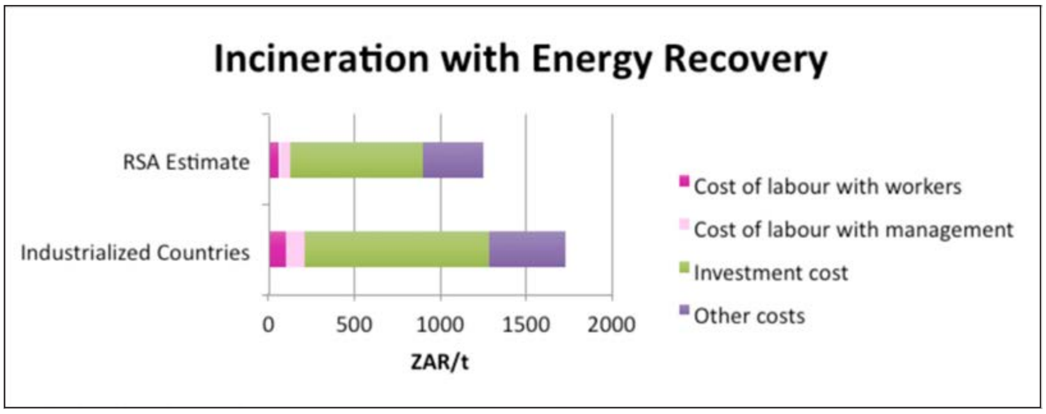


Figure 18: Full cost breakdown for incineration with energy recovery

As illustrated in Figure 18, incineration with energy recovery is a capital-intensive technology. The full cost is estimated at approximately 1,200 ZAR/tonne, but costs could be higher. The cost of managing the flue gas treatment (FGT) process and residues, coupled with the costs associated with the options for managing bottom ash/slag and fly ash residues is significant; roughly a quarter of the material input requires disposal to landfill.

The efficiency, in terms of the percentage of time in operation, has a great impact on the business case. Outages are very expensive due to the loss of revenue from the sale of energy during these periods. Similarly, re-starting operations can be costly due to requirement for injection of fuel to catalyse the combustion process. Preventive maintenance is of decisive importance. An attempt to save on maintenance in one year may well result in postponement of increasingly greater problems to subsequent years and may ultimately lead to unplanned outages.

7.2.3 Revenues and gate fees

The main characteristics of Incineration with energy recovery and the factors that influence the revenues from this technology are presented in Table 30.

Table 30: Factors influencing revenue for incineration with energy recovery

Technology Heading	Outline Description	Factors Influencing Revenue
Incineration with energy recovery	MSW or RDF is thermally treated by combustion for a minimum of two seconds above 850°C in a natural oxygen environment. The steam created by this process is used to generate energy (heat and/or power) in a steam circuit. Flue gases are treated to remove harmful pollutants from output emissions. Incinerator bottom ash (IBA) can be treated to create a stable construction material or deposited to landfill.	▫ Electricity revenue ▫ Any government incentives for low carbon energy/other energy recovery incentives ▫ Distance to outlets of bottom ash/fly ash if not recovered ▫ Revenue from metals ▫ Opportunity and value to utilise waste heat from process ▫ Revenue from fly ash if utilised in cement industry

Table 30 illustrates the factors influencing revenue, most important of these are the electricity revenue. However, even with maximised revenues from all sources, including sales of metals, revenues from fly ash utilisation, an incineration facility will regularly need to charge a relatively high gate fee. If the gate fee is too low, this may indicate that the technology is not respecting high standard environmental compliance and is saving on compliance costs.

Internationally, a large number of facilities are operational, particularly across Europe and China. Many facilities treat unsorted MSW after removal of bulky/unsuitable items. The majority of systems in operation are moving grate/mass burn incinerators. In some countries, fluidised bed technologies have a significant market share. Co-combustion facilities can use a variety of furnace configurations depending on the industry for which the waste is being treated.

Case Study 13: Waste to Energy plant in Sedibeng and West Rand Municipal Areas, 2014

Based on the information presented in the case study has been extracted from the *Waste to Energy Feasibility Study Report* in Sedibeng and West Rand Municipal Areas[54]; no operational case studies are available in South Africa.

The waste treatment activities: Four main categories of WtE technologies are assessed in the study, the recommended technology following the assessment being conventional combustion technology. This involves the oxidation of carbon-based material into ash, CO_2, water and energy in the form of heat. The technology includes two process lines operating in parallel.

Input capacity: The facility is a medium capacity WtE plant of 200,000 tonne per annum, receiving mixed municipal waste feedstock.

Output of the technology: The energy output would feed into the municipal grid to offset the Eskom coal-derived electricity. Potential energy generation for the WtE facility, power only, would be 14 MW (sufficient for supplying 5,500 homes); if heat only 41.0 MW; if CHP, heat – 12.9 MW and power – 21.9 MW, (sufficient for supplying 5,100 homes).

Diversion from landfill: The volume reduction of waste to be landfilled through this process is approximately 73%. The bottom ash potentially used in construction is 23%. Additional to this, is the limited amount of air pollution control residues (e.g. filter dusts) to be landfilled.

Project Lifetime: 25 years.

Investment costs: Include, transaction costs, civil works, equipment, facility, contractor costs and site specific costs. In this study these are estimated based on feasibility studies of existing WtE plants in Europe.

Costs include the provision of an IBA reprocessing facility, engineering, procurement and construction costs and lifecycle replacement costs.

The total capital cost of the facility is estimated in the range of 1.7 – 2.8 billion ZAR. Investment cost expressed in ZAR per tonne is estimated in the range of 8,500 – 14,200 ZAR. The upper cost is based on a PPP arrangement, assuming higher costs of financing amongst other variables.

Operational costs: Include staffing and process related costs, labour, consumables, services and maintenance costs as well as residue disposal. These costs are estimated based on similar facilities in Europe and elsewhere. Costs not factored in are the major lifecycle replacement costs.

Annual operation costs are estimated to be in the range of 700 – 850 ZAR per tonne of treated feedstock, while the total operational cost would be c. 140 – 170 million ZAR.

Based on this information being provided, the full specific cost would be in the range of 1,100 to 1,250 ZAR/t. The is roughly in line with the benchmark information presented earlier. It is important to note that all these cost estimations rely on examples from overseas and the first lessons learned for South Africa will come from the pilot incineration plants.

54 Utho Capital (Pty) Ltd., *`Technical Application Advisory Report. Feasibility Study of Waste-to-Energy Projects in Sedibeng and West Rand Municipal Areas`, 9 July 2014*

Case Study 14: Sidor MSW incinerator in Leudelange, Luxembourg

The MSW incinerator is property of Sidor intercommunal syndicate and is administered by EEW Energy from Waste Leudelange. It is the only incinerator in Luxembourg, commissioned in 2010 and it processes approximately 70% of the municipal waste in the country.

Input capacity and quality: 125 ktpa input capacity, municipal waste and assimilated. Recyclables and hazardous waste not accepted.

Gate fees: 96 EUR/tonne (1,250 ZAR/tonne equivalent) for municipal waste, 128/EUR tonne (1,700 ZAR/tonne equivalent) for voluminous waste and 178 EUR/tonne (2,300 ZAR/tonne equivalent) for household waste.

Human resources: The installation functions continuously, 24/24h and 7/7 days with 50 employees.

Investment and operation costs: Investment costs for the incinerator were 99 million EUR (1.3 billion ZAR equivalent) and operation costs amount to 12 million EUR per annum (155 million ZAR/annum equivalent). Operation costs for the treatment of waste are approximately 100 EUR/tonne (1,300 ZAR/tonne equivalent).

Equipment: The equipment of the incinerator includes: hoppers, combustion chamber with grates, ash collection pit, flue gas treatment and evacuation installation (dioxins and furans adsorbed on lignite coke, bag filters for fine particles, catalyst for nitrogen oxides removal). Combustion heat is used to produce steam that is then used for the production of electrical and thermal energy.

Remarks: Luxembourg is a high income, densely populated country where land is scarce and expensive. This environment is very favourable for an incinerator. The costs of the technology are reflected in the gate fees. This choice of technology is suitable for the specific context and gate fees are charged.

7.3 Mechanical Heat Treatment

7.3.1 Scale factors

Mechanical heat treatment (MHT) includes technologies that use thermal treatment in conjunction with the mechanical processing of waste. The purpose of these processes is to separate waste streams from mixed collection into separate components that can be further processed or used. Thermal treatment also sanitises waste by destroying bacteria and reducing water content. The key characteristics of this technology are presented in Table 31.

Table 31: Key characteristics of MHT

Characteristic	Description
Typical capacity	50 k – 500 k tonnes per annum
Indicative capital cost	c. 180 m – 550 m ZAR for a 100 ktpa MHT facility
Human resource requirement	Medium to high, includes engineers, chemists, an environmental manager, skilled workers, mechanics and drivers

Table 31 indicates that this technology is applicable in a similar scale as an MBT would be, it is able to handle the same mixed waste stream, and capital cost-wise is comparable to a complex MBT. The human resources requirement as with other of the potential technologies – long-term options is mostly highly skilled staff.

7.3.2 Cost benchmarks

The specific full cost of MHT facilities depend on the type of heat treatment used. There are essentially two types of MHT: autoclaving (i.e. batch process – steam processing in a vessel under pressure) and continuous heat treatment (i.e. continuous process waste is dried in a vessel using externally applied heat).

Specific equipment includes the 'pre-processing' waste equipment (i.e. screening equipment, shredders, loaders and waste homogenising equipment), waste heat processing equipment (i.e. autoclave, rotary kiln or other) and separation equipment for the materials removed from the heat treatment equipment (i.e. trommels and screens, manual separation conveyors, magnetic separation, eddy current air classifiers, ballistic separators and optical separators)[55].

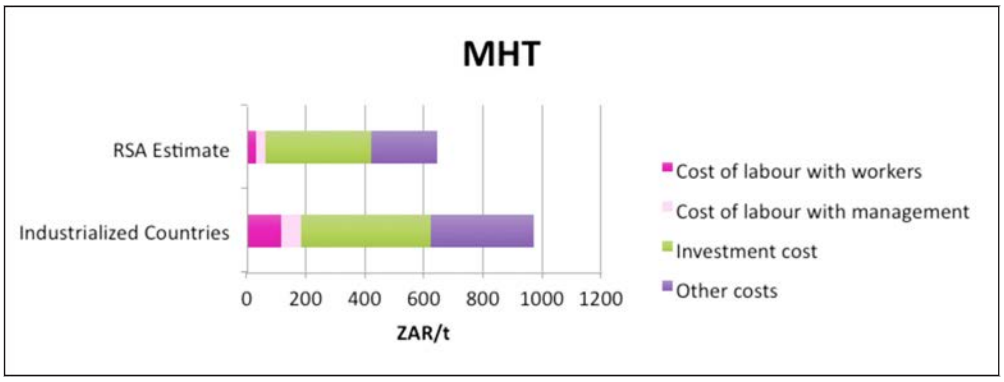


Figure 19: Full cost breakdown for MHT

The cost of the technology is estimated at 650-700 ZAR per tonne as shown in Figure 19. Important cost items include the maintenance, replacement and fuel costs, disposal costs for reject material, cost of outlets for fibre fraction, teatment of contaminants and screening costs.

7.3.3 Revenues and gate fees

A brief description of the MHT technology is presented in Table 32, which contains also the main factors that influence the revenues of this technology.

Table 32: Factors influencing Revenue - MHT

Technology Heading	Outline Description	Factors Influencing Revenue
Mechanical heat treatment (MHT)	MHT facilities combine mechanical and thermal treatment techniques, often with the prime aim of extracting either relatively high quality recyclables and/or fuel fractions (RDF) from the waste. In addition, and depending on the technology employed, they may: reduce the volume of waste; derive an organic fibre for use as a raw material/substitute fuel.	- Market value of recyclate - Distance to market/outlet for fibre, recyclables, fuel and rejects - Lack of a market for the organic fibre as raw material or substitute fuel

MHT technology is not necessarily more costly than some of the other technologies discussed in Chapter 6, suitable for the medium-term. However, the existence of a demand for the outputs of MHT (other than the recyclables) is unclear and, internationally, the market has not moved towards implementing the technology as a mainstream option. When considering the implementation of MHT, thorough market research should be conducted for the potential outputs. Combustion of waste-derived fuel or biomass may need special technology and environmental permits. A Market research would also provide information regarding the potential outlet for fibre from organic waste, which is a new product to the market.

55 *DEFRA - Department for Environment Food & Rural Affairs, UK, 'Mechanical Heat Treatment of Municipal Solid Waste', February 2013*

7.4 Advanced Thermal Treatment

7.4.1 Scale factors

Advanced thermal treatment technologies include gasification, plasma gasification and pyrolysis plants. These technologies may become viable options in the long-term, but currently suffer from a lack of an international operating track record. They also come with high implementation and operation costs, price and technical barriers to feeding the electricity produced into the grid. The key characteristics of ATT technologies are presented in Table 33.

Table 33: Key characteristics of ATT

Characteristic	Description
Typical capacity	10k – 250k tonnes per annum for gasification plants 10k – 500k tonnes per annum for plasma gasification 8k – 150k tonnes per annum for pyrolysis
Indicative capital cost	c. 620 – 860 million ZAR for a 60 ktpa gasification facility, the same for pyrolysis. Too few examples to provide capex range for plasma gasification
Human resource requirement	High skilled – includes engineers, chemists, environmental managers, skilled workers, mechanics and drivers
Land take	Similar space requirement to incineration process of equivalent scale, and more than RDF production because the energy conversion unit must be attached to the plant

7.4.2 Cost benchmarks

As with all other energy generation facilities, ATT technologies are designed in accordance with the specific properties of the input feedstock. ATT facilities require a highly homogeneous feedstock, and therefore require pre-treatment facilities to produce a suitable RDF. Land acquisition and facility buildings for ATT installations should take in to account the future development/modifications of the facility. They should have sufficient space to add new equipment to enable a swift response to market demands for materials and fuels.

The percentage of time in operation versus shut-off time due to repairs has a similar impact as in the case of incineration with energy recovery. Preventive maintenance is of utmost importance for the business case and economic viability of the facility, as unplanned outages imply a loss in income due to lack of supplied energy and the necessity for fuel injections in start-up operations.

Similar economies of scale apply as in the case of incineration to ATT: double the capacity of the plant, i.e. the tonnes handled, and multiply the capital cost by a factor of 1.6 to 1.8 to arrive to the investment cost of the facility. Thus, the investment cost per tonne decreases as the size of the facility increases.

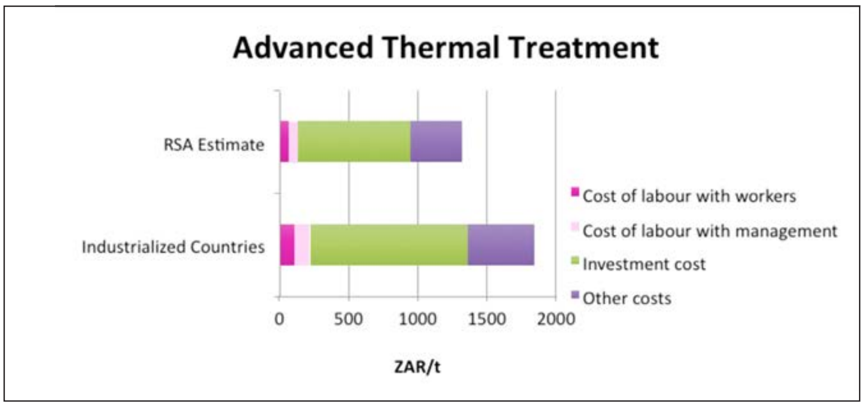


Figure 20: Full cost breakdown for ATT

As illustrated in Figure 20, ATT technologies are capital intensive. Full costs are estimated at approximately 1,300 ZAR/tonne, but could easily be higher. The cost of managing the flue gas treatment (FGT) process and residues, plus the costs and options for managing bottom ash/slag residues may be significant.

7.4.3 Revenues and gate fees

Table 34 describes ATT technologies such as gasification, plasma gasification and pyrolysis. The table further elaborates on influencing factors per technology.

Table 34: Factors influencing revenue - ATT advanced waste treatment technologies

Technology Heading	Outline Description	Factors Influencing Revenue
Gasification	Pre-treated waste feedstock (RDF) is treated in a reduced oxygen environment, therefore limiting processes to partial combustion and partial oxidation. The process produces a synthesis gas (syngas), which can be cleaned, then used as a replacement for natural gas, or combusted and used to feed a steam circuit producing electricity and/or heat. Metals can be extracted from the processed waste (ash/slag) ready for re-melting and preparation for reuse.	▫ Electricity revenue/revenue from syngas ▫ Any government incentives for low carbon energy/other energy recovery incentives ▫ Distance to outlets of bottom ash/slag and disposal of FGT ▫ Revenue from metals ▫ Opportunity and value to utilise waste heat from process ▫ Availability of feedstock/requirement for pre-treatment
Plasma gasification	Plasma gasification installations combine the gasification technology described above with plasma torches generating very high temperatures (>1,000°C). This, in theory, generates a cleaner syngas, enables use of gas in more efficient gas engines (after further clean up to remove sulphurs etc.), increasing the energy generation from the same quantity of feedstock.	▫ Electricity revenue/revenue from syngas ▫ Any government incentives for low carbon energy/other energy recovery incentives ▫ Distance to outlets of bottom ash/slag and disposal of FGT ▫ Revenue from metals ▫ Opportunity and value to utilise waste heat from process ▫ High upfront equipment costs ▫ Availability of feedstock/requirement for pre-treatment
Pyrolysis	RDF is thermally treated in an oxygen starved environment in order to facilitate the separation of waste into a char (non-combustibles, residues, etc.) and syngas. Syngas from pyrolysis typically has a higher calorific value than syngas from gasification based processes, and will be fed through a steam circuit in the same way as incineration or some gasification facilities.	▫ Electricity revenue/revenue from pyrolysis oil ▫ Any government incentives for low carbon energy/other energy recovery incentives ▫ Distance to outlets of bottom ash/slag and disposal of FGT ▫ Revenue from metals ▫ Opportunity and value to utilise waste heat from process ▫ Availability of feedstock/requirement for pre-treatment

Table 34 above illustrates that the technologies marginally differ from one another, but the factors influencing revenues, in the main, the same. The most important factor is the revenue from electricity, added to this revenues from syngas and pyrolysis oil are also important. The rest of the factors largely repeat and relate either to environmental performance, market conditions or quality requirements for inputs and outputs. These technologies are not viable unless there is a substantial gate fee being paid for each tonne of waste handled.

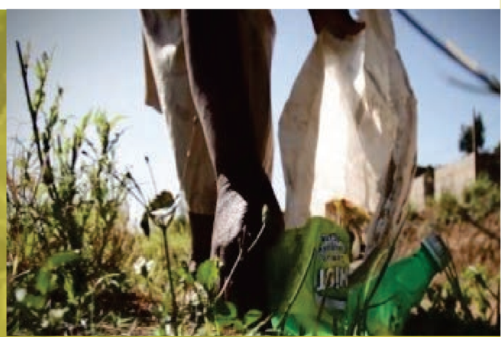
Internationally, there are a small number of pyrolysis and gasification plants that have been operating successfully for an extended period of time treating municipal waste. The more successful examples appear to operate on sub-fractions of residual municipal waste or for special waste streams such as tyres.

7.5 Concluding Remarks

As may be noted from the discussion on capital-intensive technologies, they are relatively expensive when compared to landfilling, costing approximately 800 ZAR per tonne (versus 400 ZAR/tonne for landfilling in Cape Town, as shown in Chapter 3 and 4). These are often favoured as collection systems do not need to change much. They remain mixed, and the technologies are able to generate energy (after intensive pre-processing to convert them into proper quality RDF input feedstock).

Chapter 8
CONCLUSIONS





8 Conclusions

Municipalities face a number of choices when deciding on whether or not to move from the business as usual scenario (i.e. landfill) to implementing AWT technologies. Cost is a key decision-making factor. Introducing AWT will usually entail an increase in cost to the municipality, but the scale of that increase will depend on the specifics of the AWT project. The relative cost component for investment in the full specific costs increases with the complexity of the technology options.

The business case for an AWT project may become compelling when the social and economic benefits are factored in. Labour intensity, in particular, is an important decision-making factor when selecting AWT options, and this means that those technologies that create sustainable employment opportunities are the most attractive options for implementation in South Africa. Multi-dimensional advanced integrated solid waste management (AISWM) systems have the potential to generate significantly greater business and employment opportunities compared to one-dimensional systems that depend solely on landfill.

According to recent research[56] the economic cost of landfill in South Africa is somewhere between 31.49 to 110.59 ZAR per tonne of waste. Tailored analysis should be carried out for specific situations, but it is clear that even factoring in the lower band estimate of economic cost of landfill into financial analysis of AWT projects would have a significant effect on the business case.

There are currently no economic instruments (such as landfill taxes/levies) in place that enable municipalities to take the economic costs of landfill into consideration in budget planning or project decision taking. Decisions must be taken on the basis of an assessment of the financial costs and benefits of an AWT project.

The document has modelled the costs of different AWT technologies. The cost ranges being presented, should be regarded as indicative and not definitive. Internationally, there are few authoritative sources of consolidated cost information, and assumptions need to be made to adapt these cost profiles to the South African context.

AWT technologies are presented in three categories: promising technologies – short-term, potential technologies – medium-term, and potential technologies – long-term.

The promising technologies are those that:

- are relatively inexpensive;
- have a readily accessible market demand for outputs; and
- are labour-intensive.

Promising technologies for the short-term include windrow composting of green waste, construction and demolition waste recycling, and materials recovery facilities (MRF) for municipal solid waste. For these technologies, there are existing facilities operating in the South African market to learn from, replicate and scale up. The cost ranges for these technologies are within range of the full cost of landfill (currently estimated at 200-400 ZAR/tonne):

- Windrow composting: 300 - 400 ZAR/t
- Construction and demolition waste recycling: <300 ZAR/t
- Materials recovery facilities: 300 – 400 ZAR/t

56 *Nahman, A. "Environmental and disamenity costs associated with landfills: A case study of Cape Town, South Africa", 2011, http://researchspace.csir.co.za/dspace/bitstream/10204/5284/1/Nahman_2011.pdf*

Potential technologies applicable in the medium-term include mechanical biological treatment (MBT), anaerobic digestion (AD) and in-vessel composting (IVC). Application of these advanced waste treatment technologies in the South African market is at the early stages. The cost ranges for these technologies are above the full cost of landfill, but in certain cases, in particular where there is a secure and stable local demand for the outputs from these AWT processes, the business case for these facilities may be compelling. The cost ranges are:

- Simple mechanical biological treatment (MBT): 300-500 ZAR/t
- MBT with intensive decomposition and fermentation: 700-900 ZAR/t
- Anaerobic digestion: 700-800 ZAR/t
- In-vessel composting: >600 ZAR/t

Potential technologies applicable in the long-term include incineration with energy recovery, mechanical heat treatment (MHT), and advanced thermal treatment (ATT) including pyrolysis and gasification. These are all thermal treatment processes, and in the South African market context will be significantly more costly than landfill. However, in major metropolitan cities where it may be difficult to secure sufficient landfill capacity, there may be a business case. The cost ranges for these technologies are:

- Incineration with energy recovery: 1,200-1,500 ZAR/t
- Mechanical and heat treatment: 600-700 ZAR/t
- Advanced thermal treatment – gasification: 1,300-1,700 ZAR/t
- Advanced thermal treatment – plasma gasification and pyrolysis: 1,300 - 1,700 ZAR/t

Several of the AWT technologies are tailored for specific waste fractions, and therefore require collection systems to be adapted potentially increasing costs further. However, it may be possible to locate an AWT facility at closer proximity to the main centres of waste generation than landfill, therefore making savings on the costs associated with transport.

Several AWT technologies, in particular fluidised bed incineration, and advanced thermal treatment (pyrolysis and gasification), require a pre-processing stage to prepare the input feedstock for use. This introduces further costs, which are not reflected in the specific cost ranges presented.

For all AWT projects, it is essential to undertake a detailed options analysis within planning and feasibility studies, in order to determine the most appropriate and financially sustainable option. This should take into account cost as well as other socio-economic criteria, and be specific for each case. As costs are very location specific, they are best analysed within the framework of a feasibility study.

Environmental protection and mitigation measures represent an important part of the costs. Certain technologies require very close attention to ensuring that the environmental impacts from the AWT process meet emission standards.

Since most municipalities have limited financial and operational capacity for AWT investments, private - public partnerships (PPP) are an attractive option. Financing could be stimulated through launching governmental tenders for the treatment of specific waste streams, with the condition that the cost of treatment to the municipality will not be more than the cost of legally compliant landfill - BAU. However, such contracts would need to be carefully vetted to ensure that the operator is fulfilling their landfill diversion commitments.

The avoided cost of landfilling and airspace plus revenues from recovered materials and energy may, in certain cases, tip the balance in favour of AWT. The difference between the Full Costs and the Avoided Costs represents the 'cost jump' the municipalities need to calculate when evaluating the business case for AWT. The cost jump to the municipality can be calculated by subtracting the costs of landfilling and airspace, cost of cleaning up illegal dumps, and revenues from the sale of materials from the full cost of treatment.

Under the current financial framework, AWT projects willl often require a public financing component or subsidy in order for them to be financially sustainable. This may be justifiable where a strong economic case is demonstrated, taking into account the employment benefits.

Certain industrialised countries that have succeeded in establishing higher treatment intensity, and diverting larger percentages of municipal waste away from landfill, have done so when policy instruments have been introduced to shape the market conditions. The prospects for implementing advanced waste treatment technologies in South Africa will greatly benefit from an enabling policy environment, fiscal system and from incentives delivered through economic instruments.

In view of the need to advance on meeting the National Waste Management Strategy targets, municipalities need to consider how best to divert significant quantities of municipal solid waste from landfill. With increased use of policy instruments that shape the market over time, the bottom line for introducing AWT is set to improve.

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