Planning and Achieving Full Beneficiation of Waste Incorporating Waste-to-Energy in a large Metropolitan City: A Case Study

L.J. Strachan. Market Segment Leader (Waste & Resources Management), Royal HaskoningDHV, South Africa. lindsay.strachan@rhdhv.com
R. Green. Market Segment Leader (Biomass & Waste), Royal HaskoningDHV, South Africa.
R. Jagath. Projects Engineer (Waste & Water Systems), Royal HaskoningDHV, South Africa.
N. Sithole. Snr Advisor Renewables, Sustainability Division, Eskom Holdings SOC Ltd.
R le Roux. Acting Director: Waste Management, Nelson Mandela Bay Municipality (NMBM).

ABSTRACT

The planning of successful waste management processes and associated transportation infrastructure, where the full beneficiation of waste as a resource is the principal objective, must adhere to the widely established waste management hierarchy. Omnipresent in South Africa are examples of stillborn waste-to-energy (WtE) projects in Metropolitan Cities which never proceeded owed to a failure to take complete cognisance of the full waste hierarchal requirements - prior to the consideration of energy recovery from waste. Furthermore, such projects have considered the procurement of WtE technology providers in the absence of a detailed waste management plan!

Eskom and the Nelson Mandela Bay Metro (NMBM) are jointly committed to the development of renewable energy by employing waste-to-energy technologies, meeting targets on energy diversification and reducing carbon emissions. However, the NMBM aims to achieve this through an integrated waste beneficiation plan which is economically advantageous. This paper describes this approach as a case study.

1. INTRODUCTION

1.1 Planning a Waste Management Strategy for Beneficiation

“Plans are of little importance, but planning is essential.”

Winston Churchill

Crucial to the beneficiation of waste resources is a well-planned waste management system which may produce significant benefits whereby the terminology “Resources Management” may be more fitting. Planning in waste management for Cities, Metros and local Government infrastructure should consider the full waste hierarchy (as depicted in Figure 1 below) enabling required action towards waste reduction, re-use and recycling prior to the consideration of energy recovery. Recovery of energy (prior to final disposal) is a step yet to be fully taken in any Metropolitan City in South Africa which, apart from landfill gas (LFG) recovery and utilisation in eThekwini (where LFG is not a WtE technology by definition) there are limited examples of waste-to-energy currently.

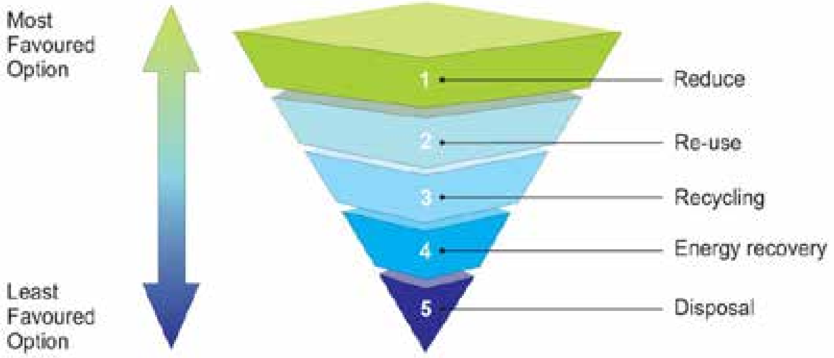

Figure 1. The full waste management hierarchy to be considered for all infrastructural planning and development.

1.2 Energy Beneficiation

The quality characteristics of any Municipal Solid Waste (MSW) waste-stream such as that from the NMBM can provide large volumes of fuel resource (also termed *feedstock*) for possible energy utilisation. Moreover, the thermal calorific values of waste, particularly prepared wastes such as Refuse Derived Fuel (RDF) and Solid Refuse Fuel (SRF), are close to those of coal – as illustrated in Table 1 below. Significant advantages of using waste as a fuel resource are:

1. A Waste Management Solution is provided whereby waste-volumes may be reduced; and
2. Hence, transportation costs for waste may be significantly reduced where a WtE plant could be located close to the source of waste generation thus curtailing transport distances;
3. Energy generated is Renewable Energy;
4. Carbon Emission Reductions would be realised by displacing coal fuel – where coal derived carbon emissions are some 1 ton CO_2 per MWh, and by displacing landfill gas methane emissions where waste is reduced to landfill disposal;
5. Significant job creation may be created where wastes are separated at source or at transfer (after collection) wherein by-hand separation is applied. A materials recovery facility (MRF), operated in recent times in the eThekwini Municipality reported the creation of 1 sustainable job created per 2 tons of raw waste processed; and
6. Large volumes of (saleable) recyclables are simultaneously recovered from the waste-streams for economic benefit.

Table 1. Estimated Gross Calorific Values of fuels (comparing Coal vs Renewable (Waste) Resources (values in GJ per tonne) (DTI(UK), 2014)

Coal		Waste Resources	
Power Stations	26.1	Municipal Solid Waste (MSW)	9.5
Coke ovens	30.5	Refuse Derived Fuel (RDF)	18.5
Pulp & Paper	28.8	Solid Refuse Fuel (SRF)	22.5
Engineering incl. Iron & Steel	30.5	Tyres	32.0
Other Industries (av)	26.8	Industrial wood waste	11.9

1.3 Waste Management Cost Beneficiation

The most significant cost factor for the management of waste in a city or metropolis is arguably the cost of waste-logistics and transportation. Possibly in excess of 70% of a gross operational expenditure (opex) budget is typically attributed to the cost of waste collection, transfer and transport. Often misunderstood can be the overall unit cost of waste management of a city, and the weighbridge tariff charge is widely misinterpreted as being the cost of waste disposal. In the case of the NMBM the unit cost for waste management encompassing collection, street sweeping, illegal dumping, disposal to landfill, etc, is some R500million pa. This expenditure, for the overall management of some 500,000tpa of waste, detailed in Figure 2 below, provides a unit cost of some R1,000.00 per ton. The actual waste tonnage portion conveyed by the NMBM vehicles and their contractors only, is some 200,000tpa which, therefore, provides a theoretical unit cost of some R2,500.00 per ton. Consequently, the beneficiation economics (for cost savings) were compared against such unit costs.

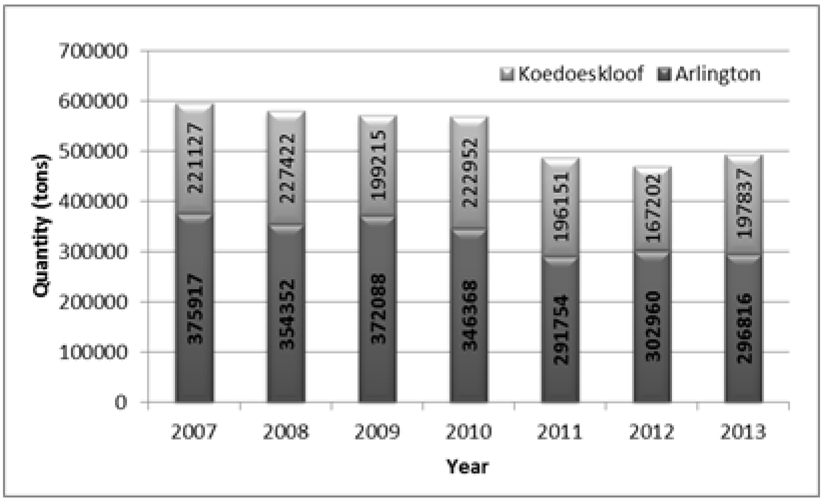

Figure 2. Total Waste Generated within the NMBM disposed to the Arlington and Koedoeskloof landfills

1.4 Zero Waste to Landfill?

Landfills are the most widely utilised method for the disposing of solid wastes in South Africa and Africa as a whole (Strachan and Csepany, 2012). Landfills in South Africa currently serve the public's need as the most economically-appropriate option for the disposal of wastes and will arguably continue to do so for the foreseeable future. However, as available landfill airspace diminishes in SA and distances to the landfills increase, total waste management costs will congruently also increase significantly. Most alternative waste management options such as anaerobic digestion (AD), incineration, pyrolysis, gasification, composting, waste recovery and recycling by and large realise reductions in waste volumes with energy benefits – whilst they rely on landfill for the final disposal of their by-products and process residues. In the case of the NMBM the curtailing and optimisation of transportation distances, by the strategic location of a WtE plant(s) and associated waste infrastructure i.e. MRF's and transfer stations, was of significant economic importance. Additionally, the optimal location of other waste treatment infrastructure for example composting plants, anaerobic digestion (AD) plants and aggregate recovery plants also contributes favourably to the overall economic feasibility of waste management planning – and the near-achievement of 'zero waste'.

Energy from Waste represents a favourable step towards achieving complete waste diversion from landfills – towards the widely used adage 'zero waste'. Arguably there will always be waste residues to any waste treatment or disposal method adopted – even landfills leak out large volumes of biogas and noxious leachates. Planning in South Africa (the NWMS; 2008), encompassing waste management plans for Cities, Metros and Government infrastructure must consider the full waste hierarchy (as depicted in Figure 1 above) and there has been much action towards waste reduction, re-use and recycling. But, to an energy intensive SA where energy costs are rising possibly more steeply than growth and price indices, recovery of energy (prior to final disposal) is a step that is yet to be fully taken. The NMBM may spearhead such development with the primary aim of determining the 'best mix' of waste management solutions within NMBM to realise:

I. Diversion of as much waste from landfills as is possible, according to the waste hierarchy; and to
II. Stimulate economic development through waste (resource) beneficiation by applying appropriate, cost-effective and sustainable methods including waste-to-energy (WtE).

2. WASTE STREAM CHARACTERISATION AND PLANNING OF SYSTEMS

2.1 The Waste-Streams of the NMBM

2.1.1 Waste Transportation

The NMBM transports waste with their fleet of specialist waste vehicles comprising rear-end-loaders (REL'S), industrial REL's, tally-hoists, hook-lifts and box-trucks. Furthermore, much waste is transported within the municipal area by vehicles owned and operated by the private sector. One such private company of predominance in the Metro, namely EnviroServ, own and operate the Aloes II hazardous waste landfill site and also utilise the NMBM owned landfills for the disposal of general waste. Furthermore, the NMBM and appointed contractors currently transport waste-streams amounting to some 200,000tpa (~550tpd) whilst the total overall waste transported and disposed to landfills within the NMBM is 510,000tpa (~1,400tpd).

2.1.2 Waste Drop-Off Sites

The NMBM employ a system of waste drop-off sites located throughout the municipal metropolitan area. Whilst these sites function as effective transfer stations, they are not engineered transfer stations *per se*. Generally none of the sites carry out waste compaction and the waste is transported from the sites to the landfills in loose form. These sites are simply engineered, low cost yet highly practical, accessible and strategically located throughout the Metro. Figure 3 illustrates a NMBM drop-off site within the metro area.

Figure 3. Illustration of a waste drop-off site in the NMBM which are simple and effective facilities.

2.1.3 Arlington Landfill Site

The Arlington Landfill is a large General waste landfill, permitted as a G.L.B$^+$ facility in accordance with the Minimum Requirements (DWAF, 1998), located to the south of the City of Port Elizabeth as illustrated in Figure 4 below, and accepts all wastes of a General Waste categorisation. The landfill has been operational since 1987. The most recent landfill airspace assessment estimated that the site has airspace capacity to continue operations until 2034. The site received an average of 334 322 tons of waste annually between 2007 and 2013. The daily average waste disposal rate to Arlington landfill is some 830 tons per day.

2.1.4 Koedoeskloof Landfill Site

The Koedoeskloof Landfill is a large landfill permitted as a G.L.B$^+$ landfill with a H:h disposal facility in accordance with the Minimum Requirements (DWAF, 1998), accepting all types of general waste and, to an independent facility, low hazardous liquid wastes. The landfill, located to the North West of the City of Port Elizabeth and illustrated in figure 4 below, has been operational since 1984. The site received an average of 204 558 tons of waste annually between 2007 and 2013. The site has sufficient airspace capacity for +20 years. The daily average waste disposal rate to Koedoeskloof landfill is some 570 tons per day.

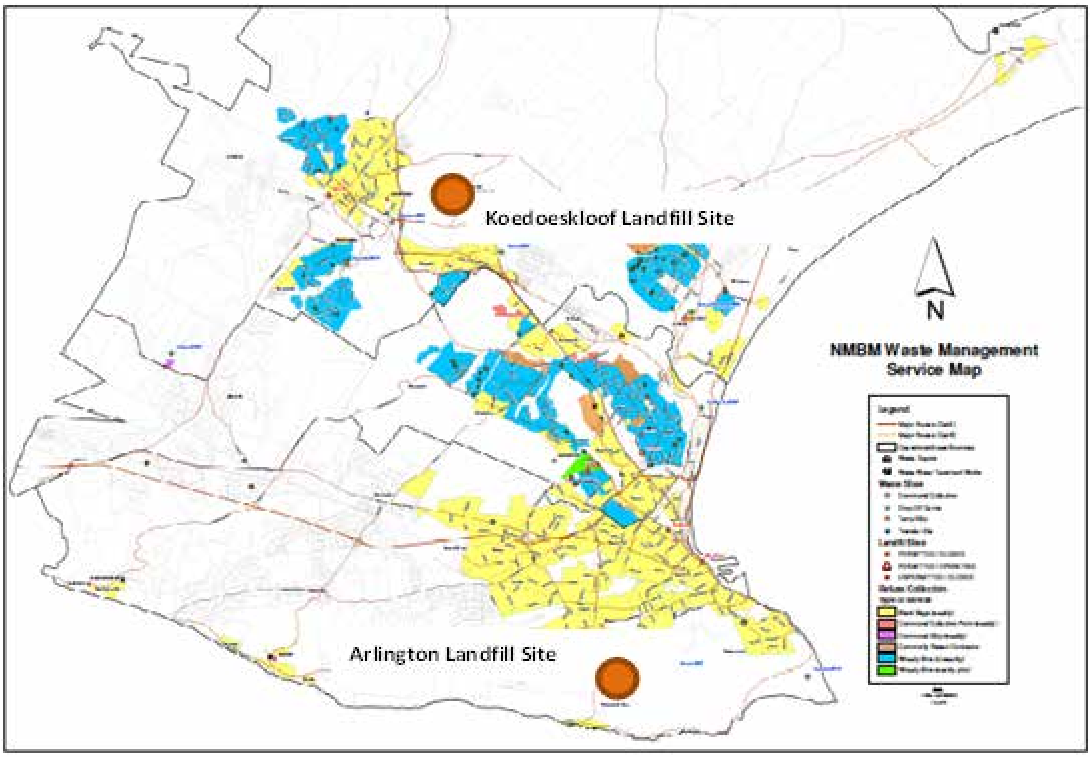

Figure 4. The locations of the NMBM owned and operated Arlington (GLB+) and Koedoeskloof (GLB+ and H:h) landfill sites within the Nelson Mandela Bay Metro Area.

2.1.5 Waste Streams to be Characterised

As part of the planning stage of the waste planning and WtE feasibility study, weighbridge data for both Arlington and Koedoeskloof landfill sites was reviewed. Further to this, on-site waste characterisation assessments were carried out at each landfill to verify the data. The data records kept by the NMBM were found to be comprehensive, with every type of waste classified into a sub-category. Each of the categories were characterised by employing the following methods:

- Using existing waste characterisation data from a NMBM 2011 IWMP Waste Characterisation study;
- Using existing data from a NMBM 2010 Illegal Dumping Waste Characterisation study that was further characterised by incorporating the latest data of a 2013 IWMP Waste Characterisation study;
- Using the NMBM’s 2014 *RHDHV Visual Assessment Waste Characterisation Methodology* during field visits to each Landfill Site;
- By grouping waste categories that originate from a similar source or activity. For example, the categories ‘Rubble and Concrete’ and ‘Cleansing Rubble’ were jointly characterised as ‘Construction Waste’.
- By classification in accordance with an established and widely applied Waste Category definition.

The remaining categories were classified as ‘Other waste’ since they were either of negligible quantity or considered to have no recognisable characteristics for specific waste diversion or waste treatment apart from that of being considered a waste residue for landfill disposal. The characterisation and method for each of the waste categories is summarised in Table 2 below.

Table 2. Waste Categories Employed in the Waste Management Planning by the NMBM

WASTE CATEGORY		METHOD OF CHARACTERISATION
CD	cleansing domestic	2011 IWMP Waste Characterisation
CF	cleansing filling	Classified as 'Other Waste'
CG	cleansing garden	2014 RHDHV Visual Waste Assessment Protocol
CM	cover material	Classified as 'Cover Material'
CR	cleansing rubble	Classified as 'Construction Waste'
CT	cleansing trade	2014 RHDHV Visual Waste Assessment Protocol
CU	cleansing unclassified	Classified as 'Other Waste'
DA	dead animals/carcass	Classified as 'Other Waste'
DD	domestic dumping	Updated 2010 Illegal Dumping Waste Characterisation
FD	fine dust	Classified as 'Other Waste'
FE	feathers	Classified as 'Other Waste'
FO	foodstuffs	Classified as 'Food Waste'
GL	glass	Classified as 'Glass'
HA	Hazardous (Surcharge)	Classified as 'Hazardous Waste'
HN	hazardous no treatment	Classified as 'Hazardous Waste'
GR	garden refuse	2011 IWMP Waste Characterisation
JB	junk / car bodies	Classified as 'Other Waste'
MP	mayoral projects	Classified as 'Other Waste'
MW	mixed waste	2014 RHDHV Visual Waste Assessment Protocol.
OS	offcuts steel	Classified as 'Metals'
PR	private waste	Classified using Weighbridge Service Categories
RC	rubble & concrete	Classified as 'Construction Waste'
RP	rubber, plastic & textiles	Classified as 'Rubber, Plastic and Textiles'
SE	sewerage screenings	Classified as 'Other Waste'
TS	tree stumps	Classified as 'Wood Waste'
TY	tyres	Classified as 'Tyres'
UB	uncut belting	Classified as 'Other Waste'
WL	wool	Classified as 'Other Waste'
WP	wood & paper	2014 RHDHV Visual Waste Assessment Protocol
XX	Clean and Green Specials	Classified as 'Other Waste'

2.2 Waste Management Planning

A medium to long term waste management plan (WMP), based upon an accurate waste characterisation and quantification study, in strict accordance with the waste hierarchy discussed previously, was a crucial requirement of the feasibility study for the NMBM. From this WMP, the various waste management options were assessed, quantified, costs estimated and timelines programmed. Figure 5 below provides an illustrative typical output for the study. It is perhaps important to note that such a WMP is akin to a business plan and strategy and is not a generic plan that is often devised as a submission for regulatory purposes.

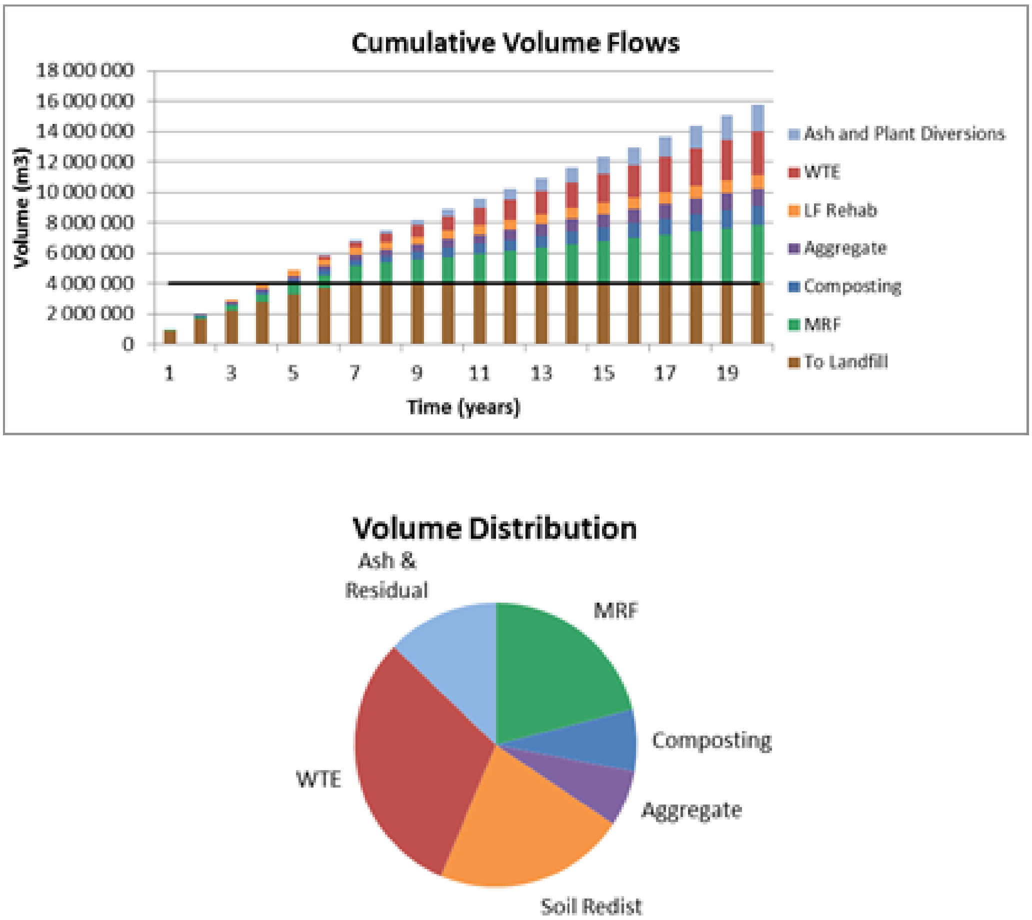

Figure 5. Illustration of medium to long term waste management planning based upon a waste characterisation and quantification study, which was carried out in accordance with the Waste Hierarchy for Eskom-NMBM.

2.3 Waste Treatment Systems

Thermal technologies for the conversion of waste-to-energy are typically categorised under the three principal (and generic) headings of mass burn (or incineration), gasification and pyrolysis covering the full range of combustion processes. ‘Mass burn’ technologies are arguably the most economical cost option in comparison to the more novel gasification and pyrolysis technologies. However, gasification and pyrolysis can be suitable to smaller scale (<1.0 tpd) and decentralised installations. Gasification and pyrolysis processes are descriptions for what may be considered as intermediate stages in the combustion process that additionally create synthetic hydrocarbon fuels (syngas). These fuels may be processed to recover energy through a range of additional processes. Plasma arc gasification technology has been in use in commercial applications and is currently being introduced as an application for waste treatment. Plasma arc technology is not, however, generally used as the sole means for processing waste materials as this would require very high levels of energy without comparable benefits.

Waste-to-energy by and large does not involve new technologies and 'unchartered waters'. AD in particular is not a new technology, and has been widely applied for the treatment of sewage sludge for over a century. However, only recently has it been considered for application in SA for treating other organic wastes and agricultural wastes in order to generate renewable energy and divert waste from landfill. AD is a natural process in which micro-organisms break down organic matter or biowaste (such as food wastes, slurry, crop residues, etc.), in the absence of oxygen, into biogas (a methane rich mixture comprising some 40 to 50% carbon dioxide (CO_2) and some 50 to 60% methane (CH_4)) and digestate/biofertiliser. AD is a viable industrial process to manage waste and to generate renewable energy. The biogas can be used in a number of ways:

- directly in gas engines (gen-sets) for electricity generation and possibly in a Combined Heat and Power (CHP) type engine arrangement (noting that exhaust heat may also be utilised);
- burned to produce heat; (which could also produce steam) or can be cleaned/scrubbed to become bio-methane and used in the same way as natural gas or as a vehicle fuel.

The digestate/biofertiliser, which is produced by the biological processes contains valuable chemical nutrients such as nitrogen and potassium, and can be used as a renewable fertiliser or soil conditioner.

3. SITE SELECTION, TECHNOLOGY SELECTION AND CONCEPT DESIGN

3.1 Feedstock-Fuel, Land and Energy Off-take

The principal factors for the location of a WtE plant are, almost simplistically, FEEDSTOCK / FUEL, LAND and ENERGY OFF-TAKE. Each one of these must be effectively *'ticked off'* prior to further serious consideration of the development of a project. For the selection of a viable site for the proposed waste management infrastructure including a MRF, a WtE plant and possibly a waste transfer station, the following approach for the NMBM, also illustrated in Figure 6 was employed:

I. FEEDSTOCK (availability, quantification, characteristics);
II. LAND (availability, sufficient area, environmentally acceptable, close to waste (fuel) source to provide benefit to transportation of waste within the NMBM, and energy off-take points i.e. electricity sub-station and heat and/or steam off-take);
III. ENERGY OFF-TAKE (purchase of electricity and heat/steam. Also, if applicable – the purchase of ash (fly-ash and bottom ash) and/or bio-char).

Organic wastes would also be potentially available for anaerobic digestion (AD) to the order of a total of some 30,000 tons per day in the NMBM area. However, the major portion of this amount would have to be recovered by way of a MRF, hence the Mechanical Biological Treatment (MBT) processes would be the underlying technology application for the organic wastes within the NMBM.

The determination of the most appropriate location(s) for the development of the WtE facility in the NMBM was made with the following considerations of a decision making matrix:

i. Land Ownership: Existing municipal owned land availability was favoured within the identified areas;
ii. Distance from waste source: Location as close as possible to the waste generation source to reduce transportation and logistics costs as well as to secure feedstock-fuel supply for the facility;
iii. Transportation access to the proposed site using (as far as possible) existing infrastructure;
iv. Safety and security risks;
v. Proximity of surrounding residential communities;
vi. Proximity of neighbouring industries – primarily for steam or heat energy off-take;
vii. Air Emissions: background data and modelling for the proposed activity;
viii. Immediate environmental concerns e.g. wetlands, biodiversity, water resources, etc;
ix. Electrical connection concerns of significance;
x. 'Fatal flaw' concerns e.g. the location of an airport – such as was the case with the potential WtE site at the Arlington landfill site;

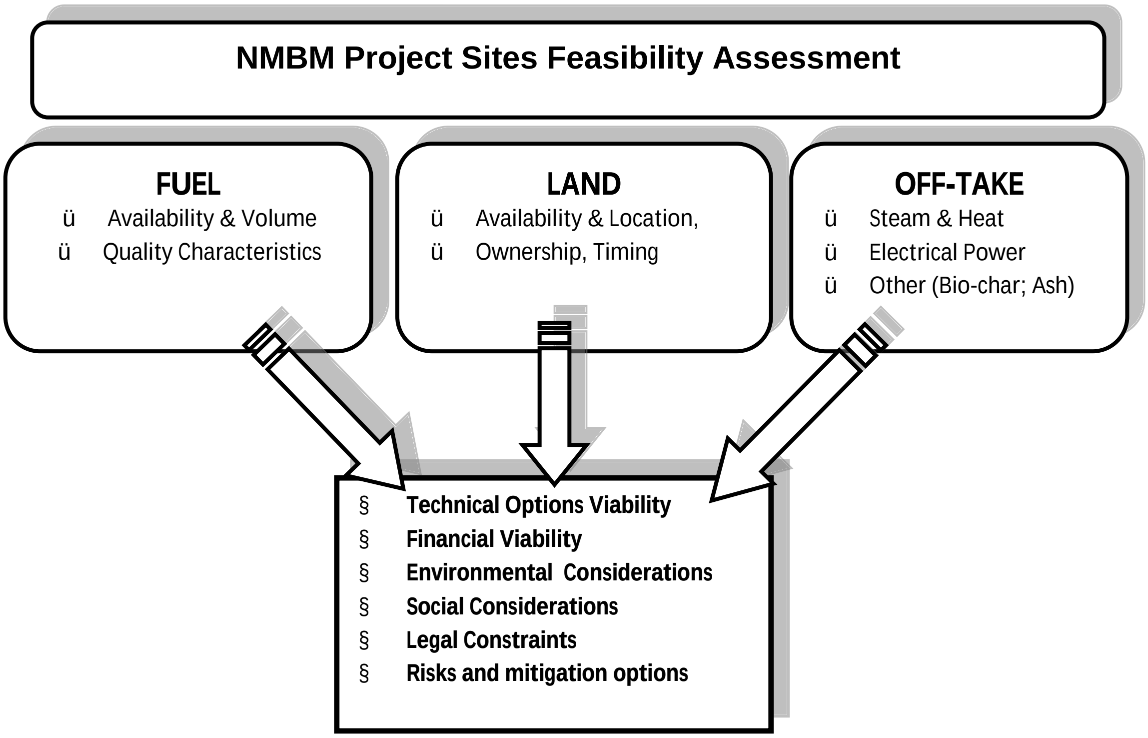

Figure 6. Illustration of the initial crucial selection criteria for the establishment of a WtE plant.

3.2 Front End Engineering Design (FEED) Study

There are a wide range of treatment and disposal options that could be considered as part of any long term integrated waste management strategy where waste-to-energy is a consideration. Whilst the solution may include a selected form of thermal waste to energy technology there could be other treatment and disposal options available to a municipality like the NMBM, which may prove to be economically or environmentally attractive as well as necessary to specific waste-streams. In reviewing the treatment and disposal options there was the requirement to show how the principles of the waste management hierarchy were applied. This involved demonstrating how waste minimisation, reuse, recycling, recovery and final disposal were incorporated. Such options for waste management infrastructure included:

- Waste transfer stations;
- Material recycling facilities (*clean* MRF and *dirty* MRF);
- Storage facilities;
- Composting facilities;
- Anaerobic digestion (AD) – for waste organics;
- Mechanical Biological Treatment (MBT) - with and without energy recovery;
- Mechanical heat treatment;
- Mass Burn (or incineration);
- Advanced Thermal Treatment - Gasification and Pyrolysis; and
- Landfill with leachate and gas recovery (landfill gas to energy or bio-methane).

The output of this phase of work was a summary report setting out the options considered and the preferred option(s) identified under this task, together with a clear recommendation for taking the project forward. The output of the FEED study is a key requirement for any future procurement considerations by the municipality on the preferred solution(s).

4. CALORIFIC VALUES DETERMINATION

4.1 Representative Sampling

The accurate determination of the waste characterisation was crucial to the determination of a representative sample selection for the analysis of the calorific value (CV) – required for the WtE plant concept design. This becomes important in determining the type of WtE plant to be selected, the quantity of energy to be generated, thermal energy potential and the remaining ash composition. The CV was determined both theoretically (based on the detailed waste characterisation and planning study) and by laboratory analyses.

Representative samples had to accurately reflect the ultimate treatment design options. This was a challenging task as the solid waste stream was highly variable and heterogeneous unlike other streams or fuel feedstocks or biomass in industrial production processes. To offer an illustration of the sampling dimensions for the determination of the CV value: representative samples were obtained from each of the landfill sites whereby *four 10 litre samples were obtained from a football field of waste a metre deep – and the laboratory took four teaspoon samples from these!* Two sample types were obtained from each of the landfills. The first representative sample, following a protracted quartering process, was of *non-recovered* wastes. The sampling team then removed all potentially recyclable materials from the same remaining quartered sample, and thus obtained a *recovered* waste sample.

4.2 Moisture content analysis

The moisture content of the sample was determined according to the methods specified in the American Standard Test Methods (ASTM) for direct moisture content measurement of waste material at a temperature of 1050^{o}C for 24 hours. This involves the continual weighing and reheating every hour until a constant weight was observed to +/-0.02g of the previous weight. The preliminary results for the moisture contents for the various representative waste-streams of the NMBM are provided in Table 3 below.

Table 3. Preliminary results for moisture contents of representative waste-streams in the NMBM.

Determinand	Arlington waste-streams (% av. moisture content)	Koedoeskloof waste-streams (% av. moisture content)
Without waste recovery	25.9%	37.6%
With waste recovery	45.4%	41.1%

4.3 Organic matter, ultimate elemental analysis and heating value determination

The determination of the calorific values was still underway at time of print of this paper nonetheless, some further explanation is provided. The dried sample from moisture determination must be incinerated in an oven at high temperature. During this process all the organics are combusted at 9500^{o}C to carbon dioxide and water (vapour) and the residual ash remains. The mass of ash divided by the starting dried mass of waste will determine the percentage ash and by difference, the percentage organics is determined. For combustion calculations it is also important to determine the composition of targeted elements such as hydrogen (H), carbon (C), oxygen (O), nitrogen (N) and sulphur (S) according to ASTM methods.

Standard Test Methods will be used for gross caloric value or higher heating value (HHV) determination on a dry basis using an oxygen bomb calorimeter, suitably standardized to determine the gross caloric value (HHV) while the net (lower) calorific value (LHV) is calculated using the weight % of hydrogen resulting from elemental analysis. For quality control purposes duplicate samples are to be taken to ensure consistency and reliability in results. Several representative samples were supplied to the laboratory so to obtain an average value and to determine the variability in the samples. The procedure should preferably be repeated again to ascertain seasonal influences.

5. WASTE TO ENERGY PLANT

5.1 Options for waste management infrastructure and WtE plant sites

Three final selected sites were established, following the detailed planning process discussed previously for the potential placement of a WtE plant, namely Coega, Koedoeskloof and PPC West. These sites were selected from an initial selection of 7 sites. Only the PPC West site has a current demand for steam off-take whilst the Coega site provides high probability since the Coega Industrial Development Zone (IDZ) could earmark future tenants in their development strategy - whereby they could offer steam and/or heat energy in addition to renewable electrical energy from waste to future tenants. The Koedoeskloof site is remotely located and there is currently no foreseeable option for steam or heat energy off-take.

5.2 WtE options with resource recovery

Of the several options for waste management systems on the proposed sites, Table 4 below provides estimated electrical energy outputs for a proposed WtE plant with resource recovery from the waste-streams of the NMBM region. The theoretical calorific value (CV) was 7.0MJ/kg. Waste input varies from some 140tpd to 395tpd. The 1,000tpa difference between option B and option C is the current reported available waste-stream (for WtE) from the Coega IDZ. The specific WtE technology option is still to be decided.

Table 4. Indicative electrical energy outputs for WtE plants in the NMBM (with resource recovery)

WtE Waste Streams [With Resource Recovery]	Input (est. tons)	Input (tons/day)	Bottom Ash (est. tons)	Fly Ash (est. tons)	WtE Power Est. Output (MWe)
Option A (WtE at PPC West) *MRF at PPC West only*	39 910	140	9 977	1 995	5
Option B (WtE at PPC West) *MRF's & Transfer thru'out NMBM*	111 868	391	27 967	5 593	14
Option C (WtE at Coega) *MRF's & Transfer thru'out NMBM*	112 868	395	28 217	5 643	14
Option D (WtE at Koedoeskloof) *MRF's & Transfer thru'out NMBM*	112 868	395	28 217	5 643	14

5.3 WtE options without resource recovery

Similarly, of the several options for waste management systems on the proposed sites, Table 5 below provides estimated electrical energy outputs for a proposed WtE plant without resource recovery from the waste-streams of the NMBM region. The theoretical calorific value (CV) was 9.0MJ/kg. Waste input varies from some 254tpd to 722tpd.

Table 5. Indicative electrical energy outputs for WtE plants in the NMBM (without resource recovery)

WtE Waste Streams [Without Resource Recovery]	Input (est. tons)	Input (tons/day)	Bottom Ash (est. tons)	Fly Ash (est. tons)	WtE Power Est. Output (MWe)
Option A (WtE at PPC West) *No MRF at PPC West*	72 706	254	18 176	3 635	7
Option B (WtE at PPC West) *No MRF's & Transfer thru'out NMBM*	205 634	719	51 409	10 282	20
Option C (WtE at Coega) *No MRF's & Transfer thru'out NMBM*	206 634	722	51 659	10 332	20
Option D (WtE at Koedoeskloof) *No MRF's & Transfer thru'out NMBM*	206 634	722	51 659	10 332	20

6. CONCLUSIONS

Planning in waste management for Metropolitan Cities and any local government waste management infrastructure should consider the full waste hierarchy of processes, enabling required action towards waste reduction, re-use and recycling - prior to the consideration of energy recovery. Recovery of energy (prior to final disposal) is a step yet to be fully taken in any Metropolitan City in South Africa which, apart from landfill gas recovery and utilisation in eThekwini, there are limited examples of energy from waste currently. Eskom, in partnership with the NMBM and National Treasury are carrying out detailed waste management planning to ensure that optimal economical options are established for waste management systems, processes and infrastructure - so that full beneficiation of waste for the NMBM can prevail. The cost of waste transportation and logistics is a significant cost contributor in the NMBM. The unit cost of waste management the NMBM is some R1,000 per ton for waste collected, transported and disposed to landfill.

The preliminary results for moisture content displayed a 75% and 10% variation, for without-waste-recovery vs with-recovery waste samples, for the Arlington and Koedoeskloof waste-streams respectively. The calorific values currently calculated (at time of print of this paper) were 7MJ/kg and 9MJ/kg for without-waste-recovery vs with-recovery waste-streams. The estimated electrical output of a possible WtE plant for the NMBM varies from 14MWe to 20MWe for without-waste-recovery vs with-recovery waste-streams.

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