WASTE-TO-ENERGY: CAN IT BE A SOLUTION TO THE SA WASTE PUZZLE?

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ABSTRACT

The limited availability of land for landfills coupled with the environmental challenges has necessitated the need to investigate waste treatment technologies for improved understanding and awareness of what the market has to offer. The International Solid Waste Association (ISWA) hosted a practical seminar on waste-to-energy (WtE) which was held in Austria in June 2014. The objective of the tour was to offer developing countries such as South Africa (ZA) and other nations a high quality seminar taught by experienced professionals from developed countries in waste management. This paper reviews the overall integrated waste management strategy within Austria with particular focus on the experiences of WtE plants visited. The relevance of WtE adoption in the South African context is discussed and highlights to the incineration technologies are detailed.

1. INTRODUCTION

The International Solid Waste Association (ISWA) hosted a practical seminar on waste-to-energy (WtE) which was held in Austria. The objective of the tour was to offer developing countries such as South Africa (ZA) and other nations a high quality seminar taught by experienced professionals from developed countries in waste management. The study tour included visits to some 10 operational plants across Austria and also included a WtE plant in the Czech Republic (Bruno), Eastern Europe. The waste treatment facilities were all based on Best Available Technique's (BAT's) and allowed for discussion with operators, suppliers, designers and other industry players. Participants covered a mix of countries such as Brazil, Malta, Australia, South Africa, Argentina, Greece, Norway Brussels, Pakistan, India and Turkey – totalling some 25 delegates.

2. THE QUEST TO STAY INFORMED OF WASTE MANAGEMENT OPTIONS

The South African industry's most practical, economical and bankable waste management option for municipal solid waste is still waste disposal by landfill. Whilst there had been past goals set by industry such as the Polokwane Declaration and most recently reference to NEMA legislation to secure alternative waste management targets i.e. tyre ban to landfill, future reduction targets of garden refuse to landfill etc., there has not been any significant reduction in waste to landfill. The limited availability of land for landfills coupled with the environmental challenges has necessitated the need to investigate waste treatment technologies for improved understanding and awareness of what the market has to offer.

With the quest for sustainable waste treatment solutions is in progress, the local market has seen "project developers" offering a one stop treatment solution to most municipalities. These solutions claim to produce energy from waste, reduce environmental impacts such as greenhouse gases (GHG's) and guarantee "zero air pollution" and in some cases with no capital investment required. This in fact sounds too good to be true! When the appropriate questions are channelled such as: Are there any local projects of similar operating? Or compatibility with existing waste practices? or How will waste be handled if the

WtE plant shuts down? The responses from such project developers are "*we are not sure*". Thermo-chemical processes such as Gasification, Pyrolysis, Hydrolysis, incineration based technologies and biochemical processes such anaerobic digestion may indeed be the waste industries future but it is understood that these are high tech, require large investments, sensitive to change in feed/input material etc. As a result, the ISWA study tour offered an ideal opportunity to visit operating WtE plants, network with project operators and related waste professionals in Austria to first learn and secondly try to apply the experience to the quest for sustainable waste management options.

3. PERSPECTIVES ON INTEGRATED WASTE MANAGEMENT, RECYCLING AND RECOVERY OF ENERGY FROM WASTE

Global waste management statistics show that waste disposal contributes to approximately 1billion tons of CO_2 per annum and projected to increase to 3billion tons by 2030. ISWA's database shows that there are some 4billion tons per year of solid waste in total from the around the world and the waste management solutions are as follows:

- ✓ 70% landfilled or open dumps
- ✓ 20% recycled and
- ✓ 10% incinerated

The world is further faced with pollution of water by plastic and other waste and research shows of the 125million tons of plastic produced, 80% of this waste ends up in water courses, (Welt, 2008) and are fatal for natural ecosystems and human health.

The European Union (EU) in particular practises recovery and treatment as opposed to disposal. According to the EU directive 2008/98/EC demands waste prevention as top priority with reuse and recycling of materials taking preference over energy from waste. Moreover, waste containing more than 5% Total Organic Carbon (TOC) is banned from landfill in Austria.

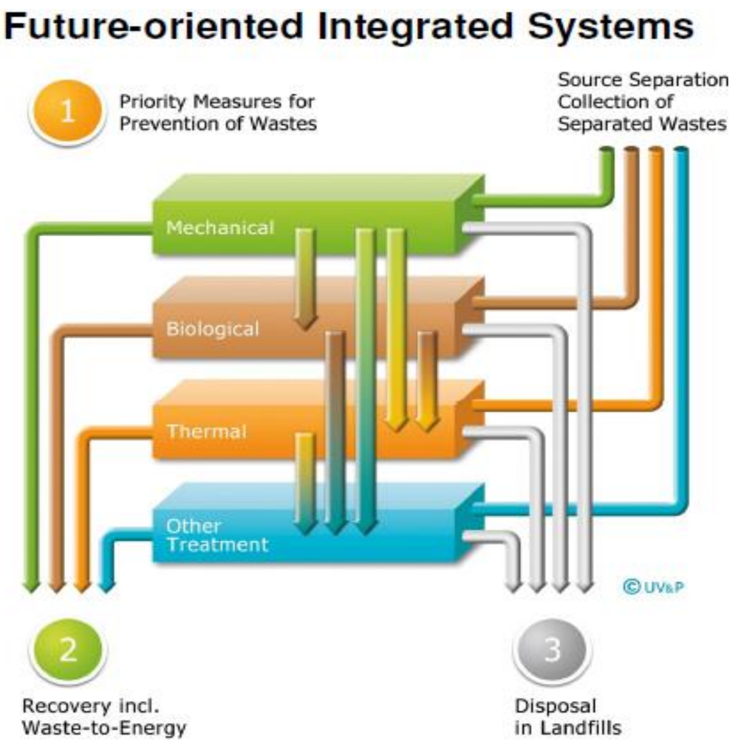

Figure 1: Typical Integrated system for sustainable waste management, UV&P, 2014.

Figure 1 above briefly details the an integrated system for sustainable waste management by prevention and source separation and collection of separated waste for treatment in order to achieve recycling and recovery and the treatment of residues with controlled disposal.

4. THE DEVELOPMENT OF MUNICIPAL SOLID WASTE MANAGEMENT AND TREATMENT FACILITIES IN VIENNA

The city of Vienna is the capital of Austria with some covering a $415km^2$ service delivery area of approximately 862000 households. The city's waste management is operated by the MA 48, a unit within the municipality which is responsible for complete system from waste collection of MSW and recyclables, waste treatment, composting to electricity and heat distribution.

A total of 1 037 000 tons per annum of MSW is collected with some 62% sent to WtE plants and the balance recycled, composted and minimal sent to landfill (TOC < 5%). Figure 2 below provides a graphical representation of the MSW management. The first incinerator dates back to 1960 and WtE plants are cited and operational within the city close to industry and residents. The South African "NIMBY" concept seems not to apply as communities have some 60years of WtE knowledge by socially accepting the treatment plants. This is realised through continuous consultation and communicating understanding in simply terms e.g. flue gas concentrations expressed in equivalent number of car exhaust or number of cigarettes smokes.

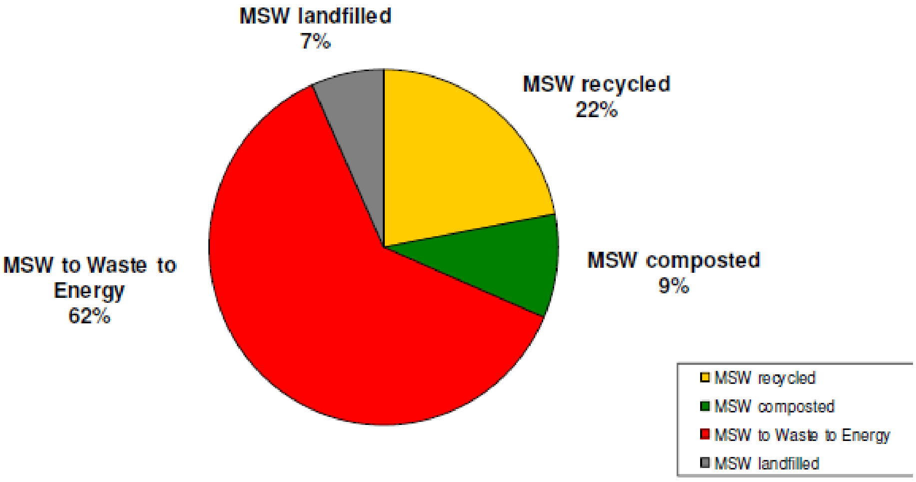

Figure 2: MSW management in Vienna, (R, Kronberger, 2014).

The city's waste strategy plan is clearly set out in terms of *ongoing public awareness on source separation* which benefits separate collection of clean recyclables and finally thermal treatment of the residual waste for energy recovery (electricity and heating).

4.1 Separate Collection of Waste

Vienna offers a combination of collection systems and waste drops off that is well understood by the citizens. Waste paper, clear and coloured glass, organic waste, scrap metal and plastic bottles are collected as recyclables. Containers range from 240L to 1100L with coloured lids to identify the type of recyclable with additional pictograms indicating the types of materials specific to each container. There is ongoing advancement of educating the public and improving the separation for example recent amendments for plastic bottle containers introduced posting chutes for easier discarding. The separate recyclable collection containers receive approximately 250 000tons/annum of recyclables.

Nineteen (19) waste drops off centres are in place for the bulky waste, electrical appliances, WEE, and hazardous waste free of charge. The city further allows for green waste drop off in exchange for high quality aerobic compost of biowaste/greens (only garden refuse and not kitchen waste). Such incentive provides for a practical working system and promotes active community participation.

The financing of the collection and treatment of the MSW is based on the volume of residual waste collected i.e. the more you produce, the more you pay and therefore citizens are incentivised to source separate. Some 650 000tons/annum of residual waste is sent for thermal treatment (WtE) with slags and ashes destined for further treatment and recovery and end disposal to landfill equates to some 250 000tons/annum.

Since 2007, all kitchen waste (17 000tons/annum) from restaurants (controlled separately collected food waste) is sent to an anaerobic digestion (AD) plant for biogas production destined for district heating.

4.2 Waste Treatment Facilities Visited in Vienna

There are three (3) waste incineration plants in Vienna viz. Flotzersteig, Spittelau and Pfaffenau for treatment of residual waste (MSW) and bulky waste as well as a fluidised bed furnace predominately for sewage sludge with and a rotary kiln for hazardous waste treatment. The site visits only covered the Pfaffenau, Fluidised bed Furnace and a waste logistics centre for baling waste.

- ✓ **Pfaffenau Waste-to-Energy Plant**: The site was commissioned in 2008 with a 250 000t/a capacity of residual and bulky waste. The energy generated is some 65 gigawaht hours (GW) of electricity and 410GW of district heating per annum. The plant is equipped with state of the art flue gas treatment technologies which guarantees low emission that are lower than the EU air quality limits. The capital cost of this plant was some 220million€ which is approximately 3.5billon rands! The operating costs are financed through the energy produced. There are 50 employees in total in this facility and all highly skilled and plants are fully automated with specialist operating systems throughout each process.

  The site receives some 200 refuse trucks per day and waste is tipped into a 50m deep concrete bunker. Two grab cranes are operated from a control room overlooking the bunker room and feeds approximately 32t/hr of MSW into the furnace of 850^{0}C. In the heat recovery boiler, the flue gas is used to generate steam and this steam at approximately 400^{0}C drives a steam turbine to generate electricity. The balance of the steam after the turbine is used to recovery the heat energy through heat exchangers for district heating. The burning retention time is an hour and non-combustibles such as scrap metal is sent for steel recovery and slag/ash sent to landfill. The four stage flue gas cleaning set up consists of electro filter; two stage wet scrubber, activated coke filter and a denitrification unit. The cleaned flue gas is meets air quality limits and is emitted 80m up in the chimney stack.

- ✓ **Pfaffenau AD plant**: The plant was commissioned in 2007 and accepts only restaurant waste, expired foods of some 117 000t/a. The process is fairly onerous in that there are contamination of the waste with packaging, soil, grit and other waste which is screened and separated before being pumped to the fermentation tank. The waste undergoes wet treatment processing and the waste suspension is allowed to ferment. During the fermentation process, microorganisms degrade the waste suspension and forms biogas with a methane content of some 58%. This biogas is used for the production of district heating. It was understood from the guided tour that the retention time AD was 12days before the biogas it cleaned and fed into the district heating network (11200MW/a).

- ✓ **Simmeringer Haide Waste-to-Energy**: This plant is situated directly opposed the Pfaffenau plant and waste logistics centre and is based on the fluidised bed incineration type process. The following wastes are treated:
  - *Drained sewage sludge: 250 000t/a*
  - *Processed MSW: 90 000t/a*
  - *Hazardous Waste: 125 000t/a (industrial and infectious hospital waste)*

The energy produced are 61GWh/a of electricity, 390GWh/a district heating and residues for recycling (metals, glass etc). The plant layout design is complex and incorporates a combination of storage, pre-treatment, thermal treatment, energy productions and flue gas treatment. Of importance was that approximately 50% of the total area and capital costs are for the flue gas treatment. The plant has specialist chemists and laboratory technicians constantly checking loads and testing waste which enables process control and treatability. The operation entails rigorous parameter monitoring of emission, maintenance of furnaces and overall upkeep. Temperature of fluidised bed and rotary kiln reach 850^0C. Typical disposal costs are 1000 €/t of hazardous waste but this depends on the toxicity of loadings. The overall treatment process is best understood by chemical engineers and specialist chemists. The plant further allows for recovery of gypsum, silica dioxide and metals which are used back in the industry.

The plant has a three stage flue gas treatment/scrubbing system and modern filters for fly ash separation. A DeNox system for combined catalytic denitrification and dioxin destruction is installed to ensure cutting edge emission control technologies for low environmental impact.

- ✓ **Pfaffenau Waste Logistics Centre**: This high tech facility was commissioned in 2013 for processing residual waste for the fluidised bed furnace at Simmeringer Haide. It was purposely designed and constructed to facilitate downtime of incinerators arising from plant shutdowns, unforeseen technical problems and increase in residual and bulky waste. This waste can be mechanically pre-treated (fines removed and metals extracted), baled and stored systematically onsite a lined paved site for incineration when needed. Such bales are fire wrapped to prevent fires and can be conveyed across to the Simmeringer plant with ease. Each bale is approximately 1mx1mx1.8m and is air tight from odours and flies. The capacity of the bale storage area is 44 000 bales. The design of the building allows for air extraction in the tipping halls and tip trucks dispose directly into a waste bunker.

- ✓ **Biowaste/Garden Refuse Composting**: Separately collected garden refuse from households and parks are collected by MA 48 and transported to a central compost treatment site. The plant processes some 115 000t/a of biowaste though "aerobic composting" All incoming green waste is roughly separated into two stockpiles i.e. small greens such as grass, leaves, branches and bulk greens such as large tree trimmings etc.

  The biowaste is mechanically treated using two (2) Dopperstatt hammer mills equipped with horizontal bed feeds. All stockpiling and loadings are done using a front end loader with grab bucket. The mechanically treated product is conveyed to an inclined mixing/wetting station. The product is thereafter tipped into open windrows using $30m^3$ trucks. Discussions with the plant's operator shows that the windrows reach full sanitation to 70^oC within the first week and are turned daily using compost turners with wetting. Full composting time takes some 10~12 weeks and overall some 35 000t/a of good quality compost is produced. The product is sold as a category A^+ compost, used in market gardens for organic gardening and also taken to drop off centres for public/residents collection.

5. THE UNDERSTANDING OF WASTE INCINERATION

When MSW is incinerated, organic substances are oxidised understand extreme heat (excess of 850^0C and converts into CO_2 and water vapour which are released into the atmosphere from the chimney stack after flue gas treatment. This type of process has been used dating back to the early 1900's to generate electricity from waste as well as utilising the heat for district heating and recently district cooling. **The incineration process occurs** in four (4) stages as follows:

- ✓ Drying: H_2O is evaporated to render the fuel dry.
- ✓ Degasification: As further heat is added, volatile organic substances escape. The solid residue is then referred to as "coke"

- ✓ Gasification: Solid carbon is then converted into combustible carbon monoxide (CO) utilising a gasification agent (H_2O, O_2). The solid residue left over is referred to as ash/bed material/fly ash.
- ✓ Oxidation: The combustion of the gases CO and H_2 to convert into CO_2 and H_2O with high release of heat.

6. TECHNICAL FIRING SYSTEMS FOR INCINERATION TECHNOLOGIES

Incineration further depends on the three "T's" i.e. Turbulence for good mixing of the waste, Temperature for combustion and Time for complete combustion to occur. The rule of thumb is typically 850^0C for 2 seconds with good mixing at average air supply. The following are technical firing systems available in the market: (UV&P, 2014)

- ✓ *Grate Firing Systems*: Air is typically extracted from the ambient and flows underneath the solids particulates fuel on top of the gates. Grates typically move like a walking floor.
- ✓ *Fluidised Bed Furnace*: Intense gas turbulence keeps the suspended, small piece fuel in hot sand and incineration gas in a fluidised, dynamic state of movement.
- ✓ *Dust Firing Systems*: The finely ground fuel is transported pneumatically in gas flow with simultaneous incineration.
- ✓ *Rotary Kiln with Afterburner:* Various types of solid, pasty and liquid waste can be treated in slowly rotating kiln. The flue gas is subsequently burned with auxiliary fuel in the connected afterburner zone.

The most common system known in the EU for waste incineration is the *grate firing system* as depicted in figure 3 below.

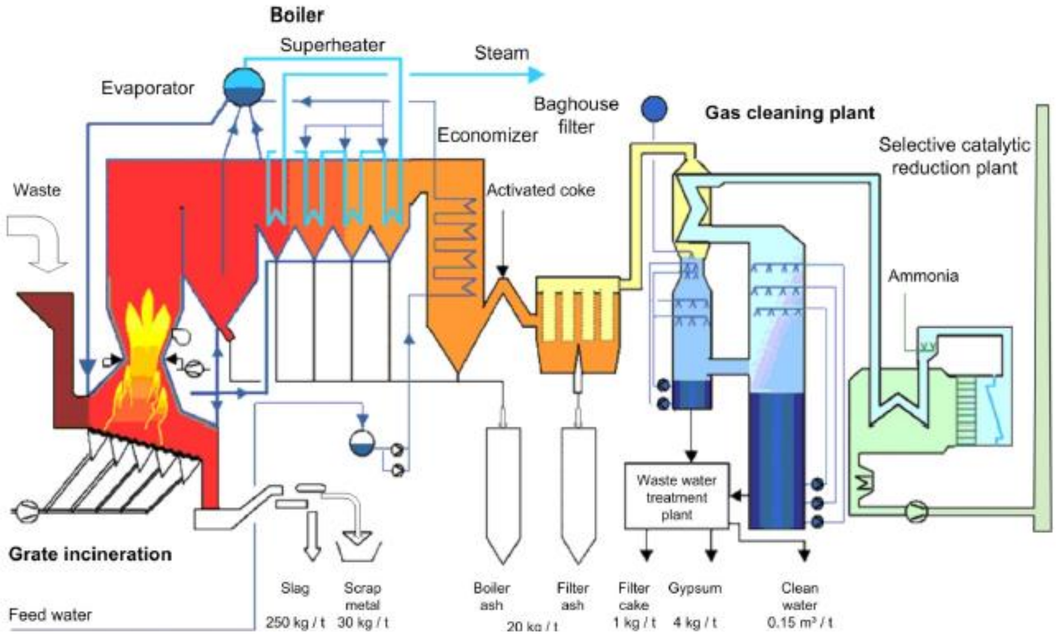

Figure 3: Grate Incineration plant with multistage flue gas treatment (UV&P, 2014)

7. THE USE OF SECONDARY FUELS IN INDUSTRIAL FURNACES

Certain waste can be converted into quality waste fuels through appropriate sorting, separating and processing steps. A common development of such use is in the cement clinker industry where waste tyres, oils, solvents and plastics are used. The Rohrdorfer cement plant visited uses such secondary fuels for the production of 600 000t/a of cement.

The Calorific Value (CV) (heating capacity) of residual waste fluctuates over time and varies from region to region. It is recommended that the WtE plant be is designed to operate of a varying CV and be flexible to input material feed. Typical CV for MSW ranges from 9~12MJ/kg as opposed to coal of 30MJ/kg. In general, it was noticed on all WtE plants visited that the bunker operator always thoroughly mixed the MSW with shredded bulky material before feeding the furnace.

8. CZECH REPUBLIC – WTE PLANT IN BRUNO

A visit to South Eastern Europe to the SAKO WtE plant in the city of Bruno revealed similar process technologies to that visited in Vienna however one can argue the attention to detail and health and safety compliances. The plant treats some 224 000t/a of MSW and energy production is as Vienna for district heating (350 000MWh/a) and electricity (63 000MWh/a). The plant recently had an upgrade with a total investment cost of some 100 million€. History shows that the first incinerator plant in Bruno was constructed in 1905 and as a result has some 100years of WtE acceptance in the country.

The incineration technology is based on the inclined grate firing system with two (2) steam boilers with semi dry flue gas cleaning. The plant includes steam production for district heating to the city of Bruno and a Siemens steam turbine (rated 23MW) for electricity generation. The plant is designed to operate of a varying calorific value but generally operates at 11MJ/kg for MSW.

Sorting Facility: The plant also has a sorting plant that processes separately collected waste from Bruno. The highlight of the plants design was that it incorporates automation with use of labour for sorting. Where opposed in Austria there recycling/sorting is mechanised with minimal labour used. This is of interest in relation to the South African market as there is a need for job creation and skills development which can be realised with such concepts. The layout design of the sorting facility uses simply conveyors, elevated sorting lines with chutes and baling machines. Recyclables processes include paper, plastics, cans, cardboard, etc. and are transported off site back into the market for recycling. The plant processes approximately 10 000t/a of recyclable and employs some 35 local people.

9. TYPICAL WASTE-TO-ENERGY ECONOMIC INDICATOR

The various WtE plants visited all work off the thermal mass burn principles. The experience shows that the EU has some 30years know how with proven technology, local skills and professional experience. As a result projects of this nature in the EU can guarantee a successful business model for funding. In general, some 50% of the investment/capital funding are secured through EU grants rendering the implementation of WtE projects much easier. However the success of the project still rests on the environmental requirements, social/legal acceptance and economic viability.

A 300 000t/a MSW WtE plant (CV 9~11 MJ/kg) typically investment costs in the order of 200 million Euros for an operational life of approximately 30years, (Neubacher, 2014). Waste treatment operating costs are typically 600~1000 million euros over 30years and revenues from electricity and heating are 12million €/a for a 100MW capacity plant.

It must be realised that a WtE solution has to be part of an integrated waste management solution with prevention upfront, separation at source and landfill as least desired option. Transportation still forms a major component of the overall waste management cost and as a result the position of any WtE plant has to justify transportation logistics (via road or rail). WtE should be cited in close proximity to existing infrastructure for energy export purposes (power plants, district heating/cooling or for industrial beneficiation.

10. IS WtE THE SOLUTION TO SOUTH AFRICA'S QUEST FOR SOLVING THE WASTE PUZZLE?

- The Austrian experience shows that WtE has been a successfully implement and operated. The primary push to such success is undoubtedly through the targets set by the EU directive. The **stringent legislation** coupled with the need for sustainable waste management and ecological preservation has ensured that the EU/Austria can thermally treat MSW to secure economic and environmental benefit. Careful examination to the European waste treatment shows that WtE is a link in the process of the overall integrated waste management plan. In comparison to SA – there is no legislation banning waste from landfill.

- **Social Awareness and On-going Education**: A key finding learnt was that each waste management organisation responsible for service delivery focuses time and energy on educating the public on how waste it to be separated, what containers to use, interaction surveys etc. This is to be taken serious as experience has proven that people require constant reminders 0to build a culture of awareness. Separation at source into various categories has proven to improve extraction efficiencies with in some areas eight (8) different bins. South Africa has predominantly a one bag collection strategy with certain municipalities implementing more than one bag collection. The argument remains – does SA have the fundamental concepts in hand?

- **Social Acceptance of WtE**: The Austrian WtE history shows that there is in excess of 30years experience in industry with society educated and technically aware of the thermal treatment limits. The Czech Republic further has a century of social acceptance. South Africa has not started, the environmental activists will surely ensure due diligence the Environmental Impact Assessment (EIA) etc. so SA is atleast 30years behind on the social scale – a true challenge for any developer!

- **Economic Viability**: An average WtE plant for MSW treatment equated to some 220million Euro's and allowed for only skilled limited employment. Can SA investors carry the risk of billions of rands investment with no proven project locally? The SA government has demanded projects to realise job creation to improve economic development and such WtE plants will unfortunately not adhere to this requirement. Operating conditions, MSW, climate etc are all variable and the probability of success can be overcome with high investment. The irony is that for SA, landfill is by far the "cheapest" most practical and environmentally safe option.

- **Energy Markets:** The EU is flexible in catering for electricity generation combined with district heating and cooling. SA on the other hand predominately has a demand for power generation and not heating. WtE has higher energy efficiency when there is power generation with heating. There is however the option of investigating heating use in industry and perhaps needs probing.

11. CONCLUSIONS

In no way is the review negative WtE but is intended to stock take the reality of the South African context in relation to the global perspective. WtE cannot be a "flavour" topic and a copy paste approach. SA has to interrogate policies and legislation with necessary support mechanisms for the industry. There has to be attention to the key focus areas such as education, awareness and formulating an integrated waste management plan which is sustainable. It is understood that the solution for waste treatment may infact be WtE BUT "Africanised" to adapt to SA needs. Until this is the case, landfill is still the industry's most bankable waste solution in the near future. A possible strategy could be more attention to separation at source, sorting facilities for job creation, composting of greens and still landfill MSW with improved landfill gas extraction and cleaning for reuse as fuel in refuse collection trucks. These are starter ideas which are not new but has to be piloted, performance documented and improved with time. The application of these technologies is currently limited in South Africa, and in many instances, such technologies have failed due to procurement flaws, poor management and other institutional and technical challenges. It is the opinion of the author that the SA industry has unique waste knowledgeable professionals whom collective as a team can engineer and implement such proposal's using the SA "know how" to solve the waste puzzle. Waste to Energy cannot be a standalone solution but instead needs to be part of an integrated waste management solution.

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