7 Appropriate solutions for Africa

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What the reader can expect

Many proven alternative waste treatment technologies (to landfilling) are available worldwide. However, not all of these are appropriate or economically viable (at least in the short-term) for implementation in Africa. This chapter explores the social and technological innovations that have emerged in Africa to deal with the increasing volumes of waste generated on the continent. Social innovations in waste prevention, reuse or collection and alternative waste treatment technologies for waste recycling and recovery are explored, and planned new waste technologies are highlighted. These innovations are also reflected on through relevant case studies.

Key messages

The following are the key messages regarding appropriate solutions for Africa:

- Many alternative waste treatment technologies are available worldwide, but only some of them are appropriate, or economically viable, for Africa, at least in the short- to medium-term.
- Some excellent social and technological innovations have emerged in the waste sector in Africa;
- As source separation of waste is not currently effected in most African cities, conventional waste treatment technologies are difficult to implement.
- Uncontrolled dumping and open burning remain the dominant "technology" choice for the management of waste on the African continent.
- Low-technology (and low-cost) solutions such as cargo bicycles, motor tricycles or donkey-carts are good alternatives for waste collection in African cities.
- Including informal actors in the waste management system is an opportunity for improved livelihoods and income generation for often disadvantaged groups.
- Reuse of end-of-life goods is already widespread across Africa, but often driven informally, with opportunity to scale up.
- Recycling technologies are already being implemented for wastes such as plastic, paper, glass, metal, oil, e-waste and organic waste, but could be significantly scaled up through the development and strengthening of local and regional end-use markets.
- Energy recovery technologies, such as landfill gas recovery, biodigestors for the organic fraction of MSW and industrial biomass are currently very limited in their implementation in Africa.

7.1 Introduction

The previous chapters have shown that while some degree of reuse, recycling and recovery is taking place in Africa, uncontrolled dumping and open burning remain the dominant "technology" choice for the management of waste on the continent. If we are to improve the management of waste and unlock the environmental, social and economic opportunities of moving waste up the hierarchy away from landfilling towards prevention, reuse, recycling and recovery, large-scale adoption of appropriate, alternative waste treatment technologies (AWT) is required.

However, a large spectrum of possible AWT technologies are available worldwide for immediate implementation. Decision makers therefore have to make the right choice of treatment and disposal solution based on the specific requirements and constraints of each town or city.

Box 7.1 Measuring the appropriateness of waste technologies in Africa

In Africa, where most countries are classified as low- and lower-middle income, there are many parameters to consider when selecting AWT technologies, including:

- sensitivity to the quantity and quality of waste;
- capital investment costs
- operation and maintenance (O&M) costs
- cost recovery potential
- efficiency of the technology
- end-product utility
- environmental impacts of operation
- land, energy and water requirements
- availability of local competences to properly manage the system
- inclusion of both formal and informal actors in the system

Guidance note: Lessons learned

- An appropriate technology should not be considered in isolation; it must be placed within an integrated waste management strategy.
- Both formal and informal actors must be considered to insure the efficiency of the waste management strategy (high level of waste collection, improvement of recycling and/or reuse, high material and energy recovery, social inclusion and income generation for the poorest people).
- The choice of the appropriate technology should consider the following:
  - The technology should be proven based on effective operating experience in African/low-income country contexts.
  - The technology should be economically viable in the context of low-income countries.
  - Technical issues related to the implementation of the technology should be easy to fix: the presence of qualified human resources for management and maintenance must be considered.
  - Low cost technologies are preferred as waste treatment solutions.
  - The technology should be an opportunity for social innovation (job creation, social inclusion, income generation).

As outlined in **chapters 3, 4 and 5**, Africa faces many challenges regarding the management of waste, especially MSW. Of the 125 million tonnes per year of MSW generated in Africa in 2012, only 4 per cent was recycled, with the bulk of the waste disposed of to dumps, often associated with open burning. With an average collection rate of only 55 per cent for the continent (**see chapter 3**), uncontrolled dumping of uncollected waste contaminates urban centres. Considering that 70–80 per cent of MSW generated in African cities is recyclable, it does not make sense that viable secondary resources are so poorly managed on the continent (**see chapter 3**).

The following sections explore real examples of the social and technological innovations that have emerged on the African continent to address the challenges of waste collection, separation at source and the diversion of waste away from landfills.

7.2 Waste prevention

According to the United Nations Industrial Development Organization (UNIDO), waste prevention "*makes more sense than trying to recycle, recover and treat wastes and pollutants once created or already discharged into the environment.*" (UNIDO 2015:3). Following the 1992 United Nations Conference on Environment and Development (Rio Conference), efforts by UNIDO, UNEP and other development partners aimed at decoupling resource use and environmental impacts from manufacturing growth through improved energy, water and materials efficiency led to the development of national cleaner production centres (NCPCs). According to UNIDO[19], "*NCPCs contribute to improved environmental performance and resource efficiency of enterprises*". However, waste prevention, as a concept, is still in its infancy in Africa. In 2015, 14 African countries were represented by NCPCs (UNIDO 2015).

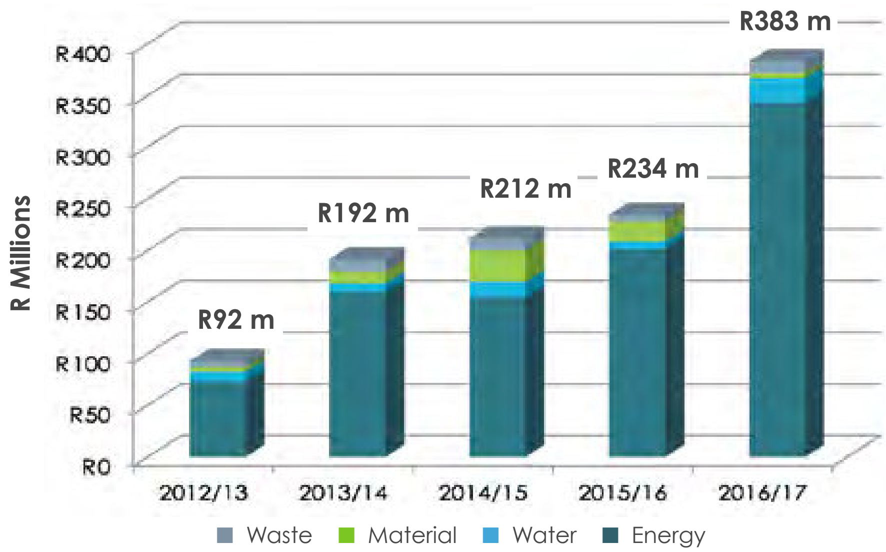
In 2016, the NCPC South Africa identified potential energy, water and materials savings of R382 million per year (around US$30 million) for local companies through resource efficient and cleaner production mechanisms (**Figure 7.2**). Furthermore, its national industrial symbiosis programme realised 6,160 tonnes of waste diverted from landfill and 8,800 tonnes of virgin input material saved in 2016 through waste exchanges between businesses (NCPC 2017).

Figure 7.1 Countries with national cleaner production centres in 2015

Source: Resource Efficient and Cleaner Production Network (RECPnet) http://www.recpnet.org

19 http://www.unido.org/ncpc/o5138.html

Figure 7.2 Potential savings identified through cleaner production assessments



Source: NCPC (2017)

7.3 Waste collection and social innovation

In high-income countries, waste collection is under the responsibility of municipalities and formal contractors. Waste is collected from households and businesses by vehicles and transported to transfer points and treatment facilities, with final residual waste going to sanitary engineered landfills. This type of collection model is currently not used in most African countries. Source separation of waste is not common in African cities and towns, nor is it mandatory, whereas it is a basic requirement in most high-income countries. It is well known that the waste collection strategy has a direct impact on the efficiency of technologies for resource recovery and reduction of final disposal volumes (Gomez 1998; Zhuang *et al.* 2008; Giugliano *et al.* 2011). Waste collection and source segregation plans therefore need to be adapted to the African context, and the opportunities for social innovations identified.

In Africa, where municipalities are struggling to implement collection services, informal collectors, small-scale entrepreneurs and private businesses have stepped in to provide service. The informal waste sector has been shown to be very effective and efficient in collecting waste, in particular valuable recyclable material that can be sold (**see chapter 6**). There is growing consensus that the informal sector must be taken into account when improving waste management systems in developing countries (Ali 2006, Dias and Alves 2008, Agamuthu 2010, Gutberlet 2010, Chaturvedi 2011, Luken 2011, Sang-Arun 2011, Besiou *et al.* 2012, Scheinberg *et al*. 2011, Scheinberg 2012). Indeed, these informal actors cover areas where it is difficult for official contractors to operate, such as suburban zones, informal settlements and areas with little to no purchasing power.

There are significant opportunities for improved waste management in Africa, by integrating informal actors, including:

- Better coverage of the city for waste collection and recycling
- Generation of income for disadvantaged people
- Lower fuel consumption and extension of lifetime for vehicles when replacing conventional waste collection vehicles with motor tricycles and donkey-carts in suburbs and areas with difficult access
- Structuring of informal actors and perception of additional taxes by the municipality

CASE STUDY 5

WECYCLERS, LAGOS, NIGERIA

In Nigeria, a small company Wecyclers (http://wecyclers.com), was started in 2012 by a young female entrepreneur as a for-profit social enterprise to address the waste management challenge facing the city. At the time, only 40 per cent of Lagos' waste was collected and only 13 per cent was recycled. Furthermore, recycling firms in Lagos faced supply constraints, unable to access adequate supplies of quality recyclable material, often operating at 50–60 per cent below capacity. Wecyclers uses low-cost, environmentally friendly cargo bicycles called "wecycles" to provide households and businesses in Lagos with convenient collection services for recyclable waste, thereby helping communities reclaim their neighbourhoods from unmanaged waste (Iwuoha 2015). According to the company, "*Wecyclers gives households a chance to capture value from their waste while providing a reliable supply of materials to the local recycling industry*". Waste volumes in programme areas in Lagos, Nigeria, have been reduced by over 35 per cent owing to this social entrepreneurial innovation. The principle is simple and adaptable to other communities in Africa.

In Ouagadougou, Burkina Faso, donkey-carts are used to collect waste from suburban households and transport it to transfer centres. Informal women's groups are generally in charge of this activity. In business and residential areas, waste is collected by vehicles and formal contractors. This integrated system of informal and formal ensures a better waste collection rate and provide incomes for both formal and informal actors.

Wecyclers tricycle collection service for recyclables
Photo credit: © Wecyclers

Women collecting waste in Ouagadougou with donkey-cart
Photo credit: © fedevaco

7.4 Alternative waste treatment technologies

As noted in **chapter 3**, the average composition of MSW in sub-Saharan African cities is about 57 per cent organic, 9 per cent paper/card board, 13 per cent plastic, 4 per cent glass, 4 per cent metal and 13 per cent other materials. An estimated 70–80 per cent of MSW in African cities could therefore be diverted away from landfills towards AWT. This would leave only 20–30 per cent residual waste requiring treatment and final safe disposal to sanitary engineered landfills. The high organic content of MSW is typical of developing countries and requires special consideration when implementing AWT technologies. Many AWT technologies, especially high-temperature thermal treatment, have failed in developing countries because they fail to take the high organic content, and therefore high moisture content, into consideration.

There are many waste treatment technologies (mechanical, biological and thermal) that can be adopted in Africa. **Table 7.1** lists categories of waste treatment technologies that can be used to manage organic waste, recyclables such as paper and packaging, and residual waste.

Table 7.1 Technology options for the management of MSW (including the organic fraction)

Technology	Purpose of the technology
Biological treatment	• Used to reduce the biodegradability of the waste and its volume under controlled conditions. • Treats organic waste such as agricultural waste, food and food processing waste, garden waste. • Includes technologies such as composting (open windrow or in-vessel composting) and anaerobic digestion. • Typically produces a soil improver/conditioner material that may generate income/agricultural benefit. • Some technologies (anaerobic digestion) are also designed to recover energy from the waste.
Materials recovery facilities (MRF) – clean	• Used to extract recyclable material from source-separated waste in order to recover value as marketable products. • Combination of various mechanical processes used to separate materials.
Materials recovery facilities (MRF) – dirty / residual waste	• Used to extract recyclable material from mixed waste streams in order to recover value as low-grade recyclate. • Produces a fraction with good combustion properties that may be appropriate for use as a fuel (refuse derived fuel). • Combination of various mechanical processes used to separate materials.
Mechanical biological treatment (MBT)	• Used to extract recyclable material from mixed waste streams in order to recover value as low grade recyclate. • Recover a fuel fraction from the waste (refuse derived fuel). • Derive biogas (for anaerobic digestion systems) for energy recovery. • Generate a compost-like output. • Stabilize (or partially stabilize) the waste and reduce its volume.
Thermal treatment – incineration	• Used to reduce both volume and biodegradability of the waste, usually also deriving energy in the form of electricity and/or heat. • Temperatures are maintained at high levels and the waste is burned to an ash. • Bottom ash from the process may be recycled in some circumstances but the fly ash and air pollution control residues require specialist disposal.
Advanced thermal treatment – pyrolysis, gasification and plasma gasification	• Used to derive energy from the waste and to reduce both the volume of the waste and its biodegradability. • Higher temperature processes may produce a usable aggregate or slag.

Source: Adapted from DEA (2015)

Table 7.2 Appropriateness of technologies for municipalities in South Africa in the short-, medium- and long-term

Promising technologies – short-term	Technology options that are in practice and/or under development in South Africa and those which have a strong potential for contributing to advanced integrated solid waste management in South Africa	• Open windrow composting • Clean materials recycling facility • Dirty materials recycling facility
Potential technologies – medium-term	Technology options that have scope for successful applications in South Africa where appropriate conditions are in place. These conditions would require a technology that is well suited to the waste streams, affordable and competitive, and that represents a considered component of an advanced integrated solid waste management system	• Anaerobic digestion • Mechanical biological treatment • In-vessel composting • Energy from waste (incineration)
Potential technologies – long-term	Technologies that are unlikely to have applications in South Africa in the short- to medium-term, except under specific circumstances (e.g. for processing a “difficult” waste stream) or where exceptional factors are in place (e.g. grant funding for a demonstration unit)	• Gasification • Pyrolysis • Plasma gasification • Mechanical heat treatment

Source: Adapted from DEA (2015)

Given the challenges facing developing countries with respect to the implementation of AWT technologies and evidence of the failings of inappropriate technologies, the South African Department of Environmental Affairs chose to prioritize the following as short-, medium- and long-term technologies for consideration in South Africa (DEA 2015) (**Table 7.2**).

The following section provides examples of different waste treatment technologies in operation in various African countries, from low-tech (and low cost) to high-tech waste management solutions.

7.4.1 Waste reuse

Africa has many examples of waste reuse initiatives. Reuse (accompanied by repair and refurbishment), is often driven by larger socio-economic issues such as poverty and unemployment, rather than integrated waste management solutions. Examples of waste reuse are evident across numerous waste streams, including paper and packaging, waste tyres and e-waste. Examples are provided in the case studies below.

CASE STUDY 6

REUSE OF WASTE TYRES IN OUAGADOUGOU, BURKINA FASO

Ouagadougou, Burkina Faso, has experienced a significant growth in the volume of waste tyres from approximately 500 tonnes in 2013 to over 8,000 tonnes in 2015 (Touré 2015). These used tyres are imported from Europe or the USA, as the local people have limited budgets for the maintenance of cars. Instead of paying about US$290[20] for four new tyres, customers pay only US$73 for used ones. As the life of these used tyres are very limited, large volumes of waste tyres are generated. In the absence of commercial recycling and recovery technology, local initiatives have been launched for the reuse of these used tyres. Many of these initiatives are subsistence activities (formal and informal in nature), conducted by individuals (and families) who earn a very basic wage from these activities. In a few cases, these initiatives have grown into unofficial business activities and still further into official business activities generating incomes above the living wage for those involved.[21]

Atelier Reclycl'Art launched by Mawourata Koné, a graduate student from the University of Ouagadougou, is one such initiative. This small business manufactures furniture from used tyres, employing about ten people.

Besides furniture and other handicrafts, citizens in Ouagadougou have also reused waste tyres as informal roundabouts for traffic regulation.

20 At an exchange rate of 549 CFA per United States dollar

21 The definitions for subsistence activity, unofficial business activity and official business activity have been adopted from ISO (2017)

Other small businesses manufacturing furniture from waste tyres have also emerged.



Waste tyres used as furniture
Photo credit: © jolijolidesign

Sale of used goods on kerbside, Kenya
Photo credit: © Janis Brizga, Green Liberty / EEB

CASE STUDY 7

REUSE OF PLASTIC WASTE AS SCHOOLBAGS IN SOUTH AFRICA

An example of social innovation in waste reuse can be found in the Rethaka Foundation's Repurpose Schoolbag initiative in South Africa, a social startup founded by two young female entrepreneurs in 2013 as a green initiative to help school children in their local community (Iwuoha 2015). Their young business collects and repurposes plastic waste such as PVC billboards into low-cost schoolbags for local disadvantaged students.

These "upcycled" plastic bags have a solar panel in the flap, which charges as the children walk to and from school. They also have strips of reflective material, an added safety design to make the children more visible to traffic. The charged solar panels are used to provide light at home in the evening, which the children can use instead of candles to do their homework and study. This helps students to do more school work and saves money that would have been spent on candles. The company has partnered with local individuals and organizations that are willing to cover the cost of the bags on behalf of the students. According to the foundation's website, "*over 10,000 Repurpose Schoolbags have been given to children in six countries on the African continent*" (http://www.rethakafoundation.org/).

This simple but highly effective idea has attracted a lot of attention. In 2014, these young entrepreneurs were first runners-up for the Anzisha Prize, a pan-African award celebrating entrepreneurs aged 15–22 who have come up with innovative ways to solve problems in their communities.

Repurpose schoolbags
Photo credit: © Repurpose schoolbags Facebook page

CASE STUDY 8

REUSE OF E-WASTE IN ABIDJAN, CÔTE D'IVOIRE

The EWIT Consortium (2016) estimated that 15,000 tonnes a year of e-waste were generated in Abidjan, Côte d'Ivoire, based on measurements at two recycling associations. E-waste collection and the reuse/repair activities are informally managed through individual actors and have a strong presence in the local economy. E-waste collectors have organized themselves into an association. They sell their wares to various repair shops situated in large refurbishment markets. These markets are also organized as an association, with a president who represents the interests of the repair shops in stakeholder engagements. Each repair technician rents space from the association, is individually registered with the municipality as a tradesman with a registration number, and pays taxes.

Repair shop in Marcory, Abidjan

Photo credit: © EWIT Consortium

7.4.2 Waste recycling

Waste recycling is still in its infancy in Africa, with only 4 percent of MSW recycled (**see chapter 3**). It is entirely market driven and has grown organically, largely due to an active informal sector that collect recyclable material from kerbsides and landfills *(supply-side)* (DEAT 2005, Samson 2010) (**see chapter 6**). This has facilitated the growth of local and international end-use markets, which use this recyclate in the manufacture of new products *(demand-side)*.

The informal sector and recycling micro-enterprises can achieve considerable recycling rates, up to 20–30 per cent by weight in low-income countries (Wilson *et al.* 2009, Wilson *et al.* 2012). According to Wilson *et al.* (2012) and Scheinberg *et al.* (2010), local authorities can save around 20 per cent or more of their budget through diversion of recyclables by the informal sector and micro-enterprises.

The majority of commercial waste recycling initiatives have been initiated by the private sector, with some public and private sector financing (**see chapter 8**). Waste sorting in African cities is essentially done manually, most of the time by informal actors or in small material recovery facilities. Such manual sorting strategies appear appropriate for countries with high levels of unemployment and a real need to create jobs for unqualified people. Source separation and recycling are sometimes encouraged by municipal authorities in establishing waste buy-back centres and garden waste drop-off centres, where waste is separated into different streams such as glass, paper/cardboard, cans, scrap metal, plastics and garden waste (CSIR 2011). Authorities can also arrange dedicated spaces on landfills for waste sorting, where reclaimers can work in controlled, relatively safe conditions (Saranel 2007, PSRDO-CER 2010). In many cities like Cairo, Egypt, despite formal contracts with delimited zones attributed to contractors, informal actors are involved in waste sorting and recycling. The official contracts signed by the municipality prohibit such actors from participating in waste collection or recycling, but authorities and formal contractors turn a blind eye to their activities. This ensures income for urban poor and favours better waste collection coverage. The inclusion of informal actors in the collection of recyclables appears to be an innovative way to improve waste recovery and reduce the volume of waste disposal to landfills in Africa.

The following section highlights recycling activities taking place in various African countries, ranging from low-technology (and low-cost) composting to high-technology (and high cost) plastic recycling and thermal treatment.

CASE STUDY 9

RECYCLING OF PLASTIC WASTE IN KENYA

The experience of EcoPost in Kenya shows how job opportunities can be created through the recycling of waste. EcoPost is a social enterprise created in response to the need to find alternative waste management solutions to Kenya's plastic waste problem. Founded in 2009 by a young female entrepreneur, the company collects plastic waste and manufactures commercially viable, highly durable and, most importantly, environmentally friendly fencing posts. EcoPost has not only provided Kenya with a commercial alternative to timber, but has in the process created over 300 jobs, generated much needed revenues, saved over 250 acres of forests and taken more than one million kilogrammes of plastic waste out of the environment (Hawken 2014).

EcoPost plastic lumber products

Photo credit: © Money Spent Well

CASE STUDY 10

MANUFACTURING UTENSILS FROM ALUMINIUM WASTE IN ABIDJAN, CÔTE D'IVOIRE

In PK 18, a district of the municipality of Abobo, in Abidjan, Côte d'Ivoire, several workers have specialized in the making of kitchen utensils from aluminium waste (Kouamé 2014). With skills passed down from generation to generation, Kanté Sakamissa, head of a workshop space of around 1,200 square metres since 1992, now employs others in the recycling of aluminium. "*I did not go to school, since my childhood my father taught me to do this work. Today, I have many workers*", he says. The technology used to produce the utensils from recycled aluminium comprises three stages housed in three different workshops: melting of aluminium, mould preparation and finally, correction of slight defects by polishing.

The melting step: Any recovered aluminium, including packaging of alcoholic or non-alcoholic beverage cans, used sheet metal, other miscellaneous packaging, piping and accessories from motor vehicles or other machinery is melted at high temperatures (around 1,000°C). In practice, beverage cans make up the bulk of the scrap material, as other materials are scarce.

The moulding step: The mould is an impression of the utensil that the craftsmen want to reproduce. The technique consists of mixing sand and wet clay. When the mould is finished, it is ready to receive the molten metal from the blast furnace. Once the metal has solidified and cooled, the mould is destroyed and the utensil is extracted. This step generally takes less than 30 minutes after casting. The workshop produces products such as furnaces, pots, skimmers, spoons, pans, and ladles. About 30 pots can be manufactured per day.

Finishing step: Once cooled, the manufactured object is transported to the finishing section where files and metal saws are used for polishing and filing as necessary.

The prices of the items vary according to the size. A small stove for making tea sells for 2,000 CFAF (US$4), while larger sizes sell for 30,000 CFAF (US$55). There is a high demand for such utensils in lower- and middle-income communities, where these products are used mainly for cooking purposes.

Melting the aluminium waste
Photo credit: © Afrique in visu

Polishing a pot at the end of the process
Photo credit: © Afrique in visu

CASE STUDY 11

COMPOSTING ORGANIC WASTE IN CAPE TOWN, SOUTH AFRICA

Cape Town is one of the three largest cities in South Africa. In 2004, 2.3 million tonnes of solid waste was collected and treated in the City of Cape Town Municipality. Some 120,000 tonnes was pure green waste, of which 30 per cent was composted. A further 31,200 tonnes of mixed household waste was treated in the municipality's facilities. Altogether, 2 per cent of all waste was treated biologically as an alternative to landfill. The warm climate in the region is favourable for the production of compost all year round, but the hot and windy summer weather puts high demands on water supply for the composting process (Ekelund and Nyström 2007).

Organization and financing of the compost project: The municipality has treated mixed wastes in municipal compost plants since 1969. When starting up the separate handling and treatment of green waste, the municipality chose a solution involving a public-private partnership. The municipality owns the drop-off sites where the green waste is received, and puts out tenders for the management of the sites. The contractor undertakes to not only manage the receipt and chipping of green waste, but also to manage the site and the sub-contractors appointed by the municipality to take away and treat other fractions of waste that are received at the site. The contractors are compensated for the site management and for the amount of chipped green waste they deal with. The City of Cape Town Municipality chose this arrangement with private contractors because commercial composting was not identified as part of their core activities. This case study focusses on one contractor: Reliance.

Reliance compost site in Cape Town

Photo credit: © Reliance

Type and collection of waste: When Reliance converted to organic farming in 1998, it started composting to fill its own needs for an organically approved fertilizer. In 2003, Reliance became a contractor to the municipality and started composting municipal green waste. Each month, Reliance collects approximately 50,000 m^3 of chipped green garden refuse from nine dropoff facilities and landfills around the City of Cape Town. Over the last decade, the company has kept over 20 million m^3 of green garden refuse out of landfills, thus preventing over one million tonnes of CO_2 from escaping into the atmosphere and mitigating the impact on climate change (http://reliance.co.za/aboutus.html).

Process: The chipped waste is treated with inoculum and placed into 1.8 metre high windrows. The intention is to measure temperature and CO_2 emissions daily and use that information to determine turning intervals, but with growing quantities the operators tend to use standard times. Turning and watering is done by a tractor-pulled straddle turner. The compost is considered ready when the temperature falls to ambient and the company's own laboratory tests show that the compost has the right pH value and is low in the phytotoxics, NO_2 and H_2S. The whole composting process takes 6–8 weeks. The ready compost is then sifted and bagged, or sold in bulk.

End product and market issues: Reliance produces different types of compost, such as plant feed, soil conditioner, lawn dressing, potting soil and mulch. Besides the company itself, the main customers are landscapers. The bulk price per cubic metre is R187 for compost and R50 for mulch. The price for wood chips that have not been composted is R45 per cubic metre. The company has a reputation for producing a high quality product and the compost has previously been organically certified.

Since Cape Town is in an expansion phase, there is a lot of construction work underway, and the company has no difficulty finding customers. Relations with many of its customers are long-term, with monthly delivery of compost.

CASE STUDY 12

PET (BOTTLE-TO-BOTTLE) RECYCLING IN SOUTH AFRICA

Extrupet (www.extrupet.com) is the largest, most advanced recycler of waste polyethylene terephthalate (PET) plastic bottles on the African continent. It specializes in reclaiming and converting waste PET bottles into various grades of PET chips and flakes. In 2015 it established the first Coca-Cola approved bottle-to-bottle recycling plant.

Waste PET bottles are converted into fibre, thermoforming, food-grade and strapping-grade material to produce high-quality, reliable end-products for use in packaging and other applications.

Currently, Extrupet has the capacity to recycle over 2.5 million PET bottles per day. Extrupet not only contributes significantly to solving the problem of post-consumer PET waste in the environment, it also helps to alleviate poverty by creating opportunities for thousands of mini-entrepreneurs and informal waste collectors in South Africa.

The company is an important part of the PET plastic recycling industry in South Africa, assisting in the country achieving a 55 per cent post-consumer bottle PET recycling rate in 2016 (PETCO 2017).

Africa's first bottle-to-bottle recycling plant, Wadeville, Johannesburg

Photo credit: © GlobalPSC

CASE STUDY 13

PROTEIN FROM WASTE IN SOUTH AFRICA

There are incredible opportunities for innovation in the waste sector. In addition to traditional organic waste treatment technologies such as composting or biogas recovery, opportunities for high-value product recovery from organic waste are emerging globally, including in Africa. Research on high value product recovery from organic waste, such as the valorisation of chicken feather waste or the recovery of xylose from sawdust waste, is currently being funded by the Department of Science and Technology in South Africa (www.wasteroadmap.co.za).

One company AgriProtein (https://agriprotein.com), based in Cape Town, South Africa, has taken eight years of research and development into commercial-scale recovery of protein from organic waste.

One of the products produced from the recycling of organic waste, AgriProtein, Cape Town
Photo credit: © Philippi Economic Development Initiative

The need: Industrial livestock farming of chickens, pigs and fish relies on protein for feed. This protein is currently sourced from either land-based grains or marine-captured fishmeal. Producing traditional agricultural protein requires vast amounts of land and water to grow crops, while marine-sourced protein has significant impacts on marine stocks. As Africa's population grows and the demand for food increases, so will the demand for protein.

The solution: Waste-to-nutrient company AgriProtein has come up with a novel solution to this problem – produce large quantities of sustainable natural protein using fly larvae fed on organic waste. The company produces three commercial products from processed organic waste, an insect-based protein, an extracted fat and a residual soil conditioner. In 2016, AgriProtein opened the world's first industrial-scale insect recycling facility in Cape Town, South Africa, with the capacity to divert 100 tonnes per day of organic waste away from landfill and produce over 2,000 tonnes per year of insect-based protein. The organic waste is currently sourced from food factories, supermarkets, farms and restaurants.

The way forward: According to Engineering News (2017), Austrian-based Christof Industries, has partnered with AgriProtein to build up to 25 fly farms a year. The new standard 250 tonne per day AgriProtein waste bio-conversion plants will each divert over 90,000 tonnes a year of organic waste away from landfill to recycling and nutrient recovery. Similar insect feed for poultry and fish production initiatives are underway in Kenya and Uganda (IDRC n.d.)

Box 7.1 The importance of source separation

In high-income countries, separation-at-source plays a key role in waste management strategies. Before thinking about re-use, recycling, recovery and safe disposal, waste has to be segregated at source. In most African cities and towns, waste management consists of uncontrolled dumping of mixed waste in open dumpsites. Municipalities and private waste contractors dump waste without thinking about prior reduction of volume.

Separation-at-source should be clearly encouraged in Africa if the full potential of “waste as resource” is to be achieved, and the efficiency of waste management systems improved. In some cities and towns, source separation is being implemented at the pilot scale (Mbiba 2014).

There are both challenges and benefits associated with separation-at-source (CSIR 2011). The challenges include:

- Source separation of recyclables without any significant financial benefit can be challenging as it is considered time consuming by households and other waste generators.
- The lack of appropriate infrastructure can hinder source separation.
- Incorporating separate collection of recyclables into existing collection systems can be challenging as typically there is no legal requirement for separation-at-source in Africa, and collection vehicles are not adapted for separate collection systems.
- The easier it is for communities to dispose of recyclables, the more likely they are to take part in the initiative.

The benefits of separation of waste at source are:

- Higher quality and quantity of recyclables entering the recycling stream, with a higher resale value.
- A cleaner working environment for workers in the recycling industry.

7.4.3 Waste recovery

Waste recovery has yet to take off at scale in Africa. This includes technologies such as anaerobic digestion, landfill gas recovery and high temperature thermal treatment such as incineration. Except when used for special waste streams like HCRW, WtE technologies for the treatment of MSW are often cost prohibitive. With the current approach to MSW management in Africa being largely uncontrolled dumping, these WtE technologies are usually unaffordable to cities and towns. While many municipalities have undertaken feasibility studies to explore WtE, the energy produced by such technologies is often more expensive than energy generated through traditional means such as coal, and now through renewables such as wind and solar. WtE technologies are therefore typically both a more expensive way of managing waste and a more expensive way of producing energy (**see chapter 6**).

CASE STUDY 14

ENERGY RECOVERY FROM MSW LANDFILL GAS IN TUNISIA

Context and background: Landfills are known to be a source of greenhouse gas emissions. Recovering the biogas produced by landfills can help minimize the adverse environmental effects of landfills. Furthermore, it can produce clean energy that offset polluting fossil fuels. Waste-to-energy (WtE) technologies are still rare in Africa. This case study presents the potential for landfill gas-to-energy at the Jebel Chakir landfill, the first and largest landfill in Tunisia (Aydi 2012).

The 2012 study addressed the followings points:

- The amount of landfill gas (LFG) produced
- The energy potential of the LFG recovered
- Greenhouse gas emission reductions
- The opportunity for revenue generation through the sale of the certified emission reductions regulated by the Clean Development Mechanism.

Background: LFG is produced from the decomposition of the organic fraction of municipal solid waste. It includes mainly methane and carbon dioxide, but also ammonia, carbon monoxide, hydrogen and oxygen. Non-methane organic compounds are also present in the stream, at less than 1 per cent of the landfill gas. Worldwide, many landfill sites have installed LFG recovery and utilization systems, or landfill gas-to-energy systems, to recover the energy value of LFG and minimize the induced pollutant effects. The rate and volume of LFG produced depends on the age and composition of the landfilled waste, moisture content; site geology; leachate level, temperature distribution within the landfill, the presence of oxygen and the effectiveness of capping of the site. Methane is considered one of the most important GHGs, with a global warming potential more than 25 times higher than carbon dioxide. It is also explosive at concentrations of 5–15 per cent in air. The LFG recovery system installed at the Jebel Chakir landfill is aimed at reducing GHG emissions and recovering energy from LFG.

Enabling environment: The Jebel Chakir landfill is located 10 km southwest of Tunis City. It has a capacity of about 7 million tonnes of MSW and an area of 31.32 ha. Landfilling started in 1999 and stopped in 2010. The composition of waste in the landfill includes an organic fraction (composed mainly of food waste) (65 per cent); paper/cardboard (12 per cent); fines (8 per cent); plastics, leather and rubber (7 per cent); metals (4 per cent); textiles (3 per cent); and glass and ceramic (1 per cent). A biogas extraction plant has been in operation on the site since 2008. **Table 1** presents the biogas flow rate measured at the plant from 2008 to 2011. It shows that biogas flow rates were almost constant from 2008 to 2010, then decreased in 2011 after landfilling stopped.

Table 1 Biogas flow rates, 2008-2011

Year	LFG (m^3/h)
2008	1012
2009	1050
2010	1024
2011	867

The annual production of LFG at the landfill was modelled using the LandGEM model developed by the United States Environmental Protection Agency. The model determines the amount of methane generated by the landfill based on the methane generation capacity and the mass of waste in the landfill.

Key findings: Annual LFG production as predicted by the LandGEM model is depicted in **Figure 1**, along with the LFG actually collected over the 38 month period from the end 2008 to 2011. The model predicted that LFG production would peak at an estimated rate of 2.61×10^7 m^3/year, one year after landfill closure (2011).

Figure 1 Annual LFG production provided by LandGEM and collected (2008-2011) in Jebel Chakir landfill

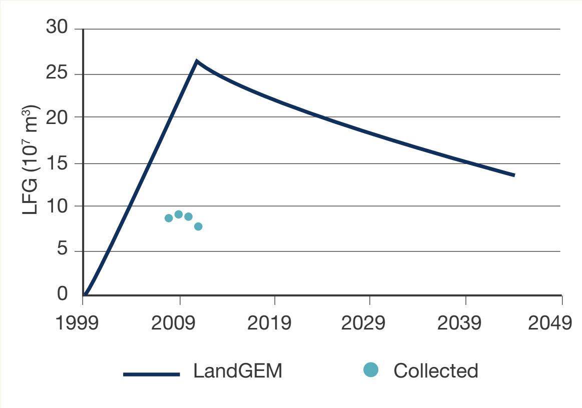
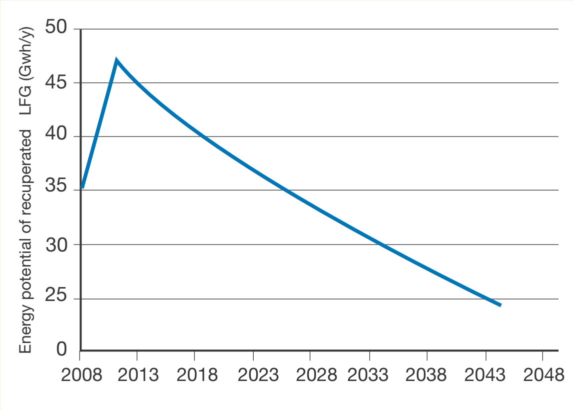


Figure 2 LFG energy potential (GWh) in the landfill of Jebel Chakir



Based on the LFG production, the electric energy potentially of the Jebel Chakir landfill was calculated (**Figure 2**).

The model showed that the estimated LFG produced and recovered in 2011 would have been sufficient to generate about 47 GWh of energy. By 2025, the plant would be 15 years old and the recovered landfill biogas would be sufficient to generate 35.5 GWh of energy, providing a significant power generation opportunity from the Jebel Chakir landfill. Furthermore, as landfill biogas recovery projects decrease green-house gas emissions, a landfill biogas recovery system and power plant should be in a position to draw income from carbon credit mechanisms.

CASE STUDY 15

INDUSTRIAL-SCALE BIOGAS FROM ORGANIC WASTE IN BRONKHORSTPRUIT, SOUTH AFRICA

The Bio2Watt plant is a commercial anaerobic digester that treats organic waste (www.bio2watt.com). In the process it produces biogas that is converted to electricity on site. The power produced by the plant is purchased by BMW for its Rosslyn production facility in Pretoria, South Africa. The BMW South Africa – Bio2Watt renewable energy partnership is the first commercially viable biogas project in South Africa. The information presented below was drawn from Bio2Watt's website and Core Earth Resources (2009).

Site selection: The site is located on a feedlot near the town of Bronkhorspruit, thereby providing the plant with access to an important waste source (manure), as well as grid connectivity and sufficient water supply from pollution control dams.

Technology: Organic waste is fed from a receiving tank towards primary and secondary digesters after being mixed with water, aiding its transport towards the digesters. The water used in the plant is obtained from pollution control dams on the feedlot. Two types of conditions are present in the airtight (oxygen-free) primary and secondary anaerobic digesters, which resemble large tanks. Thermophilic conditions in the primary digesters, where bacteria operate at temperatures of between 50–52 °C and mesophilic conditions in the secondary digesters, where bacteria operate at temperatures around 39 °C. The gas produced is eventually directed into an internal combustion engine, or gas engine, that produces electricity. A by-product of the plant is the nutrient-rich digestate, which is used as fertiliser.

Feedstock: Bio2Watt estimates that as much as 120,000 tonnes of organic waste (cattle manure and mixed organic waste) per year is fed into the plant, to

Bio2Watt biogas plant, Bronkhorstpruit

Photo credit: © Energy and Environment Partnership

[a] Based on currency exchange rates as at 28 October 2016 (R13.88 per United States dollar)

produce the biogas feedstock for a combined heat and power application. Tshwane Municipality and Kimberly Clarke are key suppliers of waste for the project. The plant is fed with 160 tonnes of manure per day, plus another 340 tonnes of waste from other sources.

Capacity: The plant has an installed electrical capacity of 4.6 MW and 3 MW of heat available for beneficiation. Its modular design means that it could be scaled up to around 8 MW, which would be in line with BMW's 12 MW demand at their Rosslyn plant.

Project cost: The project cost of R150 million (US$10.8 million[a]), or R34,090/kW (US$2,456/kW) was financed through a R98 million (US$7.0 million) loan from the Industrial Development Corporation (IDC), a R16 million (US$1.2 million) grant from the Department of Trade and Industry and about R36 million (US$2.6 million) in equity.

Partnerships: The project involves partnerships among Bio2Watt, BMW, the City of Tshwane and Eskom. Bio2Watt, a small independent power producer sells its electricity directly to BMW, a private industrial consumer, using the national grid (Eskom) to transport the power into the municipal area (the City of Tshwane). Although the electricity generated at Bronkhorstspruit is purchased by BMW, the biogas-generated electricity is not physically taken up at the Rosslyn plant. A power wheeling arrangement between the Bronkhorstspruit biogas plant and the City of Tshwane, as well as Eskom, allows the plant to connect to the grid and facilitate the sale of electricity between Bio2Watt and BMW. BMW pays a slightly higher premium for the "greener" power and Bio2Watt pays a monthly fee to Eskom for use of the grid and a wheeling fee to the city. Through this agreement, 25-30 per cent of BMW Rosslyn plant's electricity requirements are generated from renewables.

CASE STUDY 16

ELECTRICITY FROM OIL PALM RESIDUES IN ABOISSO, CÔTE D'IVOIRE

This project involves the construction and operation of the Biovea power plant in Aboisso, some 100 kilometres east of Abidjan, Côte d'Ivoire. The project is a joint venture among Biokala SA (a subsidiary of SIFCA, an Ivorian agro-industrial company) and two French partners, electrical company EDF and industrial group Bouygues. Biokala entered into a joint venture with its French partners in 2014, and in late 2017, the two companies and the Government of Côte d'Ivoire signed a rate agreement for the electricity to be generated at the plant. The project is expected to cost 120 billion CFAF (US$225 million) and create some 1,300 direct and indirect jobs.[a]

Côte d'Ivoire has one of the largest biomass deposits in Africa owing to its large agro-industrial sector. Its biomass potential is estimated at 12 million tonnes per year. The Ivorian government intends to take advantage of this potential by switching to a 15 per cent share of renewable energy from biomass in the energy mix by 2020. Biovea will be the first biomass plant on the African continent and the largest in the world exclusively fuelled by oil palm residues (branches and trunks). The biomass will be used as fuel in a boiler to produce steam and power an electric turbine. Two units of 23 MW are planned, for a total installed capacity of 46 MW.

Biokala will actively participate in improving the living conditions of rural populations through the collection of 400,000 tonnes per year of trunks and palms, both in the industrial and village plantations of Côte d'Ivoire. This collection chain, for which Biokala will be responsible, will be the subject of an additional investment of about US$11.45 million.

[a] http://www.commodafrica.com/01-12-2017-la-centrale-biomasse-biovea-entre-sifca-edf-et-la-cote-divoire-va-de-lavant Accessed 31 March 2018

CASE STUDY 17

A 50 MW WASTE-TO-ENERGY PLANT IN ADDIS ABABA, ETHIOPIA

The Reppie waste-to-energy facility will be located within a vacant brown-field site currently used to dump, burn and dispose of waste in Addis Ababa, Ethiopia. As part of a proposed transfer station that will see roughly 1,200 tonnes of waste a day, the facility will be located within a 7-hectare area, within the 37 hectare dump site. The WtE facility will be constructed within the dump site to avoid the additional cost of transporting waste from the transfer station and also to mitigate the environmental impacts by averting waste sent to landfills or open dumpsites (Messenger 2017).

The energy needs of Ethiopia are expanding rapidly, and the Government has indicated a need for a diverse range of energy sources, including new technologies like WtE, in order to alleviate dependence on factors outside of its control (the weather).

Technology: Waste combustion with energy recovery

Total estimated project: US$120 million, including transmission line

Capacity: Waste throughput of 350,000 tonnes per annum; energy output 50 MW

Feedstock: Residual municipal and commercial solid waste, and other similar waste types

Executing agency: Ethiopian Electric Power Corporation

The Koshe site has been used as an open dump and has served as the only landfill site for Addis Ababa for over 45 years. It is an area of vacant brownfield land with little ecological or visual value in its present state. Once completed, the Reppie facility will process over 1,400 tonnes of waste a day (roughly 80 per cent of the city's waste), and supply the city of Addis Ababa with 30 per cent of its household electricity needs[a].

Reppie 50MW waste-to-energy plant at the Koshe dump in Addis Ababa, Ethiopia
Photo credit: © Embassy of Ethiopia

[a] http://www.africawte.com/about.html and https://www.unenvironment.org/news-and-stories/story/ethiopias-waste-energy-plant-first-africa

TOPIC
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4

APPROPRIATE-NESS OF ALTERNATIVE WASTE TREATMENT TECHNOLOGIES FOR AFRICA:

A focus on waste-to-energy[1]

Introduction

Waste-to-energy (WtE) is a well-proven, advanced waste management technology. It has been in use for more than 100 years in Europe and has undergone significant technological evolution over this period. Today there are more than 500 European and 90 North American WtE facilities in operation (ISWA 2012). Furthermore, there are now more than 350 WtE facilities in operation in South-East Asia, primarily China. China is now the region experiencing the highest growth in WtE capacity, and it is estimated that more than 400 WtE facilities will be built in China in the coming 20 years. There are also significant numbers of WtE facilities in India, Taiwan, Singapore, South Korea and Japan, and WtE plants are currently being built in Ethiopia and the Middle East.

Globally, the most used, well-proven WtE technology is the movable-grate mass burn type. There are also fluidized bed WtE facilities and some relatively small pyrolysis and gasification facilities. To date pyrolysis and gasification are generally regarded as less robust and less proven for large-scale waste-to-energy conversion.

This topic sheet focuses on high-temperature thermal treatment by movable-grate fired WtE facilities, which is globally the most widely applied type of WtE facility in operation. Plant capacities of such facilities vary from as little as 2 tph to 35 tph (per line). Typically, a facility consists of several identical lines. Currently, only a few suppliers can supply plants with capacities in excess of 35 tonnes per hour of solid waste. Typically, economies of scale are acceptable for plants capable of treating in excess of 250,000 – 350,000 tonnes per year. However, there may be an acceptable business case for even 50,000-150,000 tonne per year plants located on remote islands or in isolated mountain communities, for instance, especially if alternative waste disposal options are problematic or energy sale is attractive.

Critically important issues for successful WtE projects

This topic sheet does not introduce details of the WtE facility design, energy production or environmental performance, as a wealth of information on those aspects is available from reputable global sources of knowledge such as the World Bank, UNDP and WHO. This topic sheet focuses on the key decision criteria and the critically important considerations in terms of WtE technology appropriateness for Africa.

[1] Topic sheet prepared by Torben Kristiansen

APPROPRIATENESS OF ALTERNATIVE WASTE TREATMENT TECHNOLOGIES FOR AFRICA:

A focus on waste-to-energy[1]

Critically important issues include:

- Waste incineration plants based on 1970, 1980 and even early 1990 design and standards of the European Union did cause unacceptable emissions to the air. There have, however, been significant improvements in combustion and flue gas cleaning technology, which means that all other past and potential environmental impacts have been engineered away, so that WtE facilities built according to current European Union standards have no local environmental impacts, other than traffic and visual impacts.
- Whereas WtE provides a 95 per cent volume reduction of waste, the flue gas cleaning system produces a small hazardous waste residue that requires safe disposal in an engineered hazardous waste landfill. The bottom ash, which is the largest part of the solid residue, can in many instances be recycled or used for road construction or as fill material, depending on processing, input waste quality and local regulations.
- WtE is capital intensive, typically requiring an initial investment in the range of US$800–1,100 per tonne of annual plant capacity (i.e. a 500,000 tonne per year plant would cost in the range of US$400–550 million, all-inclusive, depending on the actual cost of project development, planning, permitting, procurement policy and route, land development, utilities, access roads, architectural design standards, design policy, soil conditions, etc.). Annual operation and maintenance (O&M) costs are also significant and highly dependent on the revenue from sale of energy, etc. Hence, there will always be the need for a significant gate fee for the waste, even when the energy produced can be sold at a premium.
- The critically important WtE business risks include: i) waste quality and quantity risk, ii) gate fee payment risk, iii) permitting and planning risks, iv) change of legislation and policy risks, v) cost of residue disposal risk, v) revenue from energy sale risk, vi) plant availability risk, vii) currency exchange risk, viii) technology risk including obsolete technology risk and viii) political risk.
- Successful planning and procurement of WtE facilities requires international and local experience to ensure that the business case is sound and robust, all business case risks are managed well and that excellent design choices are made.
- Successful O&M requires access to skilled and qualified staff, as well as access to supplies and spare and wear parts of suitable quality.
- Well-defined and predictable waste quality, in particular in terms of calorific value, is critically important for the functioning of the plant, the available plant capacity, energy yield and the total business case. It is critically important that the waste flow and waste quality are well understood and can be controlled. The calorific value should never be less than 6 MJ/kg throughout all seasons and should preferably be higher than 7 MJ/kg. In Central and Northern Europe, the calorific value of the residual municipal solid waste is typically in the range of 9–12 MJ/kg, with residual refuse-derived fuel typically having a calorific value on the range of 11–15 MJ/kg.
- Especially in emerging economies, it is critically important to understand the informal waste management sector, including informal and formal waste picking, which can significantly affect the quality of residual waste arriving at the WtE facility.

African experience with WtE

There is only very limited and largely negative experience with WtE in Africa today. This is largely because most facilities in operation in Africa are very small waste incinerators based on 1970 type technology, mostly used for health care risk waste or certain types of hazardous waste and operated with limited or no flue gas cleaning systems (i.e. flue gas cleaning based on 1980 or early 1990 European flue gas cleaning standards).

Several WtE projects that comply with current European Union environmental standards are being considered or implemented in Africa. Environmental NGOs have been opposed to many of these, fuelled in part by the negative experience of the past.

At the moment, a modern 50 MW WtE facility is being built in Addis Ababa, Ethiopia (see **case study 17**). This project should be in operation by 2018, with construction having started in September 2014. This is a good example of how to implement WtE in Africa, where the Ethiopian power company has established the required momentum and addressed one of the critical risks, namely ensuring a reliable high revenue stream from sale of electricity. A strong international consortium of engineering, procurement and construction (EPC) contractors, advisors and project developers and strong local support also made this possible.

Several large cities in South Africa (e.g. Johannesburg, Cape Town, Pretoria, Pietermaritzburg and Rustenburg) have sought to establish advanced waste treatment facilities, including WtE plants. No investment decisions have yet been made, however.

WtE is considered a viable, relevant waste treatment technology, especially for Africa's mega-cities and high-growth urban areas, where simple collect-and-dump waste solutions are no longer sustainable or possible owing to a lack of landfill capacity, increasing transport distances and the increasing cost of land. In such areas, rapid economic growth has resulted in an explosion in waste quantities, and waste quality approximates that of many European cities. Unfortunately, the experience from many past attempts to establish WtE facilities shows that projects fail or halt because:

- The planned public-private-partnerships (PPPs) have been unattractive for potential PPP concessionaires owing to one-sided allocation of most or all business-critical risks to the private party.
- Unrealistic expectations of the revenue from the sale of electricity and recyclables and allocation of revenue risk to the PPP concessionaire and, hence, unrealistic expectations of low or no gate fees for waste.
- Inability of the public party to guarantee the put-or-pay payment and waste quality and quantity commitments, required to make the PPP concession bankable through commercial banks.
- Limited confidence in the public side's ability to honour payment commitments in a timely fashion.
- Lack of market appetite among PPP concessionaires to accept, for instance, permitting risks, political risks, regulatory risks and site procurement and development risks without caps or compensation mechanisms.
- Public opposition driven by vocal NGOs and political unwillingness to firmly support the choice of technology and required changes to waste management bylaws and residents' and businesses' waste collection fees.
- Legal or financial obstacles limiting municipalities' ability to either i) enter into PPP concession agreements or ii) finance, build and operate capital-intensive waste treatment infrastructure within the municipalities own structures or utilities.
- Resistance or regulatory barriers to securing long-term attractive power purchase agreements that secure long-term revenue and bankability of the WtE plant.

The institutional, regulatory, political and commercial barriers presented above have in many cases proved unsurmountable, even though the waste quality has often proved suitable for WtE in terms of the calorific value of the waste and the options for securing suitable waste quality through, for instance, diverting waste from markets and low-income settlements for alternative disposal to avoid waste with high food waste and moisture content.

For advanced waste treatment infrastructure such as WtE facilities to be an economically viable option, it is necessary not only to compare the cost of the WtE option with the cost of operating a non-compliant dump (where all costs have been sunk), but to also calculate the actual costs of the complete current waste management system, including the avoided costs of long-distance waste transfer and well-engineered distant landfills, complete with leachate collection and treatment and landfill gas collection and treatment systems. Typically, in most developing cities, the municipal budgets for waste

APPROPRIATENESS OF ALTERNATIVE WASTE TREATMENT TECHNOLOGIES FOR AFRICA: A focus on waste-to-energy[1]

management are currently far from reflective of the full and true costs, in part because major investments in such things as vehicles and new landfills are often financed via discretionary grants, with no reckoning of capital costs, amortisation etc. of the current assets.

Global drivers in solid waste management and their impact on WtE appropriateness globally and in Africa

Globally, we see the same key drivers for advanced waste treatment infrastructure, namely the urgency of:

- Sustainable urban living: improved public health and delivery of good, efficient public services.
- Improved resource efficiency supporting a shift towards a circular economy.
- Reduced greenhouse gas emissions and avoidance of further climate change, including avoidance of methane emissions from landfill gas, and securing of materials and energy recovery from residual waste.
- Increasing cost of land and need for urban development into peri-urban areas and conversion of former industrial and waste sites into liveable urban areas.
- Increasing cost of waste transportation and increasing cost of, and distance to, engineered landfills.
- A sense of ownership by municipal authorities, an enabling environment that provides a regulatory system supportive of thermal treatment of waste, and a low level of political resistance to development.

These urban development drivers result in, among other things, the need to change from collect-and-dump to a multi-stringed waste collection and recovery/treatment/disposal infrastructure that requires more organization, capital, skills and regulatory support systems.

Hence, there is a need for careful planning of plant capacity and ensuring that waste avoidance, resource recovery and energy recovery complement and support each other rather than competing. This puts a strain on ability of cities' to plan, finance, procure and implement, as well as enforce.

A multi-stringed waste management system that prioritizes waste avoidance, resource recovery and energy recovery is complex and requires complex regulation in terms of permitting, planning and fiscal measures, as well as capacity planning and mechanisms that support a circular economy/demand for high quality recovered materials.

Conclusion on WtE appropriateness for Africa

WtE is one of a few suitable advanced waste management technologies that, in a multi-stringed collection and treatment system, support the overall objective of sustainable urban liveable cities, such as landfill diversion, resource efficiency, energy recovery, greenhouse gas avoidance and a high level of public service.

Waste quantities are increasing in most growing African mega-cities, and there is significant availability of waste suitable for WtE treatment and energy recovery. Owing to the often large difference between less-affluent and highly affluent suburbs in African mega-cities, it is possible to source and mix the waste from the most suitable suburbs, urban centres and business districts to secure a calorific value in the range of 8–11 MJ/kg, which is suitable for energy conversion by WtE. Typically, a suitable calorific value can be maintained, particularly if there is source separation and recovery of such things as paper, cardboard, plastic bottles and perhaps garden waste/kitchen waste in affluent suburbs.

Based on technical and objective criteria, it is therefore possible in most fast-growing African mega-cities to establish WtE facilities that can contribute to much needed landfill diversion and electricity generation for the city, and support near-urban waste treatment. If the WtE facility can be located in or near (e.g. within 2 km of) industrial estates with energy-intensive industries that have large heating or cooling needs, it would further be possible to use more of the energy produced as industrial process energy. The critical factor for making WtE technology a success is not the technology itself but the mega-city's ability to evolve institutionally. This includes developing the ability to make and deliver on long-term financial and contractual commitments and the financial, institutional, enforcement and operational capacity to support a multi-stringed, capital-intensive waste management system, and securing the necessary specialised operational skills (e.g. via operational contracts or concession agreements).

In short, WtE should be considered a relevant and robust treatment technology for residual waste in fast-growing African mega-cities.

Reppie waste-to-energy plant, Addis Ababa, Ethiopia
Photo credit: © The Kenyan Wall Street

7.5 Planned new waste technology in Africa

At the time of writing, a number of large waste infrastructure development projects were planned or in construction in Africa, highlighting the growing waste management opportunity on the continent (Ecoprog GmbH 2017). These include:

Ethiopia / Addis Ababa 50 MW waste-to-energy plant	The Reppie waste-to-energy facility in Addis Ababa is expected to be commissioned in 2018. The facility at Ethiopia's largest landfill, Koshe, will produce 50 MW of electricity from the processing of 350,000 tonnes of solid waste annually. The US$118.5 million facility was fully financed by the Government of Ethiopia and jointly built by British firm Cambridge Industries Limited and China National Electrical Engineering Company. Ethiopia plans to increase energy production capacity from 4,200 MW currently to about 17,300 MW by 2020 from hydro, wind, geothermal, solar and biomass sources. http://news.xinhuanet.com/english/2017-08/31/c_136571944.htm
Zimbabwe / Harare project	The Harare City Council is awaiting government approval for a waste-to-energy power plant at the Pomona landfill and a biogas digester in Mbare. The Mbare facility is said to be 85 per cent complete, while the WtE plant is at an advanced stage of contract award. https://www.dailynews.co.zw/articles/2017/08/31/harare-moves-to-turn-organic-waste-into-energy
Nigeria / Wine bottle recycling plant opened in Jos	Nigerian recycling company Jos Masterminds Ltd. has opened a wine bottle recycling plant in the Plateau capital. At the plant, wine bottles collected from the region are cut into different shapes and sizes. The glass will then be further used for production. The source does not disclose information about the plant's capacity. https://www.pmnewsnigeria.com/2017/08/16/wine-bottle-recycling-plant-established-jos/
Nigeria / Lafarge Africa to focus on using more RE sources	In mid-2017, Lafarge Africa, one of the leading cement manufacturers in Nigeria, said that is was adding capability to use industrial waste, refuse-derived fuel from municipal solid waste and shredded tyres as a replacement for fossil fuels. This is part of the company's commitment to use renewable energy to enhance sustainable development of the construction industry. The company already uses palm kernel shells to produce biomass that fuels its plant. http://www.thetidenewsonline.com/2017/08/14/cement-firm-recommits-renewable-energy-sourcing/
Nigeria / Lagos looks for investors for waste projects	In mide-2017, the Nigerian city of Lagos issued a call for investors to invest in a new waste management programme called the "Cleaner Lagos Initiative". Under this programme, the local government aims to set up a 10-year concession plan based on a PPP, including improved waste collection services and waste treatment, recycling and the generation of energy from waste. Around US$136.38 million (NGN 50 billion) would be needed for this initiative. https://guardian.ng/business-services/money/lagos-woos-investors-for-n50b-waste-bond/

South Africa / Update on Drakenstein WtE project	According to local news, a memorandum of understanding has been signed for a WtE project in the Drakenstein municipality, South Africa. The state government has allegedly signed a memorandum of understanding with its preferred bidder for the project, South African firm Interwaste. The municipality was attempting to launch the project on a PPP basis, but had not yet received state government approval. The exact capacity of the site remains uncertain. https://www.iol.co.za/news/south-africa/western-cape/wellington-waste-project-flawed-illegal-10537494
Namibia / Windhoek city plans to invest in waste-to-energy power plant	The chief executive officer of Windhoek city, said in a recently launched strategic plan that part of an additional area of focus in the next five years includes investments in renewable energy generating 50 MW and WtE power plants creating 5 MW of power. This initiative is part of the key focus area under the spatial development framework to be completed within the 2017/18 financial year. https://www.newera.com.na/2017/07/26/windhoek-needs-to-spend-n4-billion-to-survive/
South Africa/ Johannesburg	Johannesburg landfill gas to energy plants producing up to 13W of energy. https://www.ashurst.com/en/news-and-insights/insights/waste-to-energy-african-opportunities/
Nigeria/ Lagos	MSW Composting project developed by Earthcare Nigeria Ltd processing 1,500 tonnes of solid waste per day to produce composted material. https://www.ashurst.com/en/news-and-insights/insights/waste-to-energy-african-opportunities/
Ghana/Kumasi	The biogas plant at Kumasi Abattoir, Ghana, involving production of biogas from the treatment of animal, crop and sewage waste. https://www.ashurst.com/en/news-and-insights/insights/waste-to-energy-african-opportunities/
Nigeria/ Lagos	The Ketu Ikosi biogas project in Lagos being developed by Midori Environmental Solutions in conjunction with Waste Management Authority, treating food waste as the livestock. https://www.ashurst.com/en/news-and-insights/insights/waste-to-energy-african-opportunities/
Senegal/ Ferlo	The pilot biogas initiative, Ferlo, Senegal involving a development of 40 bio-digesters in Ferlo using animal waste as feed stock. https://www.ashurst.com/en/news-and-insights/insights/waste-to-energy-african-opportunities/
Kenya/Naivasha	Gorge Farm AD power plant, Naivasha commissioned by Tropical Power with biogas plant manufacturer, Snow Leopard Projects GmbH, processing 500,000 tonnes of organic waste per year https://www.ashurst.com/en/news-and-insights/insights/waste-to-energy-african-opportunities/

7.6 Conclusion and recommendations

A large range of alternative waste treatment technologies are available on the market and could be immediately inserted into cities and towns in Africa. The appropriateness of these technologies for Africa must be questioned, however. Constraints to technology uptake include lack of political will, lack of enabling regulatory environment, large investment requirements, lack of local technical skills to properly manage the system and the need to include both formal and informal actors in the system. A further restriction is the lack of widespread separation-at-source of potentially recyclable waste. Low-cost technologies for recycling and recovery of secondary resources, combined with social innovation, appear to be the most effective technologies at this stage.

While producing real environmental and social benefits, however, many of the required social innovations may not achieve the scale of reuse, recycling or recovery necessary to address the expected growth in waste generation in Africa (**see chapter 1**). Africa will therefore need to consider a combination of technologies, ranging from small-scale, low-cost to appropriate larger-scale, traditional waste prevention, recycling and recovery technologies in the medium- to long-term. Modern recycling and recovery solutions are emerging on the continent, including various WtE technologies for organic and residual waste, which is promising for future investment and uptake.

With 19 of the world's 50 largest dumpsites in Africa (UNEP 2015), the shift from uncontrolled dumping to sanitary engineered landfilling of "residual waste" must be a priority for the continent. The resultant increase in disposal costs at sanitary engineered landfills will create opportunities for the adoption, adaptation and localization of local and inbound AWT technologies in Africa. In so doing, it creates numerous opportunities for job creation and income generation, including integration of informal actors involved in waste collection and sorting.