SAMSET brief on Waste to Energy

This briefing note has been designed for use by city officials and planners working in sub-Saharan Africa. It is a practical guide, which identifies easy to achieve energy interventions that will save money (for cities, businesses and households), promote local economic development, and enhance the sustainable profile of a city. This note is specifically aimed as a support tool to achieve the implementation of key interventions within municipalities across sub-Saharan Africa.

African municipalities need to be prepared to deal with an explosion in demand for services from burgeoning populations caused by two factors – high population growth in Africa as a whole, and rapid urbanisation. An interesting feature of population growth in sub-Saharan Africa is that it is expected to take place mostly in small and medium sized cities, rather than capitals (UN-Habitat, 2010). These changes are taking place at a time when many countries are devolving administrative powers to local governments, yet municipal authorities lack the skills and expertise to address challenges, to manage resources, and to implement and enforce policies.

Energy is only one of many services that municipalities need to address in the face of increasing urbanisation, but it is crucial to any form of urban development – planned or otherwise. People need energy as part of their every-day lives. The supply of energy is closely linked to economic development, health and individual wellbeing, as well as to local and global environmental sustainability.

Recognising the emerging role of municipalities, with limited capacity, in addressing energy provision in urban centres, the "Supporting African Municipalities in Sustainable Energy Transitions" (SAMSET) project seeks to build capacity and develop a practical and effective knowledge exchange framework for supporting actors involved with municipal energy planning. This note is an output of the SAMSET project.

The purpose of the note is to give planners an idea of the range of energy interventions that it is possible for them to implement at the municipality level. It provides enough information to give a basic understanding of different energy technologies – enough to start making enquiries and engage in discussion. More detailed technical expertise will, however, be needed in order to design a bankable project.

Full guide can be found at africancityenergy.org/uploads/resource_101.pdf

More info can be found at africancityenergy.org/

More project info can be found at samsetproject.net

Overview

Waste-to-energy (WtE) is the process of generating energy in the form of electricity and/or heat from the treatment of waste. WtE has the ability to reduce the volume of waste by approximately 90%. Residual waste, the waste left over when all possible recycling has been done, is a partially renewable energy source and is sometimes referred to as low carbon energy.

Waste-to-energy (WtE) technology, reduces the amount of waste that would otherwise go into landfill, or reduces the amount of methane being released into the atmosphere from landfill and sewerage sites. It is necessary to consider the possibilities that WtE technologies present, not only from their energy generation potential, but also from their potential to reduce greenhouse gases.

A number of WtE technologies exist worldwide, with the most prevalent being landfill gas, wastewater gas, incineration and gasification.

It is important to remember however that the most sustainable way to deal with waste is to eliminate it entirely. Reducing the amount of waste generated, reusing discarded items, and recycling and composting are fundamental principles in achieving zero waste. Municipalities should strive to achieve this goal.

Africa already has a track record of utilising industrial waste from industrial and agro-processing factories. Power generation from bagasse is the most important of these. These kinds of waste to energy schemes have already benefited from feed-in tariffs, which pay a generous amount for each kWh of electricity exported to the grid.

Landfill Gas: When organic waste decomposes without the presence of oxygen, anaerobic fermentation slowly produces landfill gas. Landfill gas contains 40-60% methane, with the remainder being mostly carbon dioxide. Methane is 23 times more potent than carbon dioxide when it comes to its properties as a greenhouse gas, making it a key climate change gas to address. Burning methane produces energy, carbon dioxide and water. This is a very useful outcome as besides being an energy source, the hugely potent methane is replaced by the considerably less potent CO2. For this reason landfill gas projects are potentially very lucrative CDM projects.

Image © eThekwini

Landfill gas energy facilities capture methane, which can be burned in an engine to produce electricity, or used directly for cooking, and for space and water heating. When concentrated and compressed, it can also be used as a vehicle fuel source.

Wastewater Gas: Wastewater is any water that has been adversely affected by human influence. It can originate from a number of sources including a combination of domestic, industrial, commercial or agricultural activities, surface runoff or storm water, and from sewer inflow or infiltration.

The theory behind anaerobic digestion of

Case study: Vegpro, Kenya

In Kenya, Vegpro is one of the country's largest exporters of fresh vegetables and flowers. Vegpro's Naivasha farm produces around 10,000 tonnes of vegetable per year, and several times that in waste vegetable matter (up to 45,000 tonnes per year). The waste is put into an anaerobic digester where it decomposes, producing methane. The company uses GE's Jenbacher gas engines to convert this methane into electricity. Award winning Tropical Power are the project developers.

The two engines have a generating capacity of 2.8 MW – enough to power the farm and 5,000 nearby homes. Waste heat from the engines can also be used to power cooling systems that will be part of a packing facility, which is to be relocated from Nairobi.

Image © Tropical Power

wastewater is very similar to that of landfill gas in that waste is decomposed without the presence of oxygen to produce a gaseous mixture of methane and carbon dioxide. The volume and mass of wastewater sludges are reduced by anaerobic digestion, as is the emission of volatile organic compounds and odours into the atmosphere. Similar to landfill gas facilities, anaerobic digestion of wastewater produces a biogas of 60% methane and 40% carbon dioxide that can be used for energy production. This biogas can be used to generate heat and electricity or it can be used as a vehicle fuel.

The energy potential contained in wastewater and its bio solids/biogases exceeds the energy used to treat it by 10 times (WERF, 2011).

Incineration: Incineration involves the combustion of organic materials into incinerator bottom ash, flue gases, particulates, and heat. The heat produced can be used to generate steam which can then be used to drive a turbine in order to produce electricity. 500 kWh of electricity can be generated per ton of municipal waste. As a result, incineration is both a landfill reduction method, reducing the volume of waste by 95-96%, and a WtE technology. High volume reductions are, however, only seen in waste streams with high amounts of packaging materials, paper, cardboard, plastics and horticultural waste. Recovering the energy from waste before disposal is much preferable to landfilling if pollution control requirements and costs are adequately addressed.

Gasification / Pyrolysis: Just about any organic material, such as biomass, wood and plastic waste, can be converted into a gas mixture of carbon monoxide and hydrogen by gasification and pyrolysis.

Unlike incineration, gasification does not produce energy from waste through direct combustion. Instead it is a thermo-chemical process in which wastes, including their biomass content, are heated in an oxygen deficient environment to produce a low-energy gas. This gas is known as synthesis gas or syngas and contains hydrogen, carbon monoxide and methane. The gas can then be used as a fuel in a turbine or internal combustion engine to generate electricity. Pollutants are removed from syngas before it is combusted so that it does not produce the high levels of emissions associated with other combustion technologies.

Like gasification, pyrolysis also turns waste into energy by heating under controlled conditions, but involves thermal degradation in the complete absence of air. Pyrolysis produces char, pyrolysis oil, and syngas, all of which can be used as fuels.

The Case

All of the WtE technologies generate energy from products that would otherwise not be used. There is a constant need for waste disposal, resulting in an equally constant energy generation potential. Currently, world cities generate about 1.3 billion tonnes of solid waste per year (Hoornweg & Bhada-Tata, 2012), a volume expected to increase to 2.2 billion tonnes by 2025. As a result of urbanisation and economic development, waste generation rates are projected to more than double in the next twenty years. Whilst there is poor data availability on waste management in Africa as a whole, sub-Saharan Africa is estimated to generate 62 million tonnes of waste per year. Whilst per capita waste generation is generally low, with an average of 0.65 kg/capita/day, it does seem to vary a lot - from 0.09 to 3.0 kg per person per day. Countries with the highest per capita rates tend to be islands, possibly due to waste generated by the tourism industry.

Most waste in Africa is either burned or simply dumped, usually in peri-urban areas on the outskirts of urban centres. Dumping sites usually have no provision for groundwater protection, leachate recovery, or soil cover, so they present risks to health, air quality (smells), groundwater contamination, and climate change (methane emissions).

WtE reduces the levels of methane being generated at the waste site. In addition, where electricity generated by WtE plants displaces electricity that is generated by fossil fuels, WtE plants also reduce the emissions these plants would otherwise produce. These technologies can also reduce other adverse impacts related to fossil fuel based electricity production, such as coal mining and transportation. WtE technologies can help meet renewable energy targets within cities and can help to diversify energy profiles.

Landfill gas: Landfill gas (LFG) recovery could be an opportunity for energy recovery and a potential source of energy in areas with low access to energy, such as Africa.

LFG can either be captured and used for energy generation or flared to reduce greenhouse gas emissions. Prior to use the gas is treated to remove trace gases and impurities, it can then be used as fuel within internal combustion engines, gas turbines and steam boilers for electricity or heat generation. LFG use in small to medium size internal combustion engines is good option for the production of electricity in Africa. Currently only a few CDM projects have been reported for methane capture from landfill sites on the continent and the large majority of landfills in Africa do not have any system for gas collection installed (Scarlat et al., 2015).

Wastewater Gas: Anaerobic digestion is a waste treatment process that powers itself. CO2 emissions can be reduced by 16% when it is used to treat sewage waste rather than using conventional sewage treatment techniques. In addition to producing energy, anaerobic digestion can also produce quality soil conditioner to fertilize land. The conditioner is a result of the solid and liquid residue called digestate that is produced throughout the process. If the digestate is clean enough, it can also be used for land reclamation and landfill restoration.

Incineration: Incineration reduces mass and volume of landfill, lightening the load of landfill management in cities. There has been concern around the health ramifications, but significant advances in emission control have occurred and strict regulations have been initiated concerning dioxin and furan emissions (both of which are highly toxic). By diverting municipal solid waste, incineration avoids the release of methane into the atmosphere. In addition to methane, for every ton of municipal solid waste that gets incinerated, approximately one ton of CO2 is prevented from being released into the atmosphere. It is estimated that 2,000 tonnes of waste have an electricity potential of 1,050 MWh (although this depends on the calorific value and composition of the waste).

Gasification / Pyrolysis: Gasification and pyrolysis are extremely efficient ways of using biomass to produce energy, both more efficient than incineration. They are flexible technologies where existing gas-fuelled devices (ovens, furnaces, boilers, etc.) can be retrofitted with gasifiers and syngas to directly replace fossil fuels. Gasification is able to generate energy in engines and gas turbines, which is cheaper and more efficient than the steam process used in incineration.

Municipal solid waste can be reduced by as much as 75%, reducing to the same degree the amount of potential emissions the waste would have created in a landfill.

Potential for Rollout

The amount of waste generated will only increase. Low-income countries have low waste collection rates, around 41%, while high-income countries average 98%. In developing countries, waste management often takes the highest share in a municipality's budget (20% to 50%) and a significant part of this (up to 80–90%) is used for waste collection. However, services typically neglect 30-60% of all urban solid wastes and serve less than 50% of the population. The potential for low income countries to produce energy from waste is therefore highly dependent upon levels of waste collection.

Landfill Gas: Landfill gas recovery is considered the most appropriate way of producing energy from waste, particularly in the short term. Landfill gas poses fewer technical difficulties and lower investment costs. LFG collection is technically feasible approximately 7 years after a landfill is opened and can continue production for a maximum of 25 years after landfill closure.

Estimates of potential electricity generation from LFG schemes are tricky because there is little data available, and it is of questionable reliability. Nevertheless, a study in Uganda explored the viability of electricity generation from LFG in Kampala and assessed the electricity potential of the landfill at 31,000 MWh in 2009 and 26,600 MWh in 2011. The study concluded that the project was not viable under current economic conditions, unless improved incentives, feed-in -tariffs and carbon credits were put in place. Electricity generation from LFG in South Africa on the other hand was found to be economically viable.

Incineration: At present, waste incineration is not realistically viable in most of Africa.

Wastewater Gas: The total potential for wastewater gas in sub-Saharan Africa is not clear. Currently there is limited focus on sewage gas methane production in the country. This is partly because landfill methane is considered a more feasible option in terms of institutional and technical capacity, and financial viability. It is however recognized as one of the options that will be exploited in the medium-term to promote the renewable energy profile of cities.

Current costs of wastewater gas facilities make them less economically viable when compared to landfill gas projects. Also given that no REFIT is available for them, it is unlikely that cities such as those in South Africa will focus on this area in the short term.

Gasification / Pyrolysis: Although high capital costs are associated with gasification power plants, there is the potential for operating costs to be significantly lower than those of conventional processes or coal-fired plants. Gasification plants are more efficient, require less pollution control equipment and are able to generate a variety of energy products. However, waste gasification has yet to be proven at a commercial scale.

Case Study: Johannesburg Wastewater Treatment Works, South Africa

To offset the electricity costs of wastewater treatment, the City of Johannesburg aims to generate its own electricity from treatment plants making wastewater works self sufficient. Upgrades to wastewater treatment works in Johannesburg, Gauteng from 2012 will see biogas production for electricity generation as part of the city's Capital Investment Programme.

By cleaning or "scrubbing" biogas, it can be used to generate electricity using co-generation methane gas engines or turbines. Biogas scrubbing has the added benefit of reducing corrosion and maintenance costs, thus increasing the sustainability of the plant. This WtE project has a short payback time of just 4-5 years and demonstrates the City's commitment to renewable energy.

Barriers to Implementation

Onerous project planning process: Establishing landfill gas projects entails a difficult process of carbon finance registration, lengthy environmental impact assessments and the approval of local governments. These constraints are a deterrent for cities to implement LFG projects. The renewable energy feed in tariff (REFIT) in South Africa will now make landfill gas projects financially feasible which will negate the need for carbon financing, and make city approval processes for projects less problematic. If cities can see a clear and simple financial case for intervention, it should pave the way for increased implementation.

Toxicity: Despite advances in emission controls and government regulations, there is still public debate over whether incineration is possible without emissions. Incineration also produces a highly toxic fly ash that requires safe disposal. This can lead to residential health concerns. Gasification and pyrolysis on the other hand are cleaner processes and do not pose toxicity threats. This does not pose an immediate threat as incineration is not currently a priority for cities.

Sustainability: The real sustainable solution is zero waste. Waste has less of an impact on climate change and more economic value when it is reused, recycled or composted than when it is converted to energy. As a result, recycling and composting programs are required, but these may be hindered where WtE technologies are implemented. This is not an immediate concern, but could become so as more WtE sites are established.

Economy: Most WtE facilities have high capital costs and require technical expertise for maintenance, requiring long contract periods to recover initial investment costs. It is likely that other forms of WtE technologies will only become implemented on a mass scale if they are also included in mechanisms to support renewable energy such as feed-in-tariffs. WtE plants can access carbon funding to make them more financially feasible. A small number of African countries have introduced Feed-in-tariffs, and some have introduced auctions.

Implementation

Landfill Gas Projects: As landfills are City owned, a landfill gas project should be predominantly a City Council driven process. Landfill sites have substantial potential for income generation through a carbon offset project in addition to the savings from electricity generation. It is therefore an attractive prospect for City Councils to consider if the business case is made. In order for the City to participate in the process, certain guarantees have to be in place, to ensure that public money will not be put at risk. A willing buyer for the carbon credits has to be sourced, and the project has to be approved by the Designated National Authority (DNA) as a valid carbon offset project. Negotiations in this area are critical as a first phase of the project, and should be done at a high level – preferably mayoral - to ensure City buy in.

Using LFG for energy generation has a number of other benefits. It reduces odours and harmful emissions, minimises local pollution and is a step towards slowing climate change. Once secured, the City will have to go through the necessary internal assessment and approval processes to determine who will plan, construct and operate the landfill gas site. These City processes are well established and should not present too many obstacles, given that:

- the project will not place a financial burden on the taxpayer, and is in fact financially viable;
- with the REFIT in place there are very low financial risks associated with the project;
- employment will be created in the City.
- CO_2 emission levels will be reduced in the City, supporting local and national targets;
- the energy security of the city will be enhanced;
- a source of renewable energy will be added to the grid, supporting local and national targets.

Other WtE Technologies: It is unlikely that Cities will pursue other WtE technologies in the short term. However, should the REFIT be made available to these technologies, it is anticipated that they too will enjoy mass implementation in the country.

Case Study: Kampala City Abattoir, Uganda

Kampala's abattoir runs 24 hours a day and was previously forced to rely on expensive polluting diesel generators when the city's power went out. However, a pilot project funded by the Swedish International Development Cooperation Agency (SIDA) through the Bio-resources Innovations Network for Eastern Africa (Bio-Innovate), began in February 2015 to turn waste into biogas.

Image © Thompson– Reuters

To do this, the slaughterhouse puts its waste and wastewater through a fermentation process that releases methane, which is then captured and burned to produce electricity. To add to the project's green credentials, it uses solar panels to heat water and raise the temperature in the digester, to allow it to produce the most burnable form of methane.

The system generates on average about 10 to 15 cubic metres of biogas daily which is used to run the abattoir's generator. It is estimated that with 60 cubic metres of gas it would be possible to run about 15 security lights, 15 deep freezers and 15 refrigerators at the abattoir, helping save around 8 million Ugandan shillings ($2,800) per month.

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