Sustainable energy solutions for South African local government

A practical guide

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Waste to Energy: Incineration, gasification and pyrolysis

Overview

Incineration, gasification and pyrolysis can be simply described as a process whereby organic matter is decomposed by burning (heating the waste). The major differences between the three processes relate to operating temperatures (linked to oxygen volumes in the burning process) and the products that you obtain from each due to the operating temperatures at which the waste is burned. While incineration and gasification technologies are similar in principle, the energy product from incineration is high-temperature heat whereas combustible gas is often the main energy product from gasification.

These technologies offer an opportunity within the South African context, but are still relatively costly, require highly specialised skills to manage and operate , and need secure volumes of waste (security of feedstock) to ensure the viability of these technologies. Another barrier relates to enabling legislation. Land zoning issues remain a challenge for the establishment of such WtE technologies.

It is likely that in the short term, given the relative costs and skills levels, municipalities will focus on the biogas to energy projects from landfill and WWTW as detailed in other chapters. However, the private sector may well pursue such projects and this may draw municipalities in. A working knowledge of the technology is therefore useful.

Implementation

Incineration

Incineration involves the combustion of organic materials into incinerator bottom ash, flue gases, particulates, and heat that can be used to generate electricity. It is both a landfill reduction method, reducing the volume of waste by 95-96%, and a WtE technology.

The heat produced upon incineration can be used to generate steam which can then be used to drive a turbine in order to produce electricity. The typical range of net electrical energy that can be produced is about 500 to 600 kWh of per tonne of waste incinerated [1]. Thus, the incineration of about 2,200 tonnes per day of waste will produce about 50 MW of electrical power. Electricity production is thus around 0.5–0.7 MWh/t of municipal solid waste (Royal Haskoning DHV, 2014[2]).

Incineration reduces mass and volume of landfill, lightening the load of landfill management in cities. There has been concern around the health ramifications of incineration, 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 substances). By diverting municipal solid waste, incineration avoids the release of methane into the atmosphere. In addition to methane, for every tonne of municipal solid waste that gets incinerated, approximately one tonne of CO_2 is prevented from being released into the atmosphere.

Medical waste incineration is the most common application in South Africa, but there are also some industrial waste incinerators for hazardous waste. There are currently few incinerators for household waste (3SMedia, 2013[3]).

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1 https://en.wikipedia.org/wiki/Waste-to-energy_plant#cite_note-Columbia-1.

2 Royal Haskoning DHV (2014) Municipal Solid Waste Diversion and Beneficiation Opportunities at Nelson Mandela Bay Metro Municipality – Feasibility study final report.

3 3s Media (2013) Should the focus rather be on waste to energy than incineration? Sourced online at Infrastructrene.ws http://www.infrastructurene.ws/2013/05/15/should-the-focus-rather-be-on-waste-to-energy-than-incineration/

Figure 1: An example of a low capacity, mobile incinerator. These may be deployed in developing countries for health purposes, for example the destruction of medical waste or to dispose of infected animals quickly.

Source: Public Domain, https://en.wikipedia.org/w/index.php?curid=11060590

The biggest challenges for waste-to-energy mass burn incineration currently in South Africa lie in the high capital costs and air emission control requirements. Incineration produces particles containing toxic metals, dioxins, and furans that are so small that they can potentially evade pollution control devices. Incineration also produces a highly toxic fly ash that must be safely disposed of; leading to transportation and residential health concerns. Gasification and pyrolysis on the other hand are cleaner processes and do not pose toxicity threats, but remain "third generation" technologies.

Although the fuel (i.e. the waste) in a WtE incineration plant may be free, and the plant may save hugely on landfilling costs, the high capital costs of plants means that incineration is still prohibitively costly as a household waste treatment approach in South Africa.

Gasification / Pyrolysis

Just about any organic material, such as biomass, wood and plastic waste, can be converted into a gas mixture of carbon monoxide, hydrogen and carbon dioxide by gasification and pyrolysis. This is achieved by reacting the material at high temperatures (>700 °C), without combustion, with a controlled amount of oxygen and/or steam.

Unlike incineration, gasification does not produce energy from waste through direct combustion. Waste, steam, and oxygen are fed into a gasifier where heat and pressure break apart the chemical bonds of the waste to form synthesis gas (syngas). It allows the breakdown of hydrocarbons into the gaseous mixture by carefully controlling the amount of oxygen available.

Syngas may be used directly in internal combustion engines or to make products that substitute for natural gas, chemicals, fertilisers, transportation fuels and hydrogen. 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 typically occurs under pressure and at operating temperatures above 430ºC (800ºF).Pyrolysis produces char, pyrolysis oil, and syngas, all of which can be used as fuels.

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

Municipal solid waste can be reduced by as much as 75% through this process, reducing to the same degree the amount of potential emissions the waste would have created in a landfill. The process of sorting and preparing the solid waste (autoclaving) for pyrolysis is well established and the technological expertise is available in South Africa.

These technologies are cleaner than incineration and do not pose toxicity threats. However, the technology is still relatively new (or "third generation") with limited plants in operation around the world (although anticipated to grow substantially into the future).