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Selection of Thermal Technology: Incineration vs Gasification

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Thermal treatment technology is gaining momentum around the world in order to meet the challenge in disposal of ever-increasing volumes of municipal solid waste (MSW) simultaneously producing energy. For example, in the European Union, thermal treatment of MSW on average increased from 14% in 1996 to 19% in 2007 (Eurostat, 2008). The thermal technologies can be grouped into two main categories: combustion based- and gasification based- thermal treatment.

Incineration is the complete rapid exothermic oxidation of organic wastes in presence of excess air in a large furnace, thus the hydrocarbon content of waste is converted to carbon dioxide and steam, while other fuel components may form by-products such as ash and gaseous pollutants requiring emission control equipment. The heat generated can be used to generate electricity.

Gasification, often referred as ‘indirect combustion’ is the partial oxidation of the substance in an oxygen deficient environment resulting in the production of a hot fuel gas (‘‘producer gas’’ or ‘‘syngas’’), containing large amounts of not completely oxidized products. Basically, part of the fuel is combusted to provide the heat needed to gasify the rest.

Conventional combustion is a well-established technology developed over 100 years ago for energy generation from waste (Waste Online, 2004). Technological improvements from that time made conventional combustion the most common WTE technology to treat MSW. The most common conventional combustion approach is called single-stage combustion or mass burn incineration. Over 90% of WTE facilities in Europe utilize mass burn incineration technology with the largest facility treating approximately 750,000 tpy (Malkow, 2004).

Recently, gasification is being advocated as the choice of the thermal technology instead of the traditional combustion of solid wastes, mainly due to the following reasons (Arena, 2012; Consonni and Viganò, 2012)

- The partial oxidation of the substrate with pure oxygen generates a syngas free of atmospheric nitrogen and then with a higher calorific value, ranging between 10 and 15

MJ/m^3, which makes the syngas suited for use in separate process equipment, even at different times or sites.

- Syngas can be used, after proper treatment, in highly efficient internally-fired cycles (gas turbines and combined cycles, Otto engines) to generate electricity or to generate high-quality fuels (diesel fuel, gasoline or hydrogen) or chemicals.
- The reducing conditions in the gasifier improve the quality of solid residues, particularly metals and reduce the generation of some pollutants (dioxins, furans and NOX).
- Gasification at high pressure enhances the opportunities to increase energy conversion.

Despite these advantages, gasification of wastes continues to face several technical and economic issues, mainly related to the highly heterogeneous nature of feed, municipal solid waste, and inadequate operating data from the relatively limited number of plants under commercial conditions. Some of the key issues are:

- The higher moisture content of the MSW necessitates pre-gasification drying, size reduction and/or feed system customization.
- Since feedstock is oxidized/converted in two steps (gasification + syngas combustion/conversion) plants tend to be more complex and costly, more difficult to operate and maintain, and less reliable.
- Combination of air, oxygen, and/or steam—has a substantial effect on the output syngas composition. Air introduces nitrogen, which dilutes the product gas and is detrimental to synthesis processes. To counteract this, pure oxygen can be used as oxidant, which requires an oxygen plant as well as energy input into the reactor that would increase the production cost.
- Syngas is highly toxic and explosive; therefore raises major security concerns and requires sophisticated control equipment.
- If required, syngas treatment is very demanding and costly that causes significant energy consumption/losses, which in turn reduce the overall energy conversion efficiency typically lower than that of combustion plants.
- The syngas must be scrubbed not only to improve the energy efficiency of the syngas but also to protect the internally fired-cycles (gas turbines, internal combustion engines) from acid gases, particulates and tar.
- The actual production of pollutants depends on how syngas is processed downstream of the gasifier; if syngas is eventually oxidized, dioxins, furans and NO_X may still be an issue.
- Gasification at high pressure may increase energy conversion but poses formidable challenges and has not been attempted by any technology developer.
- Gasification technologies involve more complex chemical processes and were less proven on a commercial scale, even though about 100 gasification-based WtE plants, mainly in Japan but now also in Korea and Europe, are in operation. But these operations indicate a convenience for size smaller than about 120,000 t/y (~328 t/d).
- Gasifiers tend to have higher operating and capital costs in comparison with conventional incinerators (typically in the order of about 10%, mainly as a consequence of the presence of the ash melting system).

Recently, Consonni and Viganò (2012) analyzed the gasifiers, assuming gasification as a 'two-step oxidation processes', and reported that their energy performances are very similar to those of conventional plants. Therefore their potential benefits relate to material recovery and operation/emission control, recovery of metals in non-oxidized form, collection of ashes in inert, vitrified form, combustion control and lower generation of some pollutants. However, as mentioned before, the actual production of pollutants depends on how syngas is processed downstream of the gasifier.

Considering these issues, reaching an acceptable (positive) gross electric efficiency is a major challenge, because the high efficiency of converting syngas to electric power is counteracted by significant power consumption in the waste pre-processing, the consumption of large amounts of pure oxygen and gas cleaning. Further, the acidic pollutants may pose challenge in having long service intervals in the plants. Most importantly up-scaling seems to be an issue as evident from the units handling lesser volumes than the incineration. In contrast, mass burn incineration in moving grate reactors and fluidized bed incineration are well established and the most common type of 'waste-to-Energy' technologies used worldwide with more than 900 plants in operation (e.g. 420 of the 450 combustion-based WtE plants in Europe are mass burn moving grate incinerators), with a plant size that ranges from 50,000 to 750,000 t/y (Arena et al., 2012).

Gasification of solid combustible matter is also not a new technology as industrial applications for the production of town gas from coke exists for centuries and production of electricity from coal or heavy oil in large scale gasifier plants exist for decades (Higman and Van Der Burgt, 2003; Minchener, 2005). Considerable literature is available on biomass gasification also. However, variations in the properties of even the coal, a much better feedstock, produces a major impact on the design, performance, maintenance and cost of gasification (Collot, 2006), thus making its operation unreliable for highly heterogeneous MSW.

Independently-verified emissions tests indicate that environmental performance is one of the greatest strengths of gasification technology; however, as Arena et al. (2012) suggested, in the aggressive working environment of MSW management, with its uncompromising demand for reasonable cost, high reliability and operational flexibility, it could be premature to indicate the gasification as the thermal processing strategy of the future or even as a strong competitor for combustion systems, at least for any size of WtE plants.

In view of the limitation of gasification and the practically absence of large scale commercial operation of over 1000 tonnes per day gasification operation in this world, it is not recommended to consider gasification as the thermal technology to be adopted as the core technology for the future Integrated Waste Management Facility (IWMF). Instead, the more mature and well proven conventional incineration technology should be adopted for the future IWMF.

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