Annex A

Thermal Treatment Technologies for Municipal Solid Waste

The major thermal treatment technologies currently used for municipal solid waste (MSW) treatment include incineration, gasification (氣化技術), plasma gasification (等離子氣化技術), pyrolysis (熱解技術) and co-combustion (共燃技術).

Incineration

2. Incineration operates with excess air in a large furnace to burn down the waste and reduce its volume and hazardous properties. Energy in the waste is recovered to generate steam for heat and/or electricity production. Coupled with advanced gas cleaning system such as electrostatic precipitators, fabric filters, scrubbers and activated carbon powder injection system, modern incinerators can meet the most stringent emission standards adopted internationally.

3. Bottom ash produced from the incineration has low carbon content (1 to 2%) and is suitable for landfill disposal or used in bounded applications such as asphalt, concrete blocks, and cement sub-bases.

4. Moving grate, fluidized bed and rotary kiln are the three known incineration technologies adopted for the treatment of mixed MSW.

a. **Moving Grate Incineration (活動爐排焚化)** – The majority of MSW incinerators adopt the moving grate design which accepts solid waste into the furnace with little pre-processing. The furnace is equipped with an inclined moving grate system which keeps the waste moving through the furnace during the combustion process. Modern incinerators adopt advanced combustion process control measures to optimize the combustion at a temperature over 850^{o}C (to 950^{o}C) with long residence time and high turbulence, so as to ensure complete destruction of organic pollutants.

b. **Fluidized Bed Incineration (流化床焚化)** – The fluidized bed incinerator consists of a lined combustion chamber loaded with a large granular bed of inert material (coarse sand or silica) which acts to transfer heat to the waste uniformly. During operation, heated air is blown vertically through the bed at a high flow rate causing the bed of particles to bubble/ boil much as a liquid, allowing intimate contact between the waste and the fuel and facilitate drying and combustion. Fluidized bed combustion is conducted at relatively low temperature at 760 ^{o}C to 870 ^{o}C and the average gas residence time is high (over 5 seconds), resulting in effective combustion even with wet waste. Fluidized bed technology is widely applied to treating sewage sludge. Combustion of mixed MSW in a fluidized bed incinerator requires pre-processing of the waste into a homogenous refuse derived fuel and its application is limited.

c. **Rotary Kiln Incineration (旋轉窰式焚化)** – Incineration in a rotary kiln is normally a two stage process consisting of a kiln and a separate secondary combustion chamber. Solid waste is introduced into the upper end of an inclined, slowly rotating refractory-lined steel cylinder. The steps of drying, combusting and ash cooling are accomplished along the length of cylinder as the waste moves through it with a tumbling action, with ash discharged at the lower end. Application of rotary kiln incineration to treat mixed MSW is susceptible to numerous technical problems such as thermal shock, ash melting and deposition and corrosion which require intensive maintenance.

Gasification

5. The gasification process was originally developed in the 1800s to produce town gas. Gasification takes place at high temperatures (typically 900 ^{o}C to 1,400 ^{o}C) in an oxygen deficient environment, where combustion cannot occur. The carbon content in the material is converted into a syngas comprising energy rich gas products such as carbon monoxide, hydrogen and methane, and various hydrocarbons. The syngas generated is scrubbed to remove some of the particulates, hydrocarbons, and soluble matter before being used as chemical feedstock, in a gas engine to generate electricity or heat, or in a hydrogen fuel to generate energy for use in vehicles and plastic reprocessing.

6. Before being fed into the furnace, the mixed waste feedstock needs to be processed through a material recycling facility into a refuse derived fuel for easy handling, transportation and storage, as well as for providing a more

uniform characteristics and higher caloric value. By consuming less oxygen and using refuse derived fuel, lower emissions are produced, particularly NO_x, dioxins and furans. The solid residues include ash or a slag which can be vitrified and recycled as construction aggregates, resulting in a higher landfill diversion rate.

Plasma Gasification

7. Plasma gasification applies a high temperature plasma arc under an oxygen-starved environment to break down waste to produce syngas for energy recovery. The operating temperature of plasma gasification can be as high as 2,700 ^{o}C to 4,400 ^{o}C or even up to 10,000 ^{o}C. At these temperatures, waste is broken into basic elemental components in a gaseous form, complex molecules are separated into individual atoms, and inorganic materials such as glass are transformed into a vitrified slag.

8. The technology is mainly adopted for treating industrial and hazardous wastes such as MSW ash, contaminated soils, military waste, used activated carbon and radioactive wastes. Application for treating mixed MSW is rare and mainly limited to refuse derived fuel treatment.

9. Emission from a plasma gasification plant is low, and there are no ash residues requiring landfill disposal. Since the process requires significant amount of energy input, the overall energy recovery rate is lower.

Pyrolysis

10. Pyrolysis is commonly used in chemical industry (e.g. to produce charcoal, activated carbon and methanol from wood). Similar to gasification process but without any air or oxygen input, pyrolysis thermally degrades the waste in the absence of air to produce pyrolysis oil, char and syngas. An external source of heat is required to drive the pyrolysis reactions which occur at temperature range of 400 ^{o}C to 800 ^{o}C. The oil produced can be used directly in fuel applications and solid char may be used as a solid fuel, carbon black or upgraded to activated carbon.

11. Most of the waste pyrolysis systems are still at pilot-scales and for specific industrial waste streams like sewage sludge, and hazardous waste such

Co-combustion

12. Co-combustion is a variation of incineration technology where two different types of materials are combusted in the same combustion system. One of the examples is the use of certain waste (e.g. waste oil, animal meal, used tyres and rubber) or fraction of MSW with high heating value (e.g. refuse derived fuel produced from Mechanical and Biological Treatment Plants) as fuel for direct feeding to the cement kiln and be burnt together with the cement raw material to produce cement. However, the waste needs to be specially prepared from mixed MSW so as to ensure the compliance with stringent standards.

13. As regards the technology of an Eco-co-combustion system proposed earlier by a local cement production company to EPD for treatment of MSW, it is considerably different from the conventional co-combustion process adopted worldwide. The **Figure** below illustrates the schematic diagram of the proposed Eco-co-combustion system.

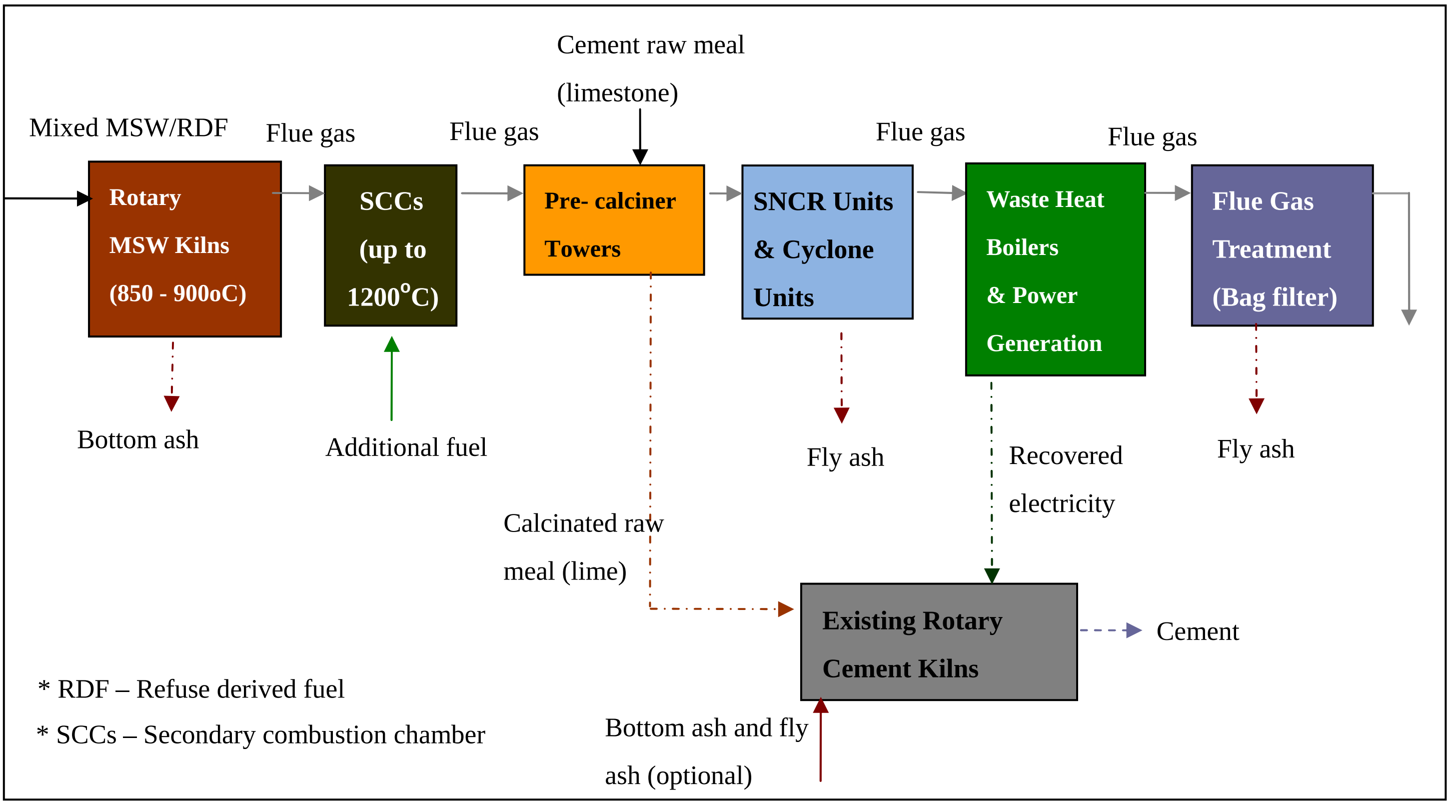

Figure - Schematic diagram of the proposed eco-co-combustion system