CHAPTER X. TYPES OF WASTE-TO-ENERGY SYSTEMS

A. Introduction

During the 1970s and early 1980s, many of the nations of the world became gravely affected by the high cost of imported oil and by the scarcity of low-cost alternative fuels. This situation precipitated a search for alternative sources of energy, which in turn led to a renewed interest in urban wastes as one potential source. The renewed interest in the energy potential of urban wastes was not surprising, for two reasons: 1) a sizeable fraction of the waste, depending on the country, can consist of combustible components, i.e., materials that can serve as a fuel in the production of heat energy; and 2) incineration of municipal waste and use of the waste heat produced therefrom had been practiced in Europe for many years.

Many of the combustible components of municipal solid waste are also biodegradable and, thus, can serve as substrates for biological conversion to a fuel gas that is immediately converted into energy (i.e., direct conversion into heat energy), or that can be stored or transported for later conversion (i.e., indirect conversion). The energy potential of all urban wastes is not the same, in that they differ both in energy content and in the ease with which the energy can be "extracted".

Energy can be extracted from solid wastes in many ways. A schematic diagram of the various methods of energy recovery, and of the types of fuel and forms of energy that can be produced from municipal wastes, is presented in Figure X-1. As illustrated in the figure, energy recovery can be accomplished with or without mechanical, manual, or mechanical/manual processing of the wastes prior to their conversion (i.e., pre-processing). Energy recovery without pre-processing is accomplished by conversion of the wastes predominantly in the form in which they were generated. Energy recovery through pre-processing is accomplished by one or more of the methods shown in the figure. The main objective of pre-processing a waste for energy recovery is to segregate the organic or combustible fraction from the remainder of the waste, i.e., the non-combustibles.

B. Incineration and refuse-derived fuel production

B1. FUEL characteristics

The value of wastes in direct conversion lies primarily in their energy content or heating value. Chemical elements that make the greatest contribution to the heating value of wastes are principally carbon and hydrogen. On the other hand, the fuel value of the wastes is adversely affected by moisture content and the inclusion of non-combustible materials.

The fuel value of the refuse-derived fuel, as well as the actual incineration of the material, is decided in large part by the composition of the wastes. For example, the relatively high moisture content of putrescible materials must be lowered before ignition can take place. The energy to accomplish this removal must come from that released when dry materials are burned, or by supplying additional energy by combusting supplemental (e.g., fossil) fuels along with the wastes. A perusal of the data listed in Table X-1 shows that the urban wastes generated in several developing nations can be approximately 50% to 70% putrescible on a wet weight basis. On the other hand, the quantities of discarded paper and plastics are relatively small. Therefore, the overall percentage of dry, combustible (volatile) matter is small. Additionally, the ash content of urban wastes in some locations in developing countries can be substantial (e.g., up to 60% where wood ash, coal ash, or both are major waste byproducts of domestic activities). The combination of these attributes of the wastes can render the waste conversion system as a net user of energy, as opposed to a net supplier. The relation among the fundamental parameters is illustrated in Figure X-2. The upshot of this situation is that incineration and thermal processing in general for energy production may not be applicable to a developing nation, or may be feasible only in certain locations or under special conditions.

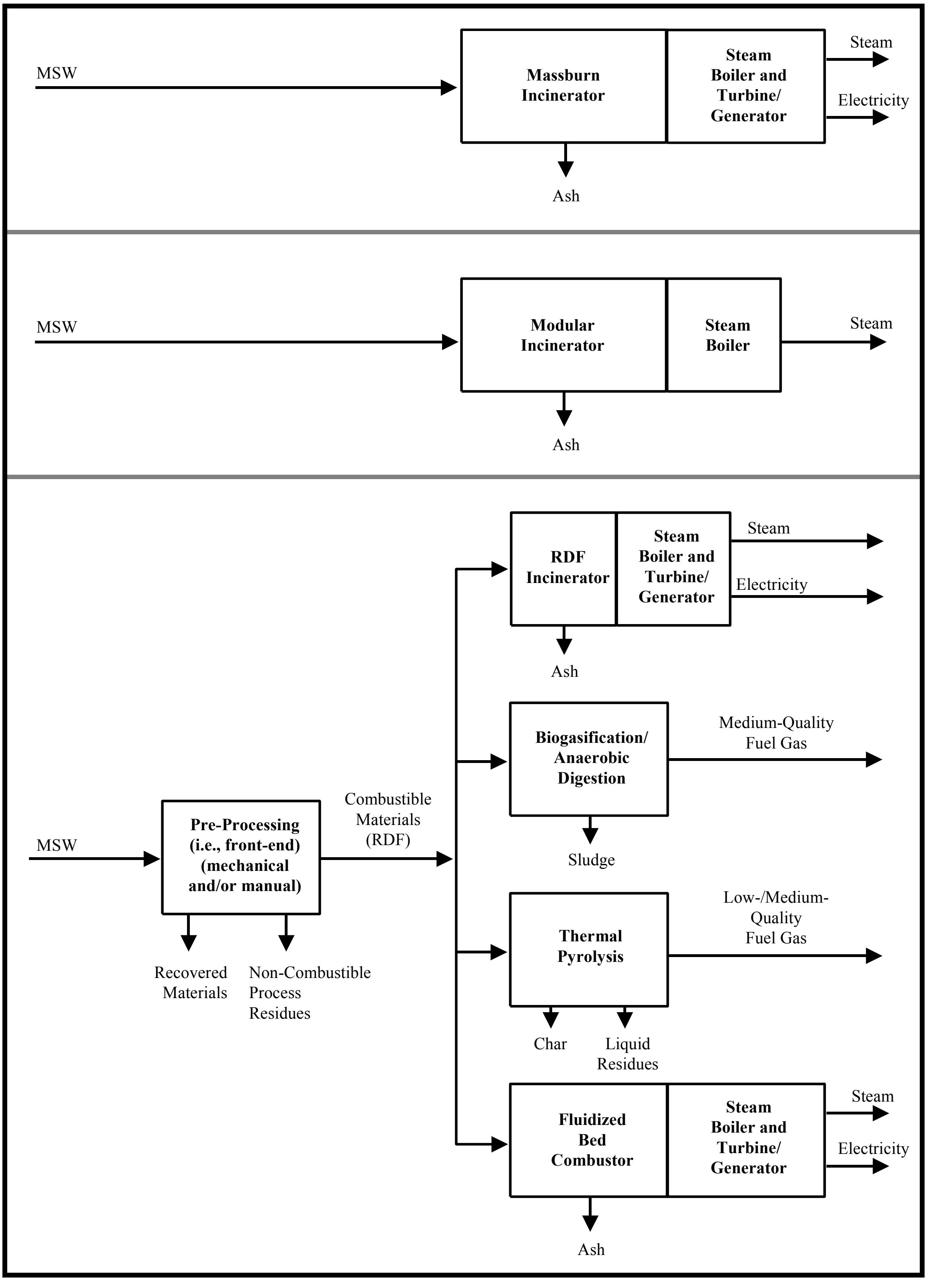

Figure X-1. Examples of methods of recovering energy from solid wastes

Table X-1. Comparison of solid waste characterisation worldwide (% wet wt)

Location	Putres -cibles	Paper	Metals	Glass	Plastics, Rubber, Leather	Tex-tiles	Ceramics, Dust, Stones	Wt (g)/ cap/ day
Bangalore, India [1]	75.2	1.5	0.1	0.2	0.9	3.1	19.0	400
Manila, Philippines [2]	45.5	14.5	4.9	2.7	8.6	1.3	27.5	400
Asunción, Paraguay [2]	60.8	12.2	2.3	4.6	4.4	2.5	13.2	460
Seoul, Korea [3]	22.3	16.2	4.1	10.6	9.6	3.8	33.4[a]	2,000[a]
Vienna, Austria [4]	23.3	33.6	3.7	10.4	7.0	3.1	18.9[b]	1,180
Mexico City, Mexico [5]	59.8[c]	11.9	1.1	3.3	3.5	0.4	20.0	680
Paris, France [4]	16.3	40.9	3.2	9.4	8.4	4.4	17.4	1,430
Australia [7]	23.6	39.1	6.6	10.2	9.9		9.0	1,870
Sunnyvale, California, USA [6]	39.4[d]	40.8	3.5	4.4	9.6	1.0	1.3	2,000
Bexar County, Texas, USA [6]	43.8[d]	34.0	4.3	5.5	7.5	2.0	2.9	1,816

[a] Includes briquette ash (average).
[b] Includes “all others”.
[c] Includes small amounts of wood, hay, and straw.
[d] Includes garden waste.

B2. INCINERATION

The incineration of raw (unprocessed) wastes is practiced throughout the world, particularly in European countries where it has been in use for decades. The simplest and crudest method of incineration is open burning. With the successive changes that have taken place in technology in general and in environmental concerns, the combustion process gradually has become subjected to increasingly “controlled” conditions. Initially, the main objective of the process was to reduce the volume of the material requiring disposal. Later, the products of combustion (hot gases) were used to generate steam.

Incineration of raw wastes has its advantages and its disadvantages. Two main advantages come to mind, particularly for an energy- and space-hungry, densely populated metropolis; they are the potential for generating steam and the accomplishment of volume reduction. On the other hand, incineration has a serious disadvantage in the form of the substantial cost of controlling and managing its pollutant emissions. The general forms of the pollutants generated during the course of incineration include air emissions, bottom and fly ash, and wastewater. Another important disadvantage is the fact that the direct combustion of the raw wastes does not provide an opportunity for substantial recovery of material resources.

Within this book, stoker-fired, modular, and fluidised bed systems are included within the definition of incineration technologies.

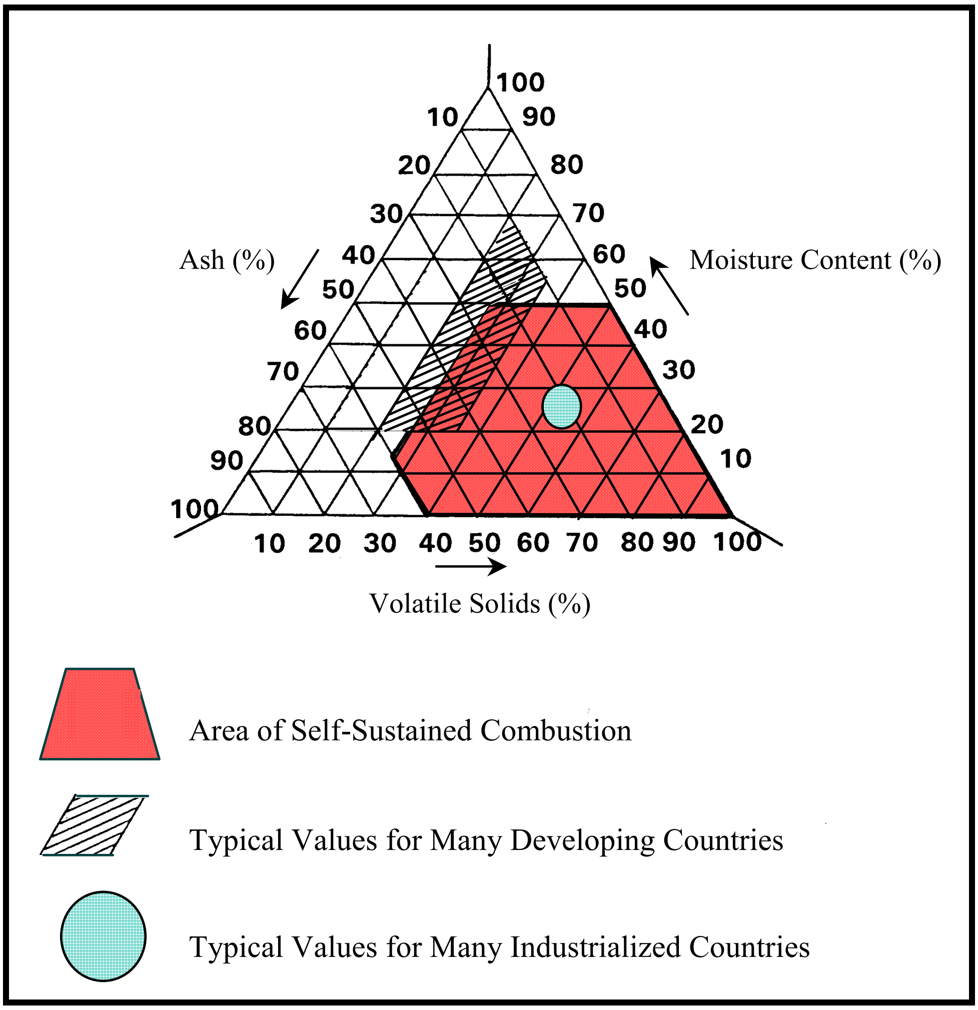

Figure X-2. Comparison of the thermal characteristics of MSW and those required for self-sustained combustion

B3. REFUSE-DERIVED fuel production

The production of refuse-derived fuel (RDF) typically involves the use of a number of operations -- among the more common operations are size reduction, screening, and magnetic separation. Manual operations (e.g., sorting of materials) are also used, especially if material recovery and RDF recovery are integrated into one processing facility. Manual processes of separation are especially appropriate in many cases in developing countries, singularly or in combination with mechanical processing operations. As mentioned earlier, for recovery of RDF, the key aspect of processing is separation of the combustibles from the non-combustibles in the waste. Refuse-derived fuels can serve as feedstocks for incineration systems with energy recovery equipment.

C. Thermal gasification and biogasification

"Gasification", as used in solid waste management, is a term applied to the conversion of wastes into a gaseous fuel. The term is used even though not all of the recovered energy is in the form of a combustible gas. Indeed, with certain processes, the fraction in the form of a combustible gas may be much less than that in a solid or a liquid form, or in both. Because, as is explained in later chapters, gasification can be a complex and expensive undertaking, recourse to it for energy recovery should be considered only in certain special circumstances. For example, there might be a local need for an organic gas as a chemical feedstock or a gaseous fuel to supply a gas-fired industrial process. Such circumstances preclude the presence of an economical supply of fossil ("natural") gas.

Gasification may be accomplished by biological and non-biological processes. Biological gasification involves the collective activities of groups of facultative and obligate anaerobes in the conversion of 30% to 40% of the energy bound in the biodegradable fraction of wastes into the chemical energy of methane. The process by which the transformation is accomplished is a well known one, and usually is referred to as “anaerobic digestion”, although the terms “methane fermentation” and “biogasification” may be used synonymously. Generally, “biogasification”, as used in the literature, has a rather generic connotation, whereas “anaerobic digestion” is regarded as implying the usage of specialised equipment (reactors) and the adherence to a well defined operational procedure. Inasmuch as biogasification takes place in nature where and whenever conditions are appropriate, it is not surprising that it takes place in a landfill. This latter phenomenon, while widely known for many years, has only recently been put into extensive beneficial use, i.e., landfill gas recovery and utilisation.

Non-biological gasification processes are thermal (or thermal-chemical) in nature. Through them, both non-biodegradable and biodegradable combustible matter can be transformed. Because of this attribute, the percentage of energy recovery from non-biological gasification processes potentially can surpass that from biological systems. Non-biological gasification, or as it is more commonly termed, “pyrolysis”, essentially is the fractional distillation of the organic matter in a waste under O_2-free, or partially O_2-free, conditions. The end products are gases, liquids (oils and tars), and solids (char). The extent of the gasification in terms of percentage of the end products in the gaseous form is primarily a function of elevation of temperature and, to some degree, of pressure. If a high yield of combustible gas is the objective of the process, then steps must be taken to elevate the temperature at some point in the process since the temperature of “strict” pyrolysis reactions results in low gas yields. One such step is to combust a portion of the gas stream by admitting a small amount of O_2 into the process, such that the overall process is a two-step one -- namely, strict pyrolysis followed by limited combustion. This has led to the development of the “pyrolysis-combustion” type of process. Occasionally, the term “gasification”, or more specifically “thermal gasification”, is restricted to pyrolysis-combustion, while “pyrolysis” is used solely for pyrolysis in the strict sense of the term.

Biogasification, production of refuse-derived fuel, and thermal (i.e., non-biological) methods of conversion are discussed in more detail in later chapters of the book.

D. References

1. Nath, K.J., “Solid Waste Management in the Present Indian Perspective”, proceedings of ISWA 1993 Annual Conference, Jönköping, Sweden, September 1993.

2. Diaz, L.F. and C.G. Golueke, “Solid Waste Management in Developing Countries”, *BioCycle*, 26:46-52, September 1985.

3. Japan International Cooperation Agency, *Master Plan and Feasibility Study on Seoul Municipal Solid Waste Management System*, Tokyo, Japan, 1985.

4. Scharff, C. and G. Vogel, “A Comparison of Collection Systems in European Cities”, *Waste Management & Research*, 12(5), October 1994.

5. CalRecovery, Inc., *Criterio de Diseño - Planta de Selección y Recuperación de Subproductos de los Residuos Sólidos Municipales*, prepared for Mexico City, Mexico, December 1992.

6. CalRecovery, Inc., *Handbook of Solid Waste Properties*, Governmental Advisory Associates, Inc., New York, New York, USA, 1993.

7. Morwood, R., "Australian Waste Management - Towards 2000", *Proceedings of 32nd Annual International Solid Waste Exposition,* SWANA, San Antonio, Texas, USA, August 1994.