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GENERATING ENERGY FROM URBAN AND RURAL WASTES IN A SELECTED COUNTRY OF THE ESCWA REGION: THE CASE OF EGYPT

to be presented at the

Seminar on the Utilization of Industrial Wastes

(Baghdad, 6-10 November 1988)

CONTENTS

I. INTRODUCTION

The management of urban and rural waste is a multifaceted problem with widespread ramifications. It encompasses the collection, transfer, treatment, resources, recovery and disposal of various wastes through the use of appropriate techniques.

Facing such a complex problem through the proper management of urban and rural waste and its utilization for various purposes, especially for generating energy, has become a major concern, particularly in countries where accumulated waste has serious environmental implications. This is primarily owing to the fact that, in many countries, the authorities concerned are now fully aware that the utilization of waste, mainly as an alternative source of energy, also represents a viable means for conserving fossil fuel, preserving the quality of the environment and resolving a critical waste disposal problem.

In view of the importance of the issue and of the interest expressed by several countries of the region in the utilization of waste for energy generation, the ESCWA Natural Resources, Science and Technology Division has been undertaking activities that cover various aspects of the management of urban and rural waste, and suitable technologies for the utilization of this waste for energy generation.

The presentation today at the Seminar is an abstract of the ESCWA publication issued in December 1987 and entitled Generating Energy from Urban and Rural Wastes in a Selected Country of the ESCWA Region: The Case of Egypt.1/

I will mainly concentrate on the different sources and types of urban and rural waste, the required technologies for generating energy from this waste, and the various economic, environmental, social, ecological and technical considerations related to the production of energy from it.

For more details on the case study of Egypt you can refer to the above-mentioned publication.

1/ See United Nations Economic and Social Commission for Western Asia, Generating Energy from Urban and Rural Wastes in a Selected Country of the ESCWA Region: The Case of Egypt, (E/ESCWA/NR/87/14) (Baghdad, 1987).

II. WASTE MANAGEMENT AND TREATMENT

A. Municipal solid waste (MSW)

Solid wastes are all wastes generated by human and animal activities that are discarded in a solid form. MSW refers to solid wastes in an urban setting, including residential, commercial and institutional sources, together with demolition and construction wastes, street sweepings, and garden waste.

Solid wastes are generally defined as those solid or semi-solid materials that are discarded at the source of generation because they are no longer of sufficient value to retain. However, they may be of significant value in another setting, whereby efforts can be made to make use of them. Indeed, economics can even change the situation to the extent that certain types of solid waste like newspapers and glass bottles may be of sufficient value at the point of generation to warrant their separation and retention for either reuse or sale to an outside agent.

MSW management is an integrated system associated with the functional elements of waste generation, on-site storage, transfer and transport, processing and recovery and final disposal. It is a multi-disciplinary activity that involves engineering principles, economics, urban and regional planning, public health and environmental aspects, as well as social considerations relating to public attitudes and concerns. It is also a highly dynamic field in which there is no ideal method for the solution of all the problems and issues that arise. In each situation, technical options and alternative management systems are worked out and then assessed and ranked in terms of cost-effectiveness, in order to provide the decision maker with a rational basis for selection. In effect, the scope of solid waste management embodies all the administrative, financial, legal, planning and engineering functions involved in the whole spectrum of solutions to the problems of solid wastes that are thrust upon the community by its inhabitants.

The quantity and quality of solid wastes generated in municipalities vary with the type of the society, the standard of living, habits of the people, climate and seasons. They also continue to change over time, and so the designer of solid waste facilities must be aware of these trends in order to make reliable projections that will allow the design of facilities that can remain functional and efficient over their estimated useful life.

B. Sewage solids

Municipal sewage is principally water, more than 99.8 per cent, with the remaining materials being in suspension or in a solution. It contains organic solids that must be filtered, treated or removed in order to abate environmental pollution and to recycle water. These solids can also constitute an important fuel or energy source. Energy recovery technologies are generally similar to those pertaining to MSW. In developed countries, energy recovery systems constitute a standard feature in sewage treatment plants. The most frequently found method is the anaerobic digestion of sewage sludge (biogas technology).

Sewage treatment involves a variety of processing combinations that depend on the composition and characteristics of raw sewage and the reuse and ultimate disposal of liquid effluent and solid sludge, in addition to financial constraints. Depending on conditions, the sewage treatment scheme can embody preliminary, primary, secondary and tertiary treatment. Normally, as a minimum, preliminary treatment is undertaken, whereby the initial screening of floatage and the removal of grit is effected. This may be followed by primary treatment in which a large portion (50-60 per cent) of the suspended solids that will settle is removed in a form called a "primary sludge". The "primary effluent" can then undergo a secondary treatment that is often biological in nature (as in the case of the activated sludge method, for instance). A "secondary sludge" is thereby produced. The secondary effluent may then undergo tertiary treatment, which can be something as simple as a disinfection process like chlorination, or it may take the form of more elaborate techniques that will produce a product of drinking-water quality. In this, or even in the previous stages, chemicals may be added to improve the removal of suspended solids or to precipitate some undesirable impurities. Under these circumstances a "chemical sludge" is formed.

Depending on the source of sewage, whether or not it is combined with industrial waste water and storm water, and the types of additives that are used during the treatment processes, almost any element can be found in sludge (specific gravities 4, 5 and 6). Primary sludge contains solids present in the raw waste water (except for those separated from it during preliminary treatment, including screened large-size solids and grit-heavy inorganic solids), while secondary sludge contains chemical or biological solids. The specific gravity of inorganic solids is about 2 to 2.5, while that of the organic portion is 1.2 to 1.3.

Primary sludge is a grey, slimy material with an offensive odour. In comparison with secondary biological waste, primary sludges thicken and de-water readily because of their fibrous and coarse nature.

The liquid waste sludge withdrawn from primary and secondary processing amounts to approximately 2 litres/person/day, and has a solid content of 5 per cent by weight. These figures are indicative, since the quantity and nature of the sludge generated relate to the character of the raw waste water and processing scheme employed.

There are wide differences in the elemental composition of various sludges. If sludges are to be reused, they need to be analysed to establish the presence of a number of elements, particularly trace elements such as cadmium, chromium, copper, lead, nickel and zinc, as well as nitrogen, phosphorus and potash. Normally, reported sludge compositions also include a proportion of certain toxins such as pesticides and polychlorinated biphenyls (PCBs), and have a number of other common characteristics such as pH; total dry and volatile solids content, specific gravity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), cellulose, hemicellulose and lignin properties and a heating value.

C. Industrial wastes

Aside from particulate matter-laden gaseous emissions, industrial wastes are composed of waste water and solid wastes. The treatment of industrial waste water also produces sludges that are classified as semi-solid organic and inorganic or biological and non-biological. Sludges can either be organic, in a raw form or already stabilized by digestion, or inorganic when they may contain numerous chemical pollutants.

Waste from living or previously live sources is called biological waste, in contrast to waste that emanates from non-living, non-biological sources. Biological waste can include discharges from tanneries, paper mills, food manufacturing plants, slaughterhouses and textile plants. Non-biological waste includes that from metal-plating industries, sheet metal industries, etc. Most of these plants discharge what are commonly referred to as "spent chemicals" into the plant effluent, and these can either be organic or inorganic.

1. Gaseous emissions

The term "industrial gaseous emissions" covers gaseous pollutants including true gases such as sulphur dioxide, carbon monoxide and nitrogen oxides, vapours such as gasoline and solvents and particulate matter (finely divided liquids and solids) such as mists, fogs, and aerosols, dust, fumes and smoke.

Four methods are commonly used to control gaseous emissions: absorption, adsorption, combustion and condensation. Particulate emissions can be controlled by mechanical collectors, wet scrubbers, electrostatic precipitators and fabric filters.

2. Waste water and sludges

Industrial waste water includes:

- Domestic waste water that is produced by plant workers, shower facilities and cafeterias;

- Process waste water resulting from spills, leaks and product washing;

- Cooling waste water that is associated with various cooling processes.

Domestic waste water is handled by the normal sanitation system. Cooling waste water poses few pollution problems as it can be recycled or disposed of safely, unless it is contaminated by processed waste water as a result of leaks in the cooling system. Processed waste presents the most serious potential hazard to the environment.

Many industrial waste water streams need to be pre-treated on site prior to discharge into municipal sewerage systems, or even into a central industrial sewerage system. Pre-treatment of industrial waste water can be followed by primary treatment and then by secondary (biological) or physical-chemical treatment. The sludge that forms is subsequently processed, reused or disposed of.

3. Industrial solid wastes

In the process of manufacturing products from raw materials, industries produce much waste material. Some of this can be recycled internally, but the rest has to be disposed of. Industrial solid wastes contain conventional waste that can be handled, treated and disposed of in ways similar to those described above under MSW. Such wastes embody food waste, paper, plastics, rubber, leather, textiles, wood and other energy-carrying residues, metals, glass, ceramics, ash, rocks and dirt.

In addition to conventional waste, hazardous wastes are generated in limited amounts through most industrial activities. Such wastes can pose substantial danger to human, plant or animal life, immediately or over a period of time. They may exhibit one or more of the following characteristics: ignitability, corrosiveness, reactivity and toxicity. Hazardous wastes warrant special handling, treatment and disposal and, in addition, they should be clearly labelled.

D. Agricultural and agro-industry residues

Residues from agriculture and agro-industries can be considered to be the unused outputs from the growing and processing of raw agricultural products such as fruits, vegetables, meat, poultry, fish, milk, grain and trees. These residues may contain materials that can be of benefit to human beings but their economic value is less than the apparent cost of collection, transportation and processing for any beneficial use. Therefore, they are discharged as waste. If residues can be utilized for human benefit such as to enhance food production and energy, they would no longer be waste matter but could be considered a new resource.

Only in a few situations has residue utilization been a component of waste management policy. The traditional focus has been on the treatment and disposal of waste, with the subsequent loss of material and energy resources. This one-time use and disposal of material is a result of policies that were developed earlier when materials and energy were abundant, when there was a lower demand for world food production and energy resources, and when there was less concern about the quality of the environment.

Most developing countries are agrarian, and the majority of the population live in rural areas. In these areas, the source of livelihood is the production of food or fibre crops, or animal husbandry that is adapted to local soil and climatic conditons. Such countries are interested in ways of raising incomes and living standards. If these objectives are to be met, an increase in food production will be required, together with the optimum use of available resources, particularly residues that currently go unused. Residues can be used to increase local energy supplies, animal production, fertilizers and microbial protein for human or animal consumption, or they can be processed to produce different human or animal foods.

The potential for agricultural and agro-industrial residue utilization requires a knowledge of how and why residues are generated, the characteristics of residues available, and the technology that can be used to exploit them.

1. Residue generation

Man's basic needs include food, fibre, fuel, fertilizer and shelter. Small operations recycle available resources. The basic cycle is one of the land furnishing fuel, fibre, shelter and food in the form of crops and animals for the consumer. In a small agricultural operation, some of the residues resulting from harvesting and processing are used directly by the consumer, while the remainder are returned to the land to be used further for additional crops.

Inexpensive fossil fuel, inorganic fertilizers and greater mechanization have been used to increase agricultural productivity, the food supply and the standard of living in many countries. Therefore, agricultural and agro-industrial residues are no longer utilized as well as they were in small systems, a fact which has become more apparent and has given rise to concern for the environment. The trend towards large-scale agricultural and agro-industrial enterprises continues in all countries. As production increases, so, too, do the size of facilities and the quantity of residues at a specific site. The larger the production unit, the more likely it is that there will be residues that require treatment and disposal; hence, the larger the quantity of residues at the production site, the more necessary it is for the possibilities of residue utilization to be considered.

2. Residue characteristics

The feasibility of energy production from residues depends on the characteristics of the residues themselves, the quantity that is realistically available, the continuity of the supply, their energy content and the cost of collection and transport. Usually, the information available on the characteristics of agricultural and agro-industrial residues is inadequate.

However, the quantities produced from each particular residue appear to have a relationship with the main end-product that is statistically reported in each country's records.

Agricultural and agro-industrial wastes and animal dung have been and are still used as energy sources.

For both municipal and industrial waste the moisture content will have an important effect on the resultant energy recovery and downstream use of the reject heat. However, the effect of carbonization to produce charcoal not only leads to the production of a higher energy value, but also eliminates the problem of air pollution and contaminants that can result from combustion if the direct firing of the drying system is used to improve the efficiency of energy consumption.

Another source of energy that is normally neglected is the reject heat from a particular system. Most low calorific fuel boilers up until now have been designed to consume as much available fuel (bagasse or rice husks) as possible. Hence, these boilers have a very low efficiency rate with the result that about 50 to 60 per cent of the available energy is wasted. The wasted energy is in the form of flue gases that in an induction-fired boiler can reach 350° C to 400° C, with a moisture load that depends on the water content of the input material. Other sources of waste energy are in the form of unused heat from condenser cooling water or air, depending on the design of the power-plant.

III. TECHNOLOGIES FOR ENERGY PRODUCTION FROM WASTE

Various processes are currently in use to produce energy from waste.

A. Thermal processes

When MSW is subjected to thermal processing, a mixture of solid, liquid and gaseous fractions are produced depending on the processing conditions. According to the amount of air, thermal processes can be divided into the following categories: combustion, gasification and pyrolysis.

1. Combustion

The combustion of MSW is a process of oxidation with oxygen in air that is commonly associated with the vigorous evolution of light and heat. Products that involve complete combustion are carbon dioxide, water, sulphur dioxide and nitrogen. The combustion of MSW can take place in open fires and by incineration.

(a) Open fires

The disposal of solid waste in open fires has been practised since the creation of mankind. Although burning is one of the most hygienic ways of disposing of refuse, combustion gives rise to flue gases, particulate matter and odour that produce an unacceptable level of air pollution. Nevertheless, it is still used on a wide scale in both urban and rural areas.

(b) Incineration

Incineration is the controlled combustion of MSW. It is a well established technology that can claim over a century of operating experience. The principles of incineration are very simple: refuse burns at temperatures of between 900°C and 1,000°C. Odourless flue gases can only be guaranteed if the combustion gases pass through a zone of temperatures high enough to eliminate smell, i.e. about 800°C. The hot gases must also be cooled to about 300°C, and cleaned before they are discharged into the atmosphere. The waste is transferred to a refractory furnace designed to ensure complete combustion. This is achieved through the proper control of temperature, excess air, gas turbulence, time spent in the hot zone, and burn-out time of the ash before discharge. After cleaning, the gases and vapours are suitable for discharge into the atmosphere. The inorganic ash can be processed further in order to recover materials for use as hard core or landfill.

Heat may be recovered for use as steam or electricity.

(c) Types of incinerators

Various types of incinerators have been developed. They can be classified into continuous grate direct incinerators and the recently proposed simple batch-loaded modular incinerators. Grate incinerators include the following types:

(i) Multiple-chamber incinerator;
(ii) Multiple-hearth incinerator;

(iii) Rotary kiln;
(iv) Fluidized bed incinerator;
(v) High temperature slagging incinerator;
(vi) Suspension-fired incinerator.

The modular-controlled air incinerator has two combustion chambers in which the air-to-fuel ratio is closely regulated. In the primary chamber refuse is ignited and burned in an oxygen-deficient atmosphere. Most of the organic material decomposes into small volatile molecules. Unburned organic material together with the exhaust pass under low turbulent flow conditions to a secondary chamber where combustion in an excess-air environment takes place. Auxiliary fuel (usually fuel oil or gas) can be used in the secondary chamber in order to promote complete combustion at temperatures of between 1,000°C and 1,200°C. Particulate emissions from a controlled air incinerator usually fall within standard limits of air pollution. The combustion of organic material is fairly complete and the entrainment of inorganic material by low turbulence in the primary chamber is minimized. Conversely, the traditional uncontrolled single combustion chamber incinerator usually requires the addition of an expensive wet scrubber or electrostatic precipitator in order to meet air pollution codes. Modular incinerators which have a capacity of about one ton per hour (ton/h) for each module are available.

The approximate overall material balance for a modern direct incinerator can be represented as follows:

(i) Moisture and combustion products	68 per cent
(ii) Fly ash	2 per cent
(iii) Residue	30 per cent

(d) <u>Heat utilization</u>

The calorific value of MSW in developed countries is about 2,200 kcal/kg. In developing countries where the paper and plastic content of waste is low, the calorific value may be as low as 1,400 kcal/kg.

The heat generated in incineration can be utilized to raise steam, and this can be used directly in order to drive processing equipment or for heating, or indirectly to generate electricity. Heat may be recovered through water-cooled walls in the upper part of the furnace and/or by passing the hot gases through a heat exchanger. Heat recovery efficiency ranges from 55 to 70 per cent. The net heat recovery from electricity generation is about 14 to 22 per cent.

The most serious problem hindering the spread of heat recovery is the difficulty in ensuring a steady market. Steam or electricity must be used directly, as it is produced, for there is no possibility of storing it.

Various developments for MSW incinerators have been proposed. The preparation of the waste into refuse-derived fuels (RDFs) (as described below) before incineration allows the use of more sophisticated furnaces. However, increased sophistication does not necessarily produce increased energy efficiency.

2. <u>Other thermal processes</u>

These essentially include pyrolysis and gasification. Pyrolysis is the thermal degradation of organic materials in the absence of air to yield solid, liquid and gaseous fuels. Gasification describes the reaction of organic compounds with a smaller volume of oxygen or air than would be required to ensure the complete combustion involved in pyrolysis. Gasification generally yields a fuel gas diluted with combustion products and nitrogen.

A great variety of processes for the thermal treatment of MSW have been proposed. However, relatively few of these have reached the pilot plant stage, and none have been successfully proved on a large commercial scale.

<u>Principles</u>. When MSWs or RDFs are used as feedstock for thermal processing, a mixture of solid, liquid and gaseous fractions are produced, depending on process conditions. A large number of reactions may take place simultaneously. The relative yield of the various products can generally be regulated through the control of the environment within the reactor.

The main controlling parameter is temperature. Control is exercised through many process variables including the mode of heat transfer, the direction of evolved gas flow, the rate of heating, the particle size of feedstock, operating pressure or the use of catalysts.

Reactor designs can be classified into three categories: vertical flow, horizontal flow and dilute-phase reactors.

The major products and optimum conditions for their production are as follows:

(a) Solid char, mainly of carbon. This is a low-grade fuel, often burnt in order to provide heat for pyrolysis reactions. At high operating temperatures, and in the presence of some oxygen, the char is completely gasified in the reactor.

(b) Ash or slag produced as a residue, which can be used either as landfill or an aggregate.

(c) Liquid products that separate into two fractions: an aqueous solution that contains highly oxygenated compounds and a tarry oil, mainly consisting of oxygenated hydrocarbons. The production of oil can be maximized by the application of a low operating temperature (about 500^{o}C), and a short retention time.

(d) Gaseous products vary greatly, depending on process conditions. Optimum yields of carbon monoxide, hydrogen and methane occur at about 1,000^{o}C. Calorific values vary between 1,000 and 5,000 kcal/cu m, depending on product dilution.

Much work remains to be done to understand the complex chemistry and to optimize processing conditions that will yield the desired products.

B. Mechanical processing

Several alternative or complementary technologies have been developed for the mechanical processing of MSW in order to recover salvageable materials and/or to facilitate further treatment or disposal. These include physical separation, baling, pulverization and the production of RDFS.

1. Physical separation

Physical methods of separation can be applied to solid waste by utilizing existing or induced differences in the physical properties of the materials to be separated.

The major differences in physical properties through which solid waste can be separated are variations in size, shape, bulk density, magnetic susceptibility, electrical conductivity, colour, brittleness, malleability and surface conditions.

Separation methods can be grouped into the following stages:

(i) Primary separation that will produce mainly organic and inorganic fractions;

(ii) Secondary separation of particular components from inorganic fractions;

(iii) Tertiary separation in upgrading the separated fractions.

The unit processes employed in each of these levels of separation can be summarized as follows:

(a) Primary separation

(i) Wet pulverization. The untreated waste is moistened and fed into a large, slowly rotating drum in which self-pulverization is achieved by the tumbling action of the hard components. The fine fraction is then passed through screens at the end of the drum. This contains about 60-80 per cent of the waste, which is mainly organic material and glass. The coarse material remaining mainly consists of inorganic material and large sheets of plastic. In developing countries where food waste constitutes a relatively large proportion of MSW, wet pulverization can replace shredding prior to composting.

(ii) Wet pulping. Waste is introduced as an aqueous slurry (3-10 per cent solids) that is then reduced in size by a segmented blade rotating at high speed. The pulped waste, which is largely organic, passes out of the bottom of the pulper, while non-pulpable or non-friable materials are pushed to the outer sections of the pulper drum.

(iii) Dry separation. This method of primary separation is most commonly used for the recovery of salvageable materials. The major unit processes are size reduction, screening, air classification and magnetic separation.

(b) Secondary separation

Secondary separation into other types of organic material and a glass-rich or metal-rich fraction are included in the primary separation schemes. The methods that can be used combine one or more of the following processes: magnetic separation, screening, jigging, hydraulic classification and heavy media separation.

(c) Tertiary separation

The tertiary separation of inorganic components aims at the recovery of non-ferrous metals or glass fractions that can be recycled. These include heavy media and electrostatic separation, together with flotation.

Most of the above-mentioned techniques for mechanical waste separation have not yet been successfully proven on a commercial scale.

(d) Baling

Although the high-density baling of solid waste is a comparatively recent development, several large-scale plants are already in operation. The basic principle is that the waste is compressed by three hydraulic rams into bales weighing approximately 1 ton and about 1 cu m in volume. These bales can then be stacked at the landfill site. The landfill operation is thereby simplified, and much of the inconvenience is eliminated. There is still no scientific understanding of the effects of baling on waste degradation. Furthermore, its technical feasibility as a reliable option for solid waste management has yet to be demonstrated.

(e) Pulverization

The mechanical processing of waste by pulverization before landfilling has the following advantages:

(i) The waste does not smell;

(ii) It minimizes the attraction for and support of vermin;

(iii) The nuisance of flies is diminished;

(iv) Daily covering may not be necessary;

(v) The space required for landfilling can be reduced;

(vi) The settlement and maturing of the landfill site is quicker and more even.

Many types of size-reduction machines are available. The most common are hammer mills and impact crushers.

(f) RDFs

A wide range of technologies have been developed to produce refuse derived fuels. These technologies differ markedly in the production methods used, their state of development, quality and the form the RDF takes. There are three basic approaches for the production of RDFs through the separation of organic and inorganic fractions, as summarized below.

(i) Dry separation. This is the most widely applied approach that is based on several combinations of unit operations. Typical procedures include the following:

a. The production of a single organic fraction containing most of the putrescible matter, in addition to paper and plastics. Upgrading before use may involve further size reduction or pelletization.

b. The upgrading of the prepared RDF in order to produce a powdered fuel suitable for co-firing with fuel. This is considered to be a suitable substitute for pulverized coal in suspension-fired boilers.

c. The production of two organic fractions, where the paper and plastics are utilized as RDF and the putrescible materials are used as landfill or composted.

d. The simplest and cheapest procedure to produce RDF for direct use is pulverization and magnetic separation. This fuel is limited in its application to older boilers that have shin-grates and extensive ash-handling facilities, or to cement kilns. The quality of feedstock required in he latter case is rather high and it needs double pulverization. The high ash content is usually incorporated with a cement product. Net energy efficiency is in the region of 50-60 per cent.

(ii) Wet pulverization. The second method of producing RDF is based on wet pulverization. A further development of this theme is to replace water by an oily waste that gives rise to an enriched pulverized fuel.

(iii) Wet pulping. The third method is based on wet pulping, where the organic fraction is produced in the form of a wet slurry. Several variations for further processing include the following:

a. Processing for fibre recovery, where residual materials are de-watered and incinerated;

b. Recovering the fibre and marketing the de-watered residue as wet RDF;

c. Upgrading the RDF to 20 per cent moisture.

The net energy efficiency of RDF ranges between 30 to 60 per cent. The drawbacks to the production and use of RDF are as follows:

a. The technology has to be proven over an extended period of routine operating;

b. Markets for the fuel products have to be explored.

2. The recovery of energy from conversion products

Most of the conversion technologies described in the previous sections result in the recovery of materials and/or energy from MSW, as is summarized below:

Technology	Type of ultimate resource recovery
Sanitary landfilling with gas recovery	Energy (fuel) and reclaimed land
Composting with the sorting of salvageable materials	Recycled materials and fertilizer (compost)
Anaerobic digestion	Energy (fuel) and fertilizer
Hydrolysis	Product materials
Incineration with energy recovery	Energy (heat)
Gasification and pyrolysis	Energy (fuel)
Production of refuse derived fuel	Energy (fuel) and recycled materials

Thus direct energy recovery options include: sanitary landfilling with gas recovery, anaerobic digestion, incineration, gasification and pyrolysis and the production of RDF. All can be considered to be systems that produce fuels or energy while they dispose of solid waste.

Additional system components are required for the recovery of energy from heat: various gaseous, liquid (oils) and solid fuels. These include boilers for the production of steam, steam and gas turbines for motive power, together with electric generators for the conversion of motive power into electricity.

C. Bioconversion process

1. Anaerobic digestion

The bioconversion process generally includes enzymatic hydrolysis, anaerobic decomposition and sanitary landfilling. Of these methods, the anaerobic digestion method has been proved to be effective and economically advantageous in the production of energy (alcohols, methane, gas, etc.) from wastes rich in organic materials. This method can effectively be applied to process solid, semi-solid and liquid waste rich in organic material and nutrients.

(i) The conversion of glucose and other carbohydrates, proteins and fats by acidogenic bacteria into short-chain fatty acids;

(ii) The conversion of these acids by acetegens into acetate and bicarbonate;

(iii) Conversion by methanogens into methane and carbon dioxide.

The digester operation requires the control of the following parameters:

(i) Temperature, which can be held in the mesophilic (40°C) or thermophilic (60°C) ranges, where the latter gives higher methane yields and has a shorter retention time;

(ii) Maintenance of anaerobic conditions;

(iii) pH in the optimum range of 6.7 to 7;

(iv) Nutrients necessary for bacterial growth that can be supplied by sewage sludge;

(v) Reduction of the toxicity of the input waste through the separation of inorganic materials and by dilution.

Most of the cases studied use a single digester, but recent work suggests the use of multi-stage digestion. The gas from the digester contains about 60 per cent methane, the remainder being mostly carbon dioxide (CO_2). The remaining slurry must be de-watered if it is to be used as a fertilizer. The viability of the anaerobic digestion of MSW has yet to be proven.

2. Sanitary landfilling

Though landfilling can be classified under biological treatment, it forms a separate class in its own right. Actually, it is the ultimate sanitary disposal process where land becomes the waste sink. The word "sanitary" differentiates this technology from the bad practice of open dumping. It should be noted that whatever treatment and processing the MSW may undergo, a residual matter that has to be disposed of, presumably by landfilling, always remains.

In this method of disposal, waste is charged, spread and compacted in layers. The exposed surfaces are regularly covered with an inserted material excavated on the same site or hauled from outside. Compaction and covering help to eliminate vermin within the landfill, reduce the nuisance value of waste scattering, and improve the visual impact of the landfill operation.

The sanitary landfilling of MSW produces a methane-rich gas. At one time this was collected and flared to reduce the hazard of explosion, but since the early 1970s the gas has often been recovered. Recovered sanitary landfill gas is used to produce heat and/or electricity, or is cleaned and transported by pipeline to consumers.

(a) Gas collection and utilization

Ideally, the landfill site should be constructed in such a way as to deal with the total containment of all wastes and liquids, as well as to maximize the collection of the gas generated. Significant advances have been made in the last two decades in the recovery of processed methane-rich gas from landfill sites. Several beneficial utilization options are available through the direct firing of the raw gas and electricity generation, which are the only means immediately available on-site.

In many cases, the gas is not utilized but merely collected by suitable means such as permeable gravel trenches that are built into the landfill and then vented to the atmosphere or even flared off. With the growing energy shortage, landfill gas is viewed as a potential asset and energy source. The focus in some places has been on optimizing gas production and using it directly as a fuel. The gas can be used in nearby industrial furnaces such as brick and cement kilns.

(b) Hazards associated with landfilling

Hazardous situations can arise from two main sources:

(i) If water is allowed to come into contact with the waste, then an obnoxious mineralized leachate is produced that causes water pollution;

(ii) As the temperature within the landfill increases, there is a danger of fire hazard. In addition, the gases generated from biodegradation of the waste can escape into the atmosphere and create both a fire and explosion hazard.

Thus, landfills should be properly designed, constructed and operated in order to ensure that pollution and fire hazards are minimized.

3. Composting

Composting is a process by which micro-organisms break down organic matter into a humus-like material and carbon dioxide. Though the term composting is sometimes used to describe anaerobic or aerobic digestion, it is usually taken to signify the more widely used aerobic process. Compost is a low-grade fertilizer mainly valued as a soil conditioner. Composting would seem to have a good potential in highly populated cities of the developing countries where MSW is rich in organic matter and has a high moisture content.

IV. ECONOMIC, ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

A. Economic considerations

The economic possibilities for generating energy from urban and rural waste may vary widely. It is a very complex problem that requires a broad and detailed study in which the availability of domestic sources of energy, the cost of imported fuel, the uses and actual benefits from energy generation, the public and private costs associated with waste collection, and the technology used to generate energy must be included. Since these factors vary with each application, the evaluation of a potential solid waste recovery unit using urban or rural waste must be considered in its entirety. Aside from rising costs, the evaluation should include a complete analysis of the reliability of the quantity of the urban and rural waste.

Although municipal and industrial solid waste has a high energy value, it cannot be utilized as easily and economically as conventional fuels that have concentrated energy content such as natural gas, oil or coal. By burning solid waste, an energy source is made available, while at the same time the problem of waste disposal can be solved. Some of the costs of collection, transportation and processing could be viewed as the fuel price, and the whole cost must support the price of solid waste disposal. These, together with government policy and other factors, influence the relative costs and financial profitability of a separate collection and recycling scheme.

As was mentioned above, the actual value of urban and rural solid waste burning is dependent on the cost of conventional fuels, the actual energy content of the solid waste and the cost of conventional disposal methods. These costs should be considered along with the fact that many solid waste items have an actual and/or potential market for recycling.

The economics of a solid waste power-plant should be based on several parameters, as follows:

(a) Governmental regulations covering solid waste landfill sites;

(b) The air and water pollution affected by the process;

(c) Transportation, handling and processing costs;

(d) The cost effectiveness of alternative methods of solid waste disposal and/or utilization;

(e) Sanitary landfill costs;

(f) The recovery of valuable resources and by-products;

(g) Conventional fuel costs.

The economic feasibility of biogas production from agricultural and agro-industrial waste, using simple systems suitable for rural areas, has been examined in many countries around the world namely China, India, the Philippines, Sri Lanka, Thailand and Egypt. The economic cost of construction, maintenance, extension and organic materials has to be assessed on the input side. The value of labour appears to be a crucial parameter in this respect, as it influences not only the general economic feasibility of biogas, but also the choice between large and small-scale digesters. Therefore, the economic benefits of biogas depend to a large extent on the alternative energy source it is supposed to replace. Since biogas has no market price, its value has to be derived from the market price of the particular energy equivalent it will replace. Depending on its end-use, relevant alternative sources would be firewood, kerosene, butane gas, electricity, diesel and solar and wind energy.

B. Environmental considerations

The control of the environmental impact of urban and rural solid waste burning is one of the major stumbling blocks that inhibit the wide-scale development of solid waste as an energy source in many developed and developing countries. A possible alternative would be to accept environmental trade-offs. Obviously, such a situation would only be possible under the auspices of governmental regulatory agencies.

Environmental control or bioenergy conversion and bioconversion processes are readily available for many of the modern combustion and thermochemical options; technology from the petroleum industry is often readily available for all these processes. For example, in the case of biogas, methane is clean and smokeless-burning. It does not constitute a health hazard on contact with skin. The effects of accidental methane release upon terrestrial or aquatic organisms are nil, and air emissions of gas are relatively benign as far as environmental and health effects are concerned.

C. Social considerations

Waste generation imposes social costs on society, depending on the type of disposal method used in a particular area in the country. These social costs may be covered by government intervention, in conjunction with an economic incentive approach in order to accelerate the rate of recycling or to reduce the volume of waste generated.

As soon as benefits of a more social nature enter the picture, such as health, convenience and leisure, biogas increases its attractiveness for rural areas. Cooking with biogas is healthier and easier than traditional cooking, and it appears to be highly appreciated by female users. Therefore, biogas technology can go far to improve the quality of life of the rural population.

V. ECOLOGICAL AND TECHNICAL CONSIDERATIONS

Urban and rural waste is disposed of because of its zero market value. However, its environmental implication for municipalities calls for collection and recycling. In this report the focus is on generating energy from such disposable and recyclable waste. It is recognized that whenever waste can be utilized for human benefit, its subsequent increase in economic value changes its output status from that of a non-product to a product, as in the case of generating energy.

Within the ESCWA region, it seems difficult to visualize a common approach for the recycling of waste to energy. This is because of the population size of most Gulf countries where agricultural or animal waste either does not exist in quantities worth collecting for recycling, or it exists in scattered and remote areas. However, the municipal waste of such metropolises as Kuwait City, Doha and Abu Dhabi has an energy content that is easily accessible for collection and has a potential for generating energy. In countries like Egypt, Iraq and the Syrian Arab Republic, in view of the size of their populations and the diversity of agricultural activities, significant quantities of waste could be considered for both energy generation and environmental improvement. The recycling and utilization of such wastes are of serious concern in view of the following:

(a) Environmental hazards that result from their non-collection or non-disposal;

(b) Energy as a by-product from recycling waste deserves consideration, particularly where the calorific content of such waste is high. This is necessary in the light of expanding urbanization and rapid industrialization in the largest cities in the region.

Unfortunately, the effective mechanisms to generate energy from urban and rural waste are impeded by several socio-economic and institutional factors.

However, sound ecology is good economics. In this context, every measure should be taken to protect the environment, such as the following:

(a) The creation of a unit in the municipality of ESCWA countries that could be entrusted with the task of generating energy from recycled waste;

(b) A country-by-country assessment of types and quantity, including the characteristics of urban and rural waste;

(c) The design of a subregional programme for recycling urban and rural waste including the possibility of energy generation;

(d) Participation in a regional programme to conserve the environment, and the expansion of budgetary allocations to municipalities in order to secure technologies for recycling waste, including the generation of energy;

(e) Exploration of the possibilities of regional co-operative efforts by ESCWA countries in a long-term campaign to protect the environment;

(f) Institutionalization of an approach to waste disposal as resource management that puts a premium on energy and environmental protection.

VI. MAIN FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

It can be concluded that it is technically feasible, economically viable and socially beneficial to convert a large proportion of urban and rural waste into energy. Resource and energy recovery systems are therefore viable alternatives for the resolution of the critical waste disposal problem in some countries of the ESCWA region, the improvement of environmental conditions and, to a certain degree, the production of energy for decentralized use. The economic recovery of this potential energy source is highly dependent on the energy content of the waste and on the level of technical capability in the area of waste collection, handling and preparation, thermal and bioconversion and plant management.

A properly planned waste management programme that would utilize the various kinds of waste in the country for the production of energy could improve the situation in rural areas, reduce the cost of fuel-oil to generate power-plants in cities, in addition to making possible the recovery of valuable by-products in order to make urban and rural waste disposal safe, efficient, environmentally sound and economically attractive.