RECOVERY OF BIOGAS ENERGY FROM MUNICIPAL SOLID WASTE

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1. INTRODUCTION:

Solid waste management has become a major environmental issue in India. Generation of solid waste depends on many factors like culture and nature of the people, the socioeconomic conditions, its commercial importance and its industrial base. Table No. 1 indicates the state wise solid waste generation.

Table no. 1: State – wise Solid waste generation in class – I cities

Name of state/UT	Number of cities	Municipal Population	Municipal solid waste (million tones/day)	Per capita generated (kg/day)
Andhra Pradesh	32	10845907	3943	0.364
Assam	4	878310	196	0.223
Bihar	17	5278361	1479	0.280
Chandigarh	1	504094	200	0.397
Delhi	1	8419084	4000	0.475
Gujarat	21	8443962	3805	0.451
Karnataka	21	8283498	3118	0.376
Madhya Pradesh	23	7225833	2286	0.316
Maharashtra	27	22727186	8589	0.378
Orisa	7	1766021	646	0.366
Punjab	10	3209903	1001	0.312
Tamilnadu	25	10745773	5021	0.467
Uttar Pradesh	41	14480479	5515	0.381
West Bengal	23	13943445	4475	0.321
Total	253	116751856	44274	5.107 /14 = 0.365

Source CPCB (2000a)

It is observed that MSW generated by 253 class I cities in India is 44274 TPD (tonnes per day). The national average for class I cities in India is 0.365 Kg / day. The growth of MSW has outpaced the population growth in recent years. The survey conducted by CPCB puts the total municipal waste generated from class I & class II cities to about 18 million tonnes in 1997. The present annual solid waste generated in the Indian cities has increased from 6 million tones in 1947 to 48 million tonnes in 1997 & is expected to increase to 300 million tonnes by 2047.

Solid waste generation is directly related to economy of the country. As the society becomes richer, waste generation increases while traditional recycling practices tend to decline. As seen in Table No. 2, the physio-chemical characteristics of MSW have changed.

Table No. 2: Physico- Chemical Characteristics of Municipal Solid Waste

Component	Percentage of weight	
	1971-73 (40 cities)	1995 (23cities)
Paper	4.14	5.78
Plastics	0.69	3.90
Metals	0.50	1.90
Glass	0.40	2.10
Rags	3.83	3.50
Ash and fine earth	49.20	40.30
Total Compostable matter	41.24	41.80
Calorific value(kcal/kg)	800-1100	<1500
C: N ratio	20: 30	25:40

It clearly shows that the proportion of recyclable waste is increasing in total MSW. Also C:N ratio is between 21% - 31%.

Disposal in the landfills or uncontrolled dumping is the practice followed by most municipal bodies. Tremendous increase in solid waste generation will have significant impact in terms of land requirement as well as impact on CH_4 (methane) emissions. The land requirement for land filling is enormous as given in graph No. 1. Each year Germany generates around 1.2.-1.9 tonnes of methane accounting for 25% - 35% of Germany's CH_4 emissions. In USA, 11.6 tonnes of methane is emitted by landfills accounted for 37% of the anthropogenic methane emissions. As given in Graph No. 2, the methane emissions from land filling sites in India is estimated to be between 40-50 MT in 2047.

The methane emissions from such uncontrolled landfilling facilities are leading to increase the threat by green house gases.

In this paper an attempt has been made to discuss the various technology options available for converting waste to energy with greater emphasis on energy recovery from MSW.

Table No. 3 : Characteristics of Urban Wastes.

Sr. No	Moisture %	T. S. %	Inerts %	Organics % TS	Calorific Value* Kcal / kg (Dry basis)
1.	20-40	60-80	35-50	50-65	800-1000

2. TECHNOLOGY OPTIONS:

The MSW contains organic as well as inorganic matter. The latent energy of its organic fraction can be recovered for gainful utilization through the adoption of suitable waste processing and treatment technologies. A few options can be as follows:

Sanitary landfill
Incineration
Gasification
Biodegradation process
Anaerobic digestion
Other types

Municipal Solid Waste (MSW) has emerged as a potential energy source owing to several desirable attributes as given in Table No.3 – high organic content (55-60%), low sulphur (0.1%), and adequate calorific value for sustained combustion.

Recognizing the rich organic content of municipal solid wastes, technologies have evolved based on thermal or biological methods for energy recovery. The thermal methods utilize the calorific value of the solid waste and release the energy potential through either simple or advanced combustion processes, where the carbon and hydrogen constituents are either oxidized (incineration) to carbon dioxide and water with the generation of hot combustion gases which can be used in boilers and turbines for steam/power production, or the waste is decomposed under reducing conditions to yield carbon monoxide, hydrogen and other organic fuel gases.

Incineration systems available from leading manufacturers have been widely adopted in North American and European communities for the safe disposal of MSW and the related benefit of auxiliary power generation to augment grid suppliers. Recent technological developments have focused on advanced thermal conversion (ATC) processes like gasification and pyrolysis as potentially promising viable waste-to-energy systems with increasing commercial uptake.

Concurrent developments based on biological processing of MSW have lead to successful proprietary composting processes for the conversion of domestic garbage to compost – consisting of a matrix of humus (humic substances) suitable as a soil conditioner with moisture retention capacity and as a low grade fertilizer. The successful application of composting as a method of disposal of MSW is dependent upon five basic factors: composition and moisture content, land availability, the quantum of waste to be handled, a ready market for the compost and a need for secondary disposal (landfill for non-compostables). MSW contains about one-third of non-compostables such as glass, plastic, metal, rubber, etc., which can be salvaged for recycling or sent to landfills. With a poor off-take of product and expensive processing costs, the Indian experience is limited to a few installations, which were unviable owing to poor quality and an unsatisfactory quantum of MSW. Land filling has been the most common and widely prevalent practice of MSW disposal in many countries. Some of the parameters now tending to limit the practice of sanitary land filling include land availability, production of leachates and deleterious malodorous gases, and public acceptability as a disposal method. Adverse public opinion has been a critical factor limiting the overall success of refuse disposal by landfilling even though secure well-engineered landfills have overcome some of the operational problems. A further issue is the presence of a satisfactory waste collection infrastructure. Biomethanation of municipal sewage is also a proven WTE option with potential energy recovery as biogas. The typical content of municipal solid waste is given as below;

Table No. 4:- Waste Categories in Municipal Solid Wastes (MSW)

CATEGORY	EXAMPLES
A. RESIDENTIAL/COMMERCIAL	
Food waste	Kitchen and Food
Paper	Newspaper, Kraft paper, office and computer, magazines
Cardboard	Corrugated board, laminated paper
Plastics	PET, HDPE (containers and bottles), mixed plastics, (PVC, LDPE, PP and PS), film plastic
Textiles	Clothing, rags, etc.
Rubber	Rubber products
Leather	Shoes, upholstery, bags
Yard wastes	Grass, leaves, bush and tree cuttings
Wood	Building materials, wooden pallets
Miscellaneous	Disposable diapers, containers
Glass	Glass (clear, amber, green), flat glass
Aluminum	Cans, frames
Ferrous metals	Cans, appliances and auto parts
B. SPECIAL WASTES	
Bulky items	Furniture, lamps, book cases, cabinets, etc.
Consumer electronics	Radios, stereos, television sets, computers
White goods	Large appliances (stoves, refrigerators, washers)
Batteries	Household (Lead acid)
Oil	Spent oil and lubricants
Tyres	Car and truck tyres
C. MUNICIPAL SERVICES	
Institutional	Same as (A)
Construction and	Dirt, stones, concrete, bricks, plaster,
Demolition	lumber, shingles and plumbing, heating and electrical parts. Wastes from razed buildings, broken-out streets, sidewalks, bridges and other structures

CATEGORY	EXAMPLES
Street cleanings	Dirt, rubbish, dead animals, abandoned vehicles
Landscaping	Grass, bush and tree cuttings, tree stumps, old metals and plastic bags, bottles etc.
Parks and recreational areas	Food wastes, newspaper, cardboard, mixed paper, soft drink bottles, milk and water containers, mixed plastics, clothing, rags, etc.
Treatment plant residuals	Sludge and ash

Bio-conversion of waste matter to biogas (methane) can provide the dual benefits of energy recovery and solid waste disposal. The potential for methane fermentation of various organic feedstocks is great and can significantly contribute to the ever-increasing energy needs of society. The anaerobic digestion of the organic fraction of wastes such as proteins, fats and carbohydrates involves hydrolysis–acitogenesis and methanogenesis reactions to generate primarily methane and carbon dioxide. Bio-conversion of various solid wastes, following elaborate raw material preparation via shredders, hydropulpers, cyclones, air classifiers, etc. for the removal of grits, ferrous/non-ferrous metals, glass, etc, results in suitable slurry feed for anaerobic digestion. Proprietary raw material preparation and anaerobic digesters are available for handling MSW, animal waste, farm waste and other organic solid residues in biomethanation processes.

A wide variety of systems have been developed and commercialized during the past decades or two to tap the energy potential of various solid wastes and concurrently solve the problems of waste disposal. The use of solid waste as supplemental fuel through novel energy recovery systems has a great potential for full scale applications. Newer energy recovery process based on pyrolysis and gasification or methane production can be implemented to meet long range energy needs of modern societies. Successful implementation of such projects also requires an efficient solid waste management system specific for the type of waste considered for large scale exploitation in WTE projects.

3. CRITERIA FOR SELECTION OF TECHNOLOGIES:

Technologies for viable WTE processes are based either on thermal or biological methods for recovering the energy potential of various urban and industrial solid wastes. A wide range of proprietary systems is available for the major methods of energy recovery – incineration processes for wastes with adequate calorific value to sustain combustion reactions, gasification and pyrolysis technologies for MSW and other specific organic waste types, and anaerobic digestion processes for recovering the biochemical energy potential of a waste as methane fuel (biogas).

All of these processes are based on the use of a series of heavy duty mechanical equipment for handling a large quantity of MSW or other solid wastes for feed preparation. Both thermal systems (incineration and advanced thermal conversion) and anaerobic digesters incorporate unique process features and skills in operation to meet performance stipulations.

Energy recovery as electric power is a feature of all waste-to-energy systems. Consequently, these systems generally involve significant capital and maintenance costs. In order to match the quality and amount of waste to be processed with an appropriate technology package requires diverse expertise and skills in materials management, engineering skills, finance, judiciary, statutory regulatory aspects, ecological and socio-economic issues.

The problem of solid waste disposal has gained an immense proportion or the urban local bodies and waste management experts. The current method of disposal that is landfill – is becoming economically and environmentally unacceptable. It is increasingly being felt that energy present in its organic fraction can be recovered for gainful utilization through the adoption of suitable technologies. Recovery of energy from waste has additional benefits, in terms of an all round reduction in the volume of waste, demand for land required for landfill, cost of transportation, and reduction in environmental pollution.

3.1 Nature of Waste

The amount of waste to be processed and the characteristics of the waste are important factors. The waste quantity will decide the capacity of any WTE plant, unless storage hoppers can be utilized to take account of a waste stream which varies widely in daily quantities. The nature of the constituents making up the organic fraction of the waste will determine its thermal or biochemical energy potential. An adequate quantity of waste of a desirable quality must be available to sustain continuous operation of the system selected.

3.2 Technology

Process technology plays a key role in the selection of appropriate process equipment and accessories, process instrumentation, layout, manpower training, and capital and recurring expenses for implementation of a waste-to-energy project on a turn-key basis. A major difference between the thermal and biological process options is the process operating temperature level, viz. 1000 ^{0}C and 35 – 60 ^{0}C respectively, and the large equipment sizes associated with the incineration systems (particularly) and the associated need for large capital investment.

Table No.5 : Critical Factors for Assessment / Selection and Implementation of WTE Technologies

FACTOR		INCINERATION	BIOLOGICAL (ANAEROBIC DIGESTION)	GASIFICATION/ PYROLYSIS
A.	**NATURE OF SOLID WASTE**			
*	Capacity (Ton/d)	Large *	Medium	Small/medium
*	Organic fraction	0.5 – 0.6	0.4 – 0.5	As high as poss, after sorting
*	Feed Stock	Wide range	Wide range	Wide range
*	Moisture (%)	<20-25%	88-90 %	<20-25%
*	Industrial Aqueous Effluents	High conc./(evaporation) drying /combustion	BOD >3000 mg/l	None
*	Industrial solid waste	Suitable	Not suitable	Suitable
*	Collection/storage/ Transport	Required	Required	Required
*	Pre-treatment	Required	Required sometimes	Required
B	**PROCESS TECHNOLOGY FEATURES**			
*	Temperature ^{0}C	1000	35-37 (mesophilic), 50-60 (thermophilic)	Variable (400 – 1400)
*	Pressure	200 – 300 mbar	150 – 250 mbar	Variable
*	Reactor Atmosphere	Oxidising (Excess Air)	Strictly anaerobic	Inert (pyrolysis), Partially oxidizing (gasification)
*	Simplicity	Generally complex	Simple	Generally complex
*	Operation	Generally runs smoothly process upsets	Susceptible to process upsets	Generally runs smoothly after start-up
*	Flexibility	Inflexible	Flexible	Flexible
*	Expandability	Not readily expanded	Readily expanded	Readily expanded (modular)
*	Energy Recovery	Hot combustion gas	Biogas	Variable
*	Power generation	Gas/Steam turbine	Gas turbine	Gas/steam turbine
*	Efficiency	85-90% (based on calorific value)	50 – 60% (based on % volatiles)	90-95% (based on calorific value)
*	Residue	Ash	Digested slurry	Vitrified slag
*	Residue Disposal	Landfill	Farm land	Reuse possible, or as roading material
*	Downstream Processing	Air Pollution Control	Sludge stabilization	Limited air pollution control

FACTOR		INCINERATION	BIOLOGICAL (ANAEROBIC DIGESTION)	GASIFICATION/ PYROLYSIS
C.	**SYSTEM & COSTS**			
	Modular	Generally not	Yes	Yes
	Area (size) requirements	Varies, but considerable	Relatively limited	Varies
	Maintenance	Extensive, and costly	Very limited	Limited (few moving parts)
	Capital	Very High	Medium	Very High
	Recurring	High	Marginal	variable
	Technology upgrading	On going activity	Marginal	Via R & D
	Commercial viability	Moves to costly pollution control makes much less viable	Generally readily viable	Varies considerably
	Energy input	High	Low	Variable, but ultimately only 5-20%parasitic energy demand
	Royalty status	High	Effectively zero	High
D.	**ENVIRONMENTAL IMPACTS**			
	Air Pollution	Dust Collection, Gas Scrubbing	H_2S – Scrubbing	Negligible
	Water Pollution	Minor	Down-stream aerobic	Negligible
	Solid/Hazardous wastes	Ash	Stabilized sludge	Vitreous slag
	Overall compliance	Feasible	Feasible	Feasible
	Environmental impacts	Can be minimized, but costs are becoming increasingly prohibitive	Minimum	Completely controlled
E.	**SOCIO – ECONOMIC**			
	Waste disposal	Complete, except for ash	Complete	Complete
	Energy recovery	Efficient	Partial	Efficient
	Public acceptability	Satisfactory	Satisfactory	Satisfactory
F.	**OTHERS**			
	Waste Collection	Municipal/Agency	Municipal/Agency	Municipal
	Power distribution	Power Grid	Power Grid	Power Grid
	Facility operation	Agency	Agency	Agency

(* Remarks apply to installations abroad)

3 Economic Factors

There are two important aspects of waste to energy economics; the first is capital and operating costs, and the second is the gate fee for a treatment plant. Disposal of by-products in an efficient way can not only save disposal costs, but can also produce extra revenue.

4.1 Capital and Operating Costs

Several factors such as the size of a plant, the plant location, process type, technology developer, and cost of local labor, construction material proximity, transportation costs, and the nature of the waste pre-processing requirements help to determine the capital and operating costs. Initial costs and running costs can vary significantly due to local conditions. For example, high pressure gasification systems are more efficient and cheaper at electricity generation stages but require high initial capital, as compared to low pressure gasification. Proper consideration of all of the above factors is required while selecting a particular technology.

4.2 Revenue From By-Products

By-products produced in waste-to-energy processes present two-fold economic considerations. The first is the cost of residue disposal, and the second is possible revenue from the sale of various residues. For example, for biomethanation, the reactor residue has value as a compost or soil conditioner and, in gasification the vitrified slag comprised of inert inorganic constituents can be used as a material in road construction.

5. Waste-to-Energy Technologies Assessment

The advent of successfully commercialised technologies for biomethanation of MSW is an exciting option for waste-to-energy future. It will be essential that individual technologies, and each relevant MSW stream are closely assessed for their mutual compatibility in terms of energy content, proportion of inert materials, presence (or preferably, absence) of hazardous and toxic components detrimental to microbial populations, and a range of other key parameters. The issues of relatively high capital and operating costs to treat significant volumes of MSW, the need for careful MSW sorting, and for close control of key process parameters such as pH and temperature to maximise biogas production are all highly significant for successful MSW biomethanation and, although they may be limiting or restricting unless satisfactorily dealt with, they are not disqualifying for the application of biomethanation to waste-to-energy applications involving municipal solid wastes in India.

All WTE technologies based on MSW as feedstock require a certain degree of pre-processing to achieve the desired proportion of various organic constituents, to recover valuable materials and to remove undesirables depending upon waste characteristics.

Typical compositions of MSW generated by the varying life styles of modern societies in the different countries will also have an impact on the evaluation of suitability and selection of technology and transfer of technology/know-how. Mass and energy balance considerations of various thermal and biological WTE processes are major factors in assessing viability of technology options. These aspects are discussed in detail in the next three sections of this report as a prelude to the major task of technology assessment.

6. Anaerobic Digestion

Approximately 60% of input material by weight leaves an anaerobic digestion plant as digested residue; this may find use as a soil extender if there is a ready market for such an application.

Depending on the original composition of the substrate for digestion, typically 6-24 % by weight of the input material may be inert inorganic components. Generally, up to 80% of the digestible organic fraction can be converted to biogas (depends on the nature of the input substrate).

In anaerobic digestion a high fraction of the inherent energy (up to 55%) in the organic fraction of MSW is converted to methane. Several estimates of the energy balance in a typical anaerobic digestion process have been made in the literature. These are in quite close agreement with each other and assuming:

* a digestion efficiency of 55%
* an electrical conversion efficiency of 30%

and after allowance for the use of some derived energy for processing energy requirements, the net power generation potential of anaerobic digestion ranges in between 0.9-1 MW per 150-200 tonnes of MSW.

6.1 Bio-Chemical Conversion

This process is based on the enzymatic decomposition of organic matter by microbial action to produce CH_4 gas or alcohol. This technology is suited to wastes having a high percentage of biodegradable matter with high moisture content. The options include fermentation and anaerobic digestion. The potential energy recovery from the municipal solid waste depends on the calorific value and organic fraction.

Assessment of energy potential through biochemical conversion

Total organic solids / VS (volatile solids) = 50 %

Calorific value of biogas = 5000 kcal/ m3

Digestion efficiency = 60 %

Organic biodegradable fraction is 66 % of the VS

Biogas yield : B (m^3) = 80 m3 /kg of the VS destroyed

Biogas Yield (m^3) = 0.80 * 0.60 * 0.33 * W * 1000 = 158.4 W

Where W is the amount of waste processed in tones

1 Hence energy recovery potential (kWh) = B 5000 = 921 8 W/860

2. Power generation potential (kW) = 921 * W = 38.4 * W/24

3. Net power generation potential (kW) = 11.5 * W
(Typical conversion efficiency)

In general, 100 tonnes of raw MSW with 50 % - 60 % organic matter can generate about 1 – 1.5 MW (megawatt) power, depending upon the waste characteristics (CPHEEO 2000)

7. TECHNOLOGY ASSESSMENT MATRIX:

Technology Evaluation Matrix for Waste-to-Energy Options

Sr. No	Evaluation Criteria	Rating Range	Biological Processes		Thermal Processes		
			Biomethanation	**Landfill**	**Composting**	**Incineration**	**Gasification / Pyrolysis**
1.	Simplicity	**0-10**	**8** (Generally simple)	**10** (Very simple)	**10** (Very simple)	**2** (Generally complex)	**2** (Generally complex)
2.	Operability	**0-20**	**16** (Moderate skills)	**18** (Low skills)	**15** (Low skills)	**8** (High skills, moderate parasitic energy demand)	**10** (High skills, low parasitic energy demand)
3.	Flexibility	**0-10**	**6** (Susceptible to Process disruptions)	**10** (Very flexible)	**10** (Very flexible)	**4** (Rigid – design / operation)	**4** (Rigid – design / operation)
4.	Expandability	**0-10**	**8** (Good, Modular plants)	**10** (Large capacity)	**8** (Expandable but has higher land requirement)	**6** (Expandable Modular)	**6** (Good - modular designs)
5.	Pre-treatment	**0-15**	**10** (Emphasis on compostable organics)	**6** (Well defined, Emphasis on material recovery (Trend)	**12** (Ill-defined)	**8** (Well defined)	**8** (Well defined)
6.	Post Treatment	**0-15**	**10** (Sludge stabilization) Biogas clean-up (H_2S)	**5** (Obnoxious LFG clean-up)	**7** (Up gradation of compost to improve market acceptability)	**5** (Down stream air pollution control. Ash residue	**8** (Down stream air pollution control. Ash disposal)
7.	Land Requirement	**0-20**	**12** (Large including sludge stabilization)	**5** (Very High)	**6** (Very High)	**15** (Less)	**18** (Compact)
8.	Relevance of Scale	**0-10**	**10** (No minimum)	**10** (No minimum)	**10** (No minimum)	**5** (Minimum waste stream)	**7** (Minimum waste stream)

Sr. No	Evaluation Criteria	Rating Range	Biological Processes		Thermal Processes		
			Biomethanation	**Landfill**	**Composting**	**Incineration**	**Gasification / Pyrolysis**
9.	Scale-up practicalities	**0-10**	**10** (Modular)	**7** (Might need separate LFG recovery installations)	**7** (Practical with balancing facilities / equipment)	**10** (Not a major Issue, Modular)	**10** (Not a major Issue, Modular)
10.	Maintenance considerations	**0-20**	**18** (Not a major issue)	**15** (Low)	**10** (Moderate maintenance)	**8** (Can be very significant)	**6** (Can be very significant)
11.	Environmental Impacts	**0-30**	**25** (Generally positive in terms of GHG reductions, stabilized sludge reused as fertilizer)	**15** (Contamination of Surface & Ground water due leachate & Runoff, Contamination of air due to LFG)	**15** (Negative due to odor, control costs)	**10** (Negative and air emissions control)	**12** (Negative and air emissions control)
12.	Energy Recovery	**0-30**	**18** (Relatively efficient)	**10** (Relatively less recovery as LFG)	**0** (Nil energy generation)	**24** (Relatively more efficient)	**28** (Relatively very efficient)
13.	Commercial viability	**0-30**	**25** (Moderate Cost structure, saleable power and sludge compost)	**8** (Comparable costs, small returns with LFG recovery)	**5** (Poor/nil returns)	**15** (High pay back period, High Capital and operating costs and pollution control costs per MW power)	**18** (High pay back period, High Capital and operating costs and pollution control costs per MW power)
14.	Track record	**0-20**	**20** (Excellent, well-proven)	**20** (Excellent, well-proven in the developed countries)	**12** (Very good, though poor market for compost and poses health hazards)	**20** (Well established track record)	**15** (Severa l recent successful commercial ventures)
15.	Geographical	**0-10**	**8** (Depends on site selection, but can be sited almost anywhere)	**5** (Proper site selection is required)	**5** (Proper site selection is required)	**8** (May be relevant)	**8** (May be relevant)

Sr. No	Evaluation Criteria	Rating Range	Biological Processes		Thermal Processes		
			Biomethanation	Landfill	Composting	Incineration	Gasification / Pyrolysis
16.	Royalty	**0-10**	**10** (Not an issue)	**10** (Not an issue)	**10** (Not an issue)	**4** (A significant consideration)	**4** (A significant consideration)
17.	Issues relevant to India	**0-30**	**25** (Semi-skilled man power available)	**20** (Semi-skilled man power available)	**20** (Semi-skilled man power available)	**10** (Indian waste streams have lower thermal energy potential (calorific value)	**15** (Indian waste streams have lower thermal energy potential (calorific value) manpower, training will be issues O&M a major issue)
	Total	**300**	**239**	**184**	**162**	**162**	**181**

8. OVERALL RANKING OF TECHNOLOGIES

The above analysis has enabled a comparative picture of the status of the four technology options for energy recovery from MSW, and a comparison with composting as a competing technology for beneficial waste reuse. The overall ratings for biomethanation, incineration, gasification / pyrolysis, landfill and composting technologies gives relative scores of 239, 162, 189, 182 and 167 respectively out of 300 (maximum).

Biomethanation as a technology scores 80 % followed by gasification / pyrolysis (63 %), and landfill (61 %). Biomethanation has several advantages over all the other technologies due to good track record, less maintenance and environmental impacts. From the assessment it is clear that biomethanation will be the most appropriate technology for Indian conditions, and under most criteria used. Landfill and gasification & pyrolysis have definite prospects for specific applications, provided that certain constraining factors can be satisfactorily addressed. Incineration appears to be a less attractive option for Indian Waste-to-Energy applications, for a variety of compelling reasons. Landfill has a low energy recovery potential but because of low cost and track record in the developed countries it can be recommended as a short to medium range option even though it has reduced potential for energy generation.

Composting scores 56 % which means composting merits consideration as a independent waste disposal proposal but not of course as a waste-to-energy option. Incineration scores the least among all the five technologies, scoring 54 %, and with limited prospects of adoption as a successful WTE technology under Indian circumstances.

1. STATUS OF ANAEROBIC DIGESTION TECHNOLOGY FOR MSW IN INDIA

Biomethanation is considered the most technically viable option for the Indian MSW due to the presence of high organic and moisture content and the dual benefits associated with the process. In addition to this the temperature conditions are more suitable for the optimum performance of the digester. In spite of this there are no commercial plants for biomethanation of solid waste in India. Indigenous technologies are being developed by various organizations and small prototypes have been found functional. However, these are not commercialized as yet.

Several institutes have been carrying out research studies associated with the biomethanation of solid waste for improving the digestibility and biogas yield by providing optimal conditions, improved microbial stains, and digester designs.

ASTRA (Center for Application of Science and Technology to Rural Areas) at the Indian Institute of Science, Bangalore, has developed a plug flow digester to dispose of the leaves and other urban wastes. TERI has developed a biphasic process for treating different types of organic solid waste. The process called TEAM is a two stage anaerobic digestion process designed specially for biomethanation of the organic solid waste that are fibrous and have light floating materials.

Recently, a 5MW waste to energy plant has been commissioned in Lucknow, which is based on the technology by Entec, Austria, for biomethanation of solid waste. The BIMA (biogas induced mixing arrangement) is the technology developed by Entec. The technology is suitable for high BOD waste materials.

2. DOMESTIC COMPANIES INVOLVED IN MSW TREATMENT AND DISPOSAL

Zen Global Finance Ltd has indigenously developed a RDF (refuse derived fuel) technology for conversion of MSW into a clean fuel. Currently this company has set up a plant in Andhra Pradesh with a capacity of 200 tonnes/day and expected fuel output of 60 tonnes / day. An RDF plant is also being retrofitted in Delhi.

Enkem Engineers Ltd is promoting a biomethanation process in technical collaboration with Entec of Austria.

Future Fuel Engineering (India) Pvt. Ltd. Is promoting anaerobic biodigestion technology in collaboration with ECOTEC of Finland and presently installing a plant at Kalyan near Mumbai.

Thermax Ltd. The leader amongst Indian companies is offering environmental friendly technologies.

3. Case study of Pune city:

As per the 'Municipal Corporation MSW regulation 2000', Pune Municipal Corporation (PMC) has started collecting the segregated solid waste. But the process has no expected speed because of many reasons.

SuryaPet in AP is the only Municipal Corporation who could obey the orders of Supreme Court regarding the time limit for MSW management.

As per the statistics, the Pune city will generate 1454 MT (metric tonnes) of solid waste daily. About 750 MT MSW will be transferred to Urali dumping ground. One thousand rag pickers are disposing 350 MT of dry solid waste. At biogas project of PMC 20-25 MT of MSW is disposed off through anaerobic digestion. Vermicomposting project is used to treat about 100 MT of MSW.

In Pune city around 850 Kg of biomedical waste is incinerated daily.

As per the available figures about Pune city, out of the total MSW generated (1454 MT) daily, 65 % is the organic degradable waste. This indicates that around 850 MT of organic waste is generated daily. From one tonne of organic waste we can get 60-70 m^3 of bio gas. One m^3 of biogas can generate 1.74 kwh of energy. This indicates that daily PMC can generate 4-5 MW of electricity.(for 1MW of electricity generation about 100-200 MT of organic waste is needed.) The total project cost for one MW electricity generation from MSW is around Rs.10-12 crores.

12 Conclusion:

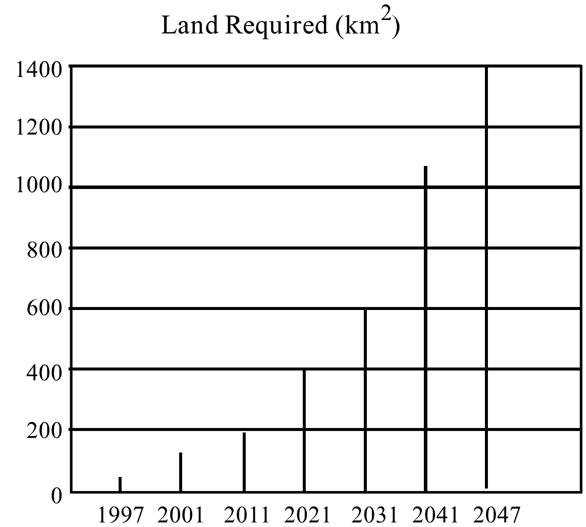
In the past, anaerobic technologies emphasized energy production from organic waste. Today, energy production and recovery are still important, but recognition of the anaerobic digestion (AD) as an inexpensive technology to stabilize organic waste, reduces BOD & SS with minimal sludge production and reduce odor which is almost as important as energy production. Energy savings in anaerobic treatment versus aerobic treatment will become more important in energy deficient countries.

A future application in many new developments is the design of MSW facilities. The AD and composting offer the only route for recycling organic matter and nutrients from the putrescible fraction of MSW.

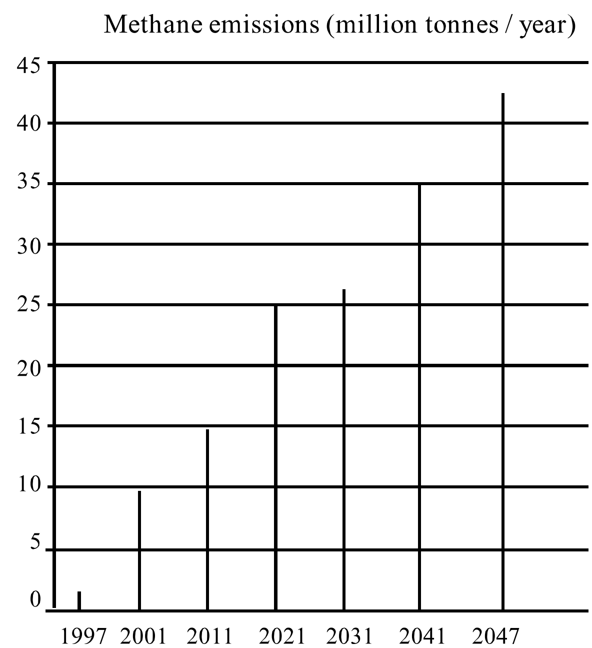
Many countries have developed standards for the MSW co-products use and any use of these co products must strictly comply with consumer quality standards.

Around one megawatt of electricity can be generated from 200-250 TPD organic waste. Thus the cities generating 1000 MT of MSW (600-650 MT organic waste) can generate 2-3 MW of electricity per day.

As far as Pune city is concerned, it is recommended to install decentralized anaerobic digestion solid waste(ADSW) treatment facilities either at ward level or at area level. Even in existing sewage treatment plants, such type of ADSW treatment facilities can be installed.



Graph NO. 1 Land Required for solid waste management



Graph No. 2 Emissions of methane form landfills