TECHNICAL MANAGEMENT OF MUNICIPAL SOLID WASTE AS A MEANS OF ENERGY SECURITY FOR BANGLADESH

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Introduction

Solid waste creates a greater problem to the environment if it is not properly managed. Bangladesh is a heavily populated country and it needs to be deeply concerned about waste management. Amount of waste in Bangladesh is getting increase because of rapid urbanization, pattern of life and economic development of the country. There are 775 towns / urban centre and 6 City Corporations in Bangladesh. Daily waste generation of these city corporations is about 13,332 tons and total amount is around 27000 tons/day in the whole country of Bangladesh. With present trend of waste generation, it is likely to be doubled by 2030. Singly in Dhaka city it is around 7500 tons/day and this amount is likely to reach about 15000 tons /day by 2030 (Sayedur, 2014) .

There is a great potentiality of extracting latent heat from Municipal Solid Waste (MSW) of Bangladesh and its calorific value ranges from 550 to 850 Kcal/KG (Dhaka City Corporation, Japan International Cooperation Agency, 2005). Unfortunately we are still unable to utilize this energy potential accumulated in MSW. At present, land filling is the only method for disposal of MSW and there are three landfills in Dhaka City. Development of any new landfill site is near to impossible due to land scarcity and increasing of land prices especially in Dhaka City. As per the report on solid waste management of Dhaka City Corporations (DCC), it is learned that, about 60% of generated waste is collected and dumped at landfill sites and rest remains uncollected (DNCC, 2017).

In general, Incineration and gasification can handle certain biodegradable & non degradable waste. Pyrolysis technologies utilize plastics, rubbers, polythene etc. Mechanical Biological Treatment (e.g. Anaerobic Digestion) utilizes biodegradable solid waste e.g. kitchen wastes (Sayedur, 2014). Suitable technology for recovery of energy from waste can play a very important role in mitigating the difficulties of solid waste that can act as a renewable source to augment the energy security of Bangladesh.

State of Energy in Bangladesh: Per capita consumption of energy in Bangladesh is one of the lowest across the globe. Currently per capita energy consumption in Bangladesh is about 370 kw hr and 74 percent of the total population of the country has access to electricity (Abdul Munim, Mahbubul Hakim, & Abdullah-Al-Mamun, 2010).

Present Power State in Bangladesh: At present power generation capacity is 13,179 MW which includes public sector 7054 MW (53%) and private sector 6,125 MW (47%) respectively (Annual Report of BPDB 2017).

Sources of Power Generation in Bangladesh

- **Natural Gas:** Natural-gas fired power generation (89.22%) is a major basis of power segment in Bangladesh.
- **Coal:** Contribution of coal is around 3% of the total composition.
- **Hydroelectricity:** There is only one hydroelectric power source in Bangladesh. Power generation by this hydroelectric source is 2.5 % of total power consumption of the country.
- **Solar Energy:** Bangladesh has managed to apply a significant number of Solar Home System (SHS) with over three million solar panels.

Projected Power Demand: Power demand of Bangladesh is likely to reach at 34,000 MW by 2030. To meet up the additional demand, Government of Bangladesh is planning to increase power generation capacity beyond the projected demand by 2030 (Azad A. K., 2017).

Ongoing Projects

- **Liquefied Natural Gas (LNG):** The government of Bangladesh has started to construct a floating LNG terminal at Maheshkhali. It will have a capacity to handle five million metric tons (MT) of LNG per year (Azad A. K., 2017).

- **Ruppur Nuclear Power Plants:** Construction works of two nuclear power plants, each of 1000 MW capacity is going on at Ruppur, Pabna. The plants are scheduled to be commissioned by 2023.

- **Renewable Energy (RE) Scenario in Bangladesh:** Different government, and non-government organizations like Infrastructure Development Company Limited (IDCOL), Grameen Shaki, Rahim-Afrooz and many more have been working separately or jointly to facilitate Renewable Energy Technology (RET).

The present renewable energy state of Bangladesh is as follows:

Table 1: Present Renewable Energy State in Bangladesh

Technology	Off-Grid	On-Grid	Total
Solar PV	193MW	1 MW	194 MW
Wind	2 MW	0.9 MW	2.9 MW
Hydro	-	230 MW	230 MW
Biogas to Electricity	5 MW	-	5 MW
Biomass to Electricity	1 MW		1 MW
Total	200 MW	232 MW	433 MW

Source: Bangladesh 2017

Waste to Energy (WTE) Technology

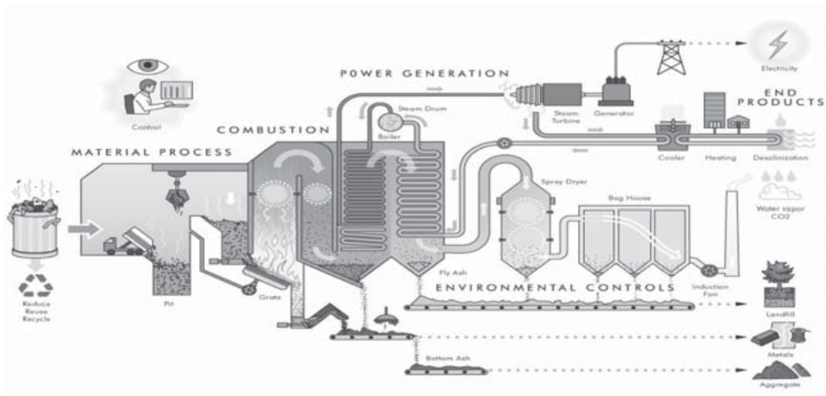
WTE Process

WTE is a process that provides generation of energy in the form of electricity or heat. WTE provides sustainable disposal of MSW. It is a robust and helpful energy generation options to reduce CO_2 emissions and other harmful gases. WTE technology is used extensively in European Countries and other developed nations. Yet, in Germany, Mechanical Biological Treatment (MBT) getting is more popular. Norway is using landfill gases a transport fuel. Generally, in Europe 50 million tons of garbage per year is converted into precious energy through WTE technology and still 50% of municipal solid waste becomes landfills. (Francesca, 2017).

WTE plant is feasible based on waste segregation, composition and collection. At present, both thermal and biological WTE plants exist. It depends on degree of operation, modality and investment. In UK, Anaerobic digestion is becoming popular. However, in land scarce country of Asia like Singapore, Japan and Taiwan Incineration is very common. In India, anaerobic digestion, Refuse Derived Fuel (RDF) is practiced. (Yusuf B. T., 2017). In Japan, 80% of MSW is treated by incineration to generate power generated from waste derived from biomass and thermal use of MSW as renewable energy is found in Tokyo. Conversely, in Europe anaerobic digestion is also getting popular. (Francesca, 2017). In China, the government is depending on all forms of solid waste management including WTE, to minimize and reduce waste management burdens and more than 50% of total wastes being disposed by anaerobic land filling.

Incineration: It is a waste handling procedure that involves the burning of waste materials. Incineration converts the waste materials into residual ash, flue gas and heat. It is also kwon as direct burning where the ash is mostly produced by the elements of the wastes, and may take the form of solid inflammation or particulates taken by the flue gas. The flue gases must be cleared of gaseous and particulate pollutants before they are dispersed into the atmosphere. In some cases, the heat generated by incineration can be used to generate electric power.

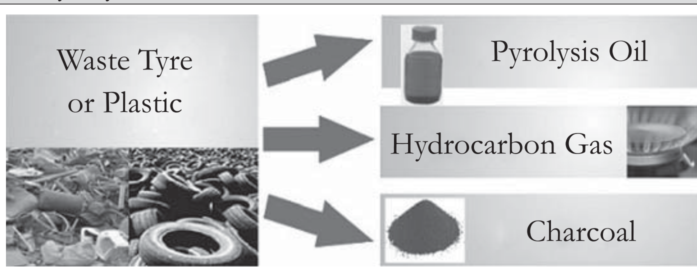
Figure 1: Conventional Diagram of an Incinerator WTE Plant



Source: JAHS Chem

Pyrolysis: It is a thermal degradation of wastes in the absence of air and produces a syngas which is then used to generate energy. Pyrolysis is the chemical reaction of molecules that involves molecular breakdown of larger particles into smaller molecules bythe presence of heat. Pyrolysis is also known as thermal cracking, thermolysis, de-polymerization, etc.

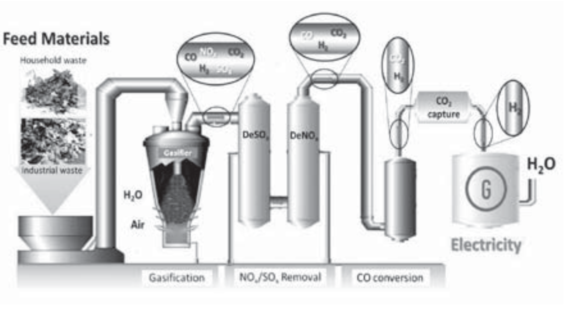
Figure 2: Pyrolysis Process



Source: JAHS Chem

Gasification. Gasification encompasses a partial oxidation of wastes, and produces a syngas which is then used to produce energy. It converts organic or fossil fuel based carbon containing materials into carbon monoxide, hydrogen and carbon dioxide. This is achieved by chemical reaction of the materials at high temperatures (>700 °C), without combustion, under a controlled amount of oxygen and / or steam.

Figure 3: Gasification Process



Source: www.WTE.wikipedia

Bio-Chemical Process

This process is based on breakdown of organic substances of wastes by microbial action to generate methane gas and alcohol. This process is favored for the wastes of even high percentage of organic, bio-degradable matter and high level of moisture/water content to help in microbial activity.

Comparison of the WTE Technologies: A brief description of the available technologies is provided below:

- **Incineration**
  - Burning is suitable for the raw MSW with moisture less than 50%.
  - Enough oxygen is required to fully oxidize the waste materials.
  - Burning temperatures are in excess of 8500 C.
  - Waste is converted into CO_2 and water contents into toxic substances (i.e. dioxin, furans).
  - Fly ash air pollution control (APC) system of residue particulates is required.

- Needs high calorific value waste to keep combustion process to continue, or else requires high energy for maintaining adequate temperatures.

- **Pyrolysis**
  - Observance of thermal dissimilation of organic materials through the use of indirect, external source of heat.
  - Temperature varies between 300 to 850^{O} C are maintained for several seconds in the absence of oxygen.
  - Product is char, oil and syngas composed primarily of O_2, CO, CO_2, CH_4 and hydrocarbons.
  - Syngas can be used for energy manufacture or proportions of it can be condensed to produce oils and waxes.
  - Syngas typically has net calorific value (NCV) of 10 to 20 MJ / m3.

- **Gasification**
  - It is considered as combination of pyrolysis and combustion (incineration) as it involves partial oxidation.
  - It is an exothermic process.
  - Oxygen is added but at low amount not sufficient for full oxidation and full combustion.
  - Temperature generally above 850^{O} C and below 3000^{O} C.
  - Main products of syngas are Hydrogen, Hydrocarbon, and synthetic gas with net calorific value of 4 to 10 MJ / m3.
  - Other product is solid residue of non-combustible materials (ash) which contains low level of carbon.

- **Anaerobic Digestion (AD)**
  - Familiar skillfulness for treatment of sorted MSW.
  - Biological conversion of biodegradable untreated materials in the absence of oxygen at temperatures between 55 to 75^{O}C (most useful temperature range).

- Digestion is used primarily to diminish quantity of wastes for disposal.
- Methane gas generated to be used for electricity / energy generation or fuel for cooking, transport fuel that is substitute of CNG.

Waste Management by 3R Strategy: It is never possible to remain absolutely free from generation of waste. Since the early society, human being has been using resources of earth fort the support of life and disposing the wastes. The process of reducing, reusing and recycling of resources and products is commonly known as "3Rs."

- Reducing means selection of items with care to reduce the amount of waste generated.
- Reusing involves the repeated use of an item or parts of items which still have functional aspects. It maximizes the practical use of an item.
- Recycling means the use of waste itself as resources by conversion of the recyclable waste into other items thermo-chemical process. The minimization efficiency of wastes is affirmed to be better achieved by following 3Rs in a hierarchical order- Reduce Reuse and Recycle.

Benefits of 3Rs: The benefits of 3Rs are many for the society and environment:

- Reduction of Green House Gas (GHG) emission.
- Techniques adaptation, employment and job creation.
- Production of organic gas from bio-degradable wastes.
- Attracts in foreign direct investment by emission reduction facility and other environmental benefits.
- Enriches soil condition and can provide a healthy environment to the people of the cities.

State of Municipal Solid Waste in Dhaka City Corporations (DCC)

Waste Scenario of Dhaka City: As per the joint report of Japan International Cooperation Agency (JICA) and office of Waste Concern Consultancy (WCC) in Dhaka, about 75% solid wastes are coming from residential sector, 20% from commercial sector, 3% from the institutional sector and rest from other sectors (Hasan, 2015). The average waste generation rate from domestic source proved to be 0.46 kg/cap/day. High moisture content and low calorific value characterized the solid waste properties in Dhaka City is observed (Dhaka City Corporation, Japan International Cooperation Agency, 2005).

Composition of Waste: Field Survey has been carried out and data has been collected from the office of Waste Concern at Banani. The percentage wise MSW composition has been found as : House hold waste is Food/Vegetable -78%, Paper 5%, Polythene 3%, Plastic/Rubber -2.5%, Wood 1.5%, leather 1.5%, Textile -3.5%, Metal -1%, Glass-1%, others-3% (Maksud, 2014).

Recycling of MSW in Dhaka City: Recycling of solid waste is composed of three principal groups: namely, collectors, buyers and factory/shops for recycled products.

Table 2: Recyclable Wastes and Recycled Products in Dhaka City

Types of Wastes	Recyclable Wastes	Recycled Products
Plastic	Mug, pipe, old sandal, doll, plastic bucket, etc	Shoes, sandal, boots, bucket, mug, bottle, lunch box, etc.
Paper	Newspaper, cardboard, duplex board etc	Media paper, simplex board, cement packing bag etc.
Glass	Any kind of broken glass	Glass sheet, bottle, lamp shade, etc.
Metal	Iron tin, iron pieces	Steel rods, nuts, bolts, pumps, etc.
Others	leather, rubber, bone etc	Shoes, Rubber pad, Packing material etc.

Source: DCC, JICA 2005

Table 3: Percentage wise Recyclable Wastes and Recycled Products		
Category	Contents	Percentage of Recycling
Major recyclables	plastics, paper, glass, metal	80%
Others	leather, rubber, bone etc	20%
Source: Dhaka City Corporation, Japan International Cooperation Agency, 2005		

Probability of Selection of WTE Plants

Establishment Conventional WTE Plants in Bangladesh

Recently, initiative was taken to set up a WTE plant with a capacity of 50 MW at Keranigonj Thana. After a detail survey and analysis, the investors refrained from setting up that WTE plant and ultimately the project not yet implemented. The main reasons were: heterogeneous mixture of waste stream, high moisture contents, non-steady flow of wastes in the area etc. Similarly other WTE projects also failed for similar reasons. Thatis possibly, why till now, no WTE plant could be set up in Bangladesh despite strong desire of the government (Haq, 2015).

Evaluation of Selected WTE Technology: Conversion of waste material to energy can proceed along two major pathways-thermo-chemical and bio-chemical. Thermo-chemical conversion, characterized by higher temperature and conversion rates, is best suited for lower moisture feedstock and is generally less selective for products. On the other hand, biochemical technologies (e.g. Anaerobic Digestion) are more suitable for wet wastes which are rich in organic matter and it can even treat the wastes with high moisture contents (Shahalam & Baki, 2005).

Advantages of Anaerobic Digestion

- **Economic Advantages**
  - With minimum time, moving, handling and processing of manure is possible.
  - Income generation can be achieved from the processing of waste (tipping fees), sale of organic fertilizer.
  - Anaerobic digestion plant increases self-sufficiency.
  - Transformation of the liquid manure and the manure into a fertilizer, more easily assimilated by the plants, with reduction in the odors and the disease-causing agents.
  - Insect elimination at the storage pit.
- **Environmental Benefits**
  - Biogas resulting by anaerobic digestion is a source of renewable energy because it replaces fossil energy.
  - Reduction of pollution due to nitrogen stripping.
  - Sustainable management of organic waste.
  - Elimination of malodorous compounds.
  - Reduction of pathogens.
  - Production of sanitized compost.
  - Decrease in Green House Gas (GHG) emission.
  - Reduced dependence on inorganic fertilizers by capture and reuse of nutrients.
  - Promotion of carbon seizure
  - Beneficial reuse of recycled water
  - Protection of groundwater and surface water resources.
  - Improved social acceptance.
- **Technical Advantages**
  - Anaerobic digestion is a net energy-producing process.
  - A biogas facility generates high-quality renewable fuel.

- Surplus energy as electricity and heat is produced during anaerobic digestion
- Anaerobic digestion reduces reliance on energy imports.
- Such a facility contributes to decentralized, distributed power systems.
- Biogas is a rich source of electricity, heat, and transportation fuel.

Survey Data and Discussion

Primary Data: A detailed survey was carried out in the accommodation area of the author at Dhaka Cantonment. The area comprises with 270 houses with 4-5 persons in each houses. Out of that 30 houses were selected for the survey. Per capita waste generation was found to be .51 KG / person and detail is shown below:

Table 4: Primary Survey Data on Waste

Type of Wastes	Amount in KG
Green Wastes	65.50
Paper	5.50
Plastic/Rubber/Polythene	6.00
Glass	6.50
Metal	7.00
Others	5.50
Amount wastes from 30 houses/ Day	97.50 KG

Source: Primary Data- 2017

Price of the Recyclables: The cost of the recyclables varies according their types/categories. During the survey it was found that the cost of each category of recyclable wastes was as follows:

Table 5: Price of Recycle Items		
Category of Wastes	Unit Price (Taka/KG)	Remarks
Plastic/Rubber	8- 10	Price Variation depends on the composition
Glass	3-4	Do
Metal	20-25	Do
Paper	15-18	Do
Plastics / Polythene	5 -6	Do
Boxes of wood /tins	10-12	Do
Source: Primary Survey by Author 2017		

Moisture Contents and Calorific Values of MSW: Average composition of moisture content as found from secondary data is shown in the following table:

Table 6: Moisture Content of MSW		
Types of Wastes	Moisture Contents (%)	Calorific Value MJ/Kg
Food/Vegetable Wastes	64	19.7
Paper	07	16.8
Plastic/Rubber	02	35
Polythene	04	35
Metal	1	-
Glass	1	-
Wood	12	20
Leather	07	14.4
Textiles	15	15
Others	40	15
Source: Rouf, 2011		

However, recyclable wastes like plastic, polythene, rubber, tires etc can be processed in a pyrolysis plant as mentioned earlier.

Analysis of Electricity Generation

There are certain tests by which, MSW can be analyzed in the laboratory e.g. proximity analysis, flash point, pour point by dry/wet basis. After completing necessary tests/analysis, electricity generation can be ascertained using certain formula. In this paper Dulong`s formula is used to ascertain the amount of electricity that can be generated from MSW through a sample test and percentage wise carbon, hydrogen, oxygen, nitrogen and sulfur in different constituents of the waste are shown below.

Table 7: Ultimate Analysis of "Dry Stream" Components of MSW

Components MSW	Chemical Comments as per percentage				
Types of MSW	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur
Food/Vegetables	46.5	4.3	42.8	2.4	.1
Paper	43.5	6.0	44.0	.3	.2
Polythene	80.0	14.3	3.2	2.0	.1
Plastic/Rubber	60.0	7.2	22.8	-	-
Wood	49.0	6.0	42.7	.2	.1
Textile	55.0	6.6	31.2	4.6	.2
Leather	69.0	9.0	5.8	6.0	.2
Other	26.3	3.0	2.0	.5	.2
Total Weight in %	.515 %	0.0792 %	.4057 %	.02	,01
Source: Rouf, 2011					

The energy content of the waste can be estimated using the modified Dulong Equation or the heating value of individual waste components. Delong's Equation for MSW Analysis:

Heat (KJ/kg) = 337C + 1428 (H – O/8)+7N + 9S

Where,
C = Carbon (%)
H = Hydrogen (%)
O = Oxygen (%)

N= Nitrogen (%)

S = Sulfur (%)

Heat (KJ/kg) $= 337 \times 0.515 + 1428\,(0.0792 - 0.4057/8) + 7\text{x}.02 + 9 \times 0.01$

$= 214.47$ KJ/kg

Now question may arise how much energy can be extracted from solid wastes of DSCC and DNCC. Theoretically, from 1000 tons of waste 7 to 10 MW electricity can be genera rated. As DNCC and DSCC are generating around 7000 to 8000 tons wastes, therefore total amount of electricity may be around 70 to 100 MW (Yusuf B. T., 2017).

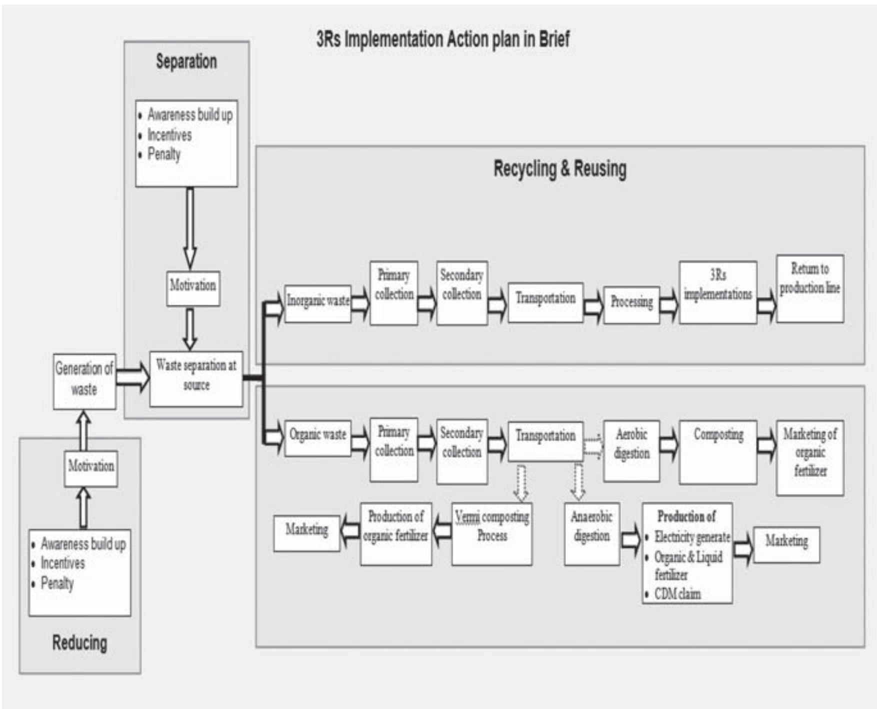
Proposed Ways to Overcome: By strict observance of 3R strategy, we can overcome the burden of MSW and we can convert it into resource too. The pathways are described below:

Figure 4: Flow Chart of Proposed 3R Concept.

Source: Chodhury, Mohammad, Haque & Hossain, 2014

Pathways of Implementation Plan of 3R: Implication plan of 3R in a diagrammatic form is shown below:

Figure 5: Flow Chart of MSW Management plan



Source: Chodhury, Mohammad, Haque & Hossain, 2014

Recommendations

Integrated Solid Waste Management: For effective management and converting wastes into resource an integrated waste management to be implemented for the country. For that we can go for certain planning/ execution with different time frame as bellow:

- **Short Term Planning/Execution**
    - Implementation of Community Based Biogas Plant of small and medium size in the green markets areas, specious/ planned residential areas etc.

- Composting of MSW as bio-fertilizer for roof top nursery, where community based Biogas Plant is difficult.
- Government should make effort to buy bio-fertilizer from the stockholders to promote green technology.
- Introducing Waste Management study in the text books of Schools and College going students.
- Implementation of waste management activities by 3R Strategy can make awareness and effective use of MSW.
- Establishment of biogas filling station adjacent to the CNG Station to augment the CNG pump.
- Promotion of recycling of both organic and inorganic wastes to reduce the cost of collection, transportation and disposal of waste.
- Arrangement of orientation training for the waste pickers for small duration especially on health and hygiene aspect.

- **Mid-Term Planning/Execution**
  - Establishment of Research & Development Centre under Ministry of Environment and Power and Energy.
  - Establishment of WTE Facilities near the landfill sites.
- **Long Term Planning/Execution**
  - Establishment of Full-fledged WTE Plants and Biogas Filling Station from MSW.

Conclusion

The waste that is generated finding their way into land and water bodies without proper treatment creates environment pollution. Openly dumped wastes also emit greenhouse gases like methane, carbon dioxide and add to air pollution. Again waste can be a resource due to its latent heat content resulting in energy generation. Varieties of options can be adopted through WTE facility, e.g., electricity, cooling, steam for heating.

Different technologies are evaluated in this paper with a focus on different parameters of energy conversion systems. The study shows potential of using waste for the production of biogas as transport fuels and thermal pyrolysis technologies are interesting for recyclable wastes e.g. plastics, polythene, rubber etc.

It seems that the use of biogas to support fuel supply can be easily managed for Bangladesh. We can also extract manure by this process from organic waste through anaerobic digestion. Anaerobic digestion is particularly is suited to wet organic material and it is commonly used for house hold wastes including waste papers, grass clippings, leftover food, and animal waste. Anaerobic digestion provides a variety of benefits which may be classified into three groups: environment, economic and energy.

General people of our country are not at all aware of the consequence of waste dumped as land- fillings. As we cannot avoid the waste, effort has to be continued to make best use of it with waste minimization strategy e.g. 3R Strategy. Once we all will be motivated then wastes will no longer be a problematic issue. We must seek for the action plan as how best we get benefits out of the MSW. It's only possible if we can technically manage it as a source of energy not considering it as burden. Technical Waste Management Plan for extraction of energy can lead to a substantial reduction in the overall waste quantities requiring final disposal.

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