Feasibility Study of Waste to Energy and Power Generation of Dhaka City

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Supervised By
Professor Dr. Saiful Huque
Director
Institute of Energy
University of Dhaka

Submitted By
Md. Sohel Rana
Exam Roll: 506
Registration No: HA-224
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Abstract

Bangladesh is a developing country with high population density and rich in natural resource. People of Bangladesh are gradually shifting from agricultural to a more service oriented economy. This means for millions of Bangladeshi now have the ability to consume an enormous variety of goods and services that were previously either unavailable or unaffordable. From small electronic items, such as cell phones, to large consumer goods like refrigerators and cars, Bangladeshi consumption has been steadily increasing and shows no signs of snoozing anytime soon. The flip side of this consumption boom is that the amount of waste generated has and will continue to increase correspondingly. Dhaka is the capital city of the country; people from different part of the country migrate for livelihood. So the City's population rises rapidly and current population is about 14.6 million and per capita waste generation is about 0.42 kg per day. Within 2030 it will be 0.73 kg per day. Collection rate of waste is 65% includes recycled 15% of total waste generated in Dhaka.

Given its increasing population trend, rapid expansion of urban areas, and scarcity of land due to very dense population, Dhaka needs a solution to its burgeoning solid waste management problem that will be sustainable, cost effective, and minimizes public health, ecological, and climate change impacts. Waste-to-energy (WtE) is a strategy that is effective, environmentally sound, and economically beneficial.

There are many technologies for converting waste into energy. For example direct combustion, gasification, pyrolysis, composting, plasma arc, refused derived fuel etc. For Dhaka city composting (i.e. anaerobic digestion) will be a convenient technology because waste generated in Dhaka city is commonly organic material (vegetables, food, paper etc.) which contribute 65% to the total waste and has high moisture content (50%-60%). The main constraint for waste to energy facility is high initial investment. However in this study the initial investment assumes $50 million base on the different WtE facility around the world and the land will lend from government at the dump site and payback period will be 7.1 years at the end of the project total revenue earned by the project Tk 247.87 crore.

CONTENTS

List of Tables

List of Figures

List of Boxes

Appendices

ABBRVIATION

WtE= Waste to Energy

MSW= Municipal Solid Waste

CFB= Circulating Fluidized Bed

BFB= Bubbling Fluid Bed

DSCC= Dhaka South City Corporation

DNCC= Dhaka North City Corporation

RDF= Refused Derived Fuel

DPDC= Dhaka Power Distribution Company Limited

CDM= Clean Development Mechanism

CER= Certified Emission Reduction

VER= Voluntary Emission Reduction

NPV= Net Present Value

IRR= Internal Rate of Return

Supervisor's Declaration

The MS level thesis report titled by "Feasibility Study of Waste to Energy and Power Generation in Dhaka" has been carried out and thesis was prepared under my supervision. Herby I confirm that, to the best of my knowledge the thesis represents the original research work of the candidate; the contribution made to the research by me, by others of the University was consistent with normal supervisory practice, and external contributions to the research are acknowledged.

I believe the thesis to be in a suitable presentational form and is ready for examination.

____

Prof. Dr. Saiful Huque

Director

Institute of Energy

University of Dhaka

Date: ____________

Candidate's Declaration

I confirm that this thesis represents my own work; the contribution of any supervisors and others to the research and to the thesis was consistent with normal supervisory practice. External contributions to the research are acknowledged.

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Md. Sohel Rana

Exam Roll: 506

Registration No: HA-224

Session: 2015-2015

Institute of Energy

University of Dhaka

Date: _______________

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CHAPTER 1

INTRODUCTION, OBJECTIVE AND METHODOLOGY

1.1Introduction

Waste is produced by different human activities, like industrialization, urbanization, improving living standards etc. Urban population and industrialization have been increasing rapidly and these are creating a serious hassle on our natural resources, which is a big challenge for sustainable development. Disorganized management and dumping of waste is a noticeable cause of ruin of the environment in most cities.

Dhaka, the capital of Bangladesh, and also its largest city, is currently facing a solid waste management crisis. Municipal solid wastes (MSW) are generated at unsustainable levels leading to a massive shortage of space for disposal. Due to lack of motivation, awareness, proper selection of technology and adequate financial support, a considerable portion of wastes, 40-60%, are not properly stored, collected or disposed in the designated places for ultimate disposal [31]

A municipal corporation of Dhaka city is trying to manage this problem but they are unable to control waste management. Each day Dhaka produces 3000 tons of household waste (Chowdhury. T. Ahmed & Afza. S. Rownok, 2006 : 1).On the other hand Dhaka city also produce more waste in different ways , like- hospital, small industry , tannery and others heavy industry.

The Clean Dhaka Master Plan budgeted USD 44 million for development and capital costs, and USD 7.3 million per year for operations and maintenance (estimate for 2015). [14,15] The Japanese government funded much of Dhaka’s waste management fleet—the Environmental Grant Aid Program donated 100 vehicles, valued at USD 5 million.16 The Japanese government also cancelled the debt incurred by Bangladesh for the purchase of 27 container carriers through the Debt Cancellation Fund. The Debt Cancellation Fund also financed the construction of the

Matuail and Amin Bazar landfills. The Japan International Cooperation Agency provided technical support for designing and implementing the program.

Dhaka is building on its success by initiating a waste-to-energy project on a “build, own, operate, transfer” basis. A private firm will build an incineration plant and an anaerobic digestion plant on two landfill sites in Dhaka. The power plants will initially have a generating capacity of 10 megawatts and will process 1,000 tons of waste per day, with plans to scale up each facility to 50 megawatts at a processing rate of 5,000 tons of waste per day within three years. [17]

Anaerobic digestion technology uses microorganisms to consume organic waste, [1] producing a clean source of methane gas with limited contributions to global warming.[2] This technology is widely used throughout the world as a waste management tool and a source of local, renewable energy. Currently, Germany has approximately 7,000 large-scale anaerobic digestion centers, Nepal has 50,000 anaerobic digestion units, and China has 8 million anaerobic digesters, all of which provide clean energy while disposing of waste. [3]

MSW incineration is found at the most advanced level of the waste disposal/treatment hierarchy: indiscriminate dumping, controlled dumping, landfilling, sanitary landfilling, and mechanical treatment (for example, composting and incineration). Deciding to incinerate waste instead of, for instance, dumping it, takes careful consideration of the criteria for success. In the mid-1980s, a number of Eastern European and Asian cities jumped directly from simple dumping to MSW incineration.

1.2 Objective

This report focuses on the use of waste-to-energy technology to mitigate the solid waste management problem in Dhaka. In several other nations waste-to-energy has been shown to be an effective, environmentally sound, and economically beneficial means for processing municipal solid wastes and recovering energy. Dhaka was selected because it is the largest city in Bangladesh, with growing population and consumption trends, and has limited availability of space for waste disposal. Besides, Dhaka's current waste disposal options are superfluous, overburdened, and enhanced with residential areas approaching open dumps and insufficient collection and transportation mechanisms. This report involves the technical, economic and environmental issues of waste to energy facility.

1.3 Methodology

The study uses both primary and secondary data. Primary data were collected from the waste management department of City Corporations of Dhaka and personal interview cleaners and community service provider of Dhaka City. Secondary data were collected from different journals, dailies, official reports, NGO publications and various wave sites.

CHAPTER 2

AN OVERVIEW OF SOLID WASTE MANAGEMENT IN BANGLADESH.

2.1 Background

Bangladesh is a developing country. Increasing prosperity and standard of livings of millions of people will increase consumption of energy and consumer goods. Concurrently, this growth will likely put a strain on the environment and on the availability of natural resources. Bangladesh has 160.9 million populations which is 2.34% of total populations of the world (worldometer-2015) and only 130,170 km^2 surface areas (World Bank report-2015).

In Bangladesh, as in other developing countries, solid waste management and sanitation are the least prioritized public services. These services are necessary for preventing the spread of diseases, promoting general well-being, and improving the standard of living. However, due to lack of knowledge about the linkages of waste management to public health and environmental protection, unwillingness on the part of the local officials to take necessary action, and a lack of funds for implementing and maintaining best practices, waste management has not received the attention it requires. This chapter provides an overview of waste generation, collection, disposal, and composition for main cities of Bangladesh. Where appropriate, comparisons are made to other countries to show whether Bangladesh has similar solid waste management practices or if it deviates from the norm. Since waste-to-energy is both an effective waste reduction strategy as well as a source of electricity and/or heat, the chapter also provides an overview of the electricity and renewable energy sectors in Bangladesh.

2.2 MSW Generation in Bangladesh

The amount of waste generated in a region or country is directly proportional to economic growth and consumption levels. On a per capita basis, low-income countries generally consume fewer goods and hence generate less waste than developed countries. Low-income countries also generally use less recyclable materials, especially in packaging.

The total solid waste management involves 3 departments namely conservancy, transport and mechanical engineering. A number of studies were undertaken from time to time by the World Bank, Bangladesh Centre for Advanced Studies (BCAS), Japan International Cooperation Agency and DCC itself for assessment of waste generation. JICA has prepared "Clean Dhaka Master Plan" that will address solid waste management of Dhaka city. Following table shows the growth rate of solid waste in Dhaka city from 1991 to 2025.The growth rate of waste is increasing dangerously. [10]

Table-1: Growth of Solid Waste Generation in Urban Cities of Bangladesh

Year	Population	Urban population (% total)	Waste production rate (kg/cap/day)	Total waste production (ton/day
1991	20872204	20.15	0.49	9873.5
2001	28808477	23.39	0.5	11,695
2004	32765152	25.08	0.5	16,382
2025	78440000	40.0	0.6	47,064

(Source- ADBI and ADB 2000 & Zurbrugg 2002)

Solid waste generation in urban areas is increasing with the growth of population (Table 1). As reported by Alamgir and Ahsan (2007), a total of 7690 tons of municipal solid waste (MSW) is generated daily from the six major cities of Bangladesh, namely, Dhaka, Chittagong, Khulna, Rajshahi, Barisal and Sylhet, while the Dhaka city contributes 69% of the total waste stream

Table 2. Generation of different categories of wastes in six major cities of Bangladesh [31]

Waste category	Per capita waste generation						
	DCC	CCC	KCC	RCC	BCC	SCC	All Waste Stream
Organic matter	3647	968	410	121	105	158	5409
Paper	571	130	49	15	9	18	792
Plastic	230	37	16	7	5	8	303
Textile & wood	118	28	7	3	2	5	163
Leather & rubber	75	13	3	2	1	1	95
Metal	107	29	6	2	2	2	148
Glass	37	13	3	2	1	2	58
Others	555	97	26	18	5	21	722
Total	5340	1315	520	170	130	215	7690
Population	11.00	3.65	1.50	0.45	0.40	0.50	
Per capita (kg/da	0.485	0.360	0.347	0.378	0.325	0.430	0.387

(Table 2). The composition of the entire waste stream is about 74.4% organic matter, 9.1%paper, 3.5% plastic, 1.9% textile and wood, 0.8% leather and rubber, 1.5% metal, 0.8% glass and 8%other wastes.[13] The factors that contribute to waste composition are population density, life styles, economic conditions, fruit seasons, climate, recycling, and waste management program.

Table- 3. Waste Generation Rate (WGR) and Total Waste Generation (TWG) in Dhaka city and other cities, 2004.

City/Town	WGR (kg/cap/day	No. of City/ Town	Total Population	Population (2005)	TWG (Ton/day)		Average TWG
					Dry season	Wet season	
Dhaka	0.56	1	6,116,731	6728404	3,767.91	5,501.14	4,634.52
Chittagong	0.48	1	2,383,725	2,622,098	1,258.61	1,837.57	1,548.09
Rajshahi	0.3	1	425,798	468,378	140.51	205.15	172.83
Khulna	0. 27	1	879,422	967,365	261.19	381.34	321 26
Barisal	0.25	1	397,281	437,009	109.25	159.51	134.38
Sylet	0.3	1	351,724	386,896	116.07	169.46	142.76
Pourashava	0 25	298	13,831,187	15,214,306	116.07	5,553.22	4,678.40
Other Urban Centers	0.15	218	8,379,674	9,217,617	1383.64	2018.68	1700.65

Table -3 shows the urban waste generation scenario in Bangladesh in 2004. It shows waste generation is proportional to population.[11]

2.2.1 An overview of MSW Generation for Dhaka city:

Dhaka is the capital, most populous city of Bangladesh and 9th mega city of world with 14.4 million people (world population review-2013) and a density of 19,447 people per square mile (50,368/square mile). Dhaka is growing up in unplanned way and faces trouble with its waste disposal. As Dhaka is financial center of Bangladesh many rural people migrate to Dhaka. Dhaka is fastest growing city of the world (CBSNEWS) A few of the elder giants New York, Tokyo, Paris, London, Beijing, New Dilly, Mumbai grew huge under the influence of forces that helped give birth to modernity itself: the rise of nation states, manufacturing and mass domestic markets. The climate is tropical as in the rest of Bangladesh; for most of the year it is warm with bright sunshine, but during the monsoon season there is heavy rainfall. During the winter months (November to March) it is cool and pleasant. Typical summer temperatures range between 30 to 37 degrees Celsius while in the winter it is a lot milder, ranging between 10 to 20 degrees. Annual rainfall is about 250cm and humidity around 80% of the total population in the city about 69.2 percent is literate. Among the workforce more than 10 percent are unemployed. Another 10 percent are employed below their qualifications. Economic indicators show that the per capita income of the people of Bangladesh is nearly $1,466 . GDP is US$119.1 billion in2015 (World Bank). Around 35 percent of people live below the poverty line in Dhaka. Half of that figure lives in slums and squatter settlements. Within a decade, the slum population has risen to about 3 million. Access to water supply, sanitation, solid waste management, and other civic services is extremely limited.

In Dhaka city, the capital of Bangladesh alone, there are a total of 4966 slums and about 3.4 million people live in those slums, which is equivalent to nearly 40% of the total population of Dhaka city (CUS, 2005). In slums the socio-environmental condition is execrable. Population density is far higher than the other parts of the city. Waste is produced by different human activities, like industrialization, urbanization, improving living standards etc. Urban population and industrialization have been increasing rapidly and these are creating a serious hassle on our natural resources, which is a big challenge for sustainable development.

This chapter first gives an overview of local governance in Dhaka, followed by a detailed description of the solid waste management sector in Dhaka. Where applicable, maps and calculations of future rates of increase are presented to give a complete picture of solid waste management.

2.2.2 Local Governance in Dhaka

Dhaka city is divided into two corporations in 2012 for better governance. Its north part named as Dhaka North city Corporation possessed area of 75 square kilometers while south part is Dhaka South City Corporation of 42 square kilometers and other part remain outside of the corporation. As with other municipalities in Bangladesh both of corporations are responsible for the city’s water supply, public health, education, solid waste management, and environmental monitoring. Dhaka North city Corporation comprises 36 wards while Dhaka South City Corporation consists of 56 wards. . DSCC and DNCC separated its area into 10 zones for supervision of solid waste production.

2.2.3Solid waste management in Dhaka city

Dhaka City is now seizing with the troubles of sky-scraping volumes of wastes. But, these troubles have also afforded a window of prospects for city to find solution. The community and all the sectors have to involve their innovative technologies and disposal methods and concerning behavior changes and awareness rising. A healthy planned waste management process will not only help of pledge a cleaner atmosphere but it also cost-effective for citizens.

2.2.3.1Formal Sector:

Table-4 shows the basic information of solid waste management in Dhaka City.(Data Source DNCC-2012)

Items	DNCC	DSCC
Geographical area (square kilometer)	75	42
Waste generation amount , ton (2012-June)	2186	1938
Waste collection amount, ton (2012-June)	1100	1400
Waste Disposal Site	Aminbazaar	Matuail
Area of waste Disposal Site (hectare)	20	40
Ward waste management offices	5 + 2	10
Waste collection vehicles	115	235
Numbers of Waste carrying containers	180	270
Waste Management Department persons	180	352
Number Waste Management Drivers	108	183
Number of cleaners	2661	5300

City corporations are responsible for Solid Waste Management (SWM).Formal system‟ is based on the conventional system of collection-transportation disposal of waste carried out by the local authorities. In this system the concept of recycling is absent.

2.2.3.2 Informal sector:

Community Initiative‟ that is based on primary solid waste collection by CBOs and NGOs, Finally, "Informal System‟ represented by the large informal labor force involved in the solid waste recycling trade chain. Partnership between these three systems is needed to promote effective solid waste management system in the country. 120000 urban poor people from the informal sector are involved in recycling trade.

2.3. Current MSW Generation in Dhaka

In recent year any research does not conduct to survey about the generation of waste in Dhaka city. According to the information from DSCC's waste manage department about 3500 ton/day (estimated) waste is generated. And DNCC claim that Dhaka generates about 3200 ton/day in north part of the city, waste rate per person per day is 0.42 kg.

2.3.1 Future MSW Generation in Dhaka

Table-5 shows the projected future generation of MSW in Dhaka using Equation 1. It uses as base year 2007, a population growth rate for the city of 3.6 percent annually estimated by the UN Department of Economic and Social Affairs, and a national per capita MSW growth rate of 1.8%per year. Hence, the figures in Table are meant to give an idea of the approximate increasing MSW generation in Dhaka over time.

Box no. 1

The growth of waste generation can be calculated by the following equation

*Domestic waste = PP * (1 + GRpp) ^n* wc * (1 + GRKF)^n*

where:

PP = present population

GRpp = population growth rate

wc = 2007 capita waste generation

GRKF = growth rate of waste generation

n = number of year

Table-5: Estimated growth rate of waste generation in Dhaka.

Year	Projected population (millions)	Projected waste generation (tpd)	Per capita waste generation (kg/prson/day)
2007	11.00	5340	0.485
2015	14.6	8165.72	0.56
2020	17.42	10654.48	0.62
2025	20.79	13901.77	0.67
2030	24.81	18138.78	0.73

2.3.2 MSW Collection in Dhaka

Maximum people are not concerned about waste management. This is an important cause of mismanagement of waste. In Dhaka city household waste are thrown in the roadside and open areas. Clinical wastes also are thrown in the open dustbin. These types of human practice create huge environmental pollution. The sources of solid wastages are garbage, refuse, sludge and discarded material and the wastages are produce by industry, hospital, or household community activities. (DU Journal, Office of land quality-2000). Waste management is a tactic used to waste collection largely from different sources, including recycling and re-use of materials.

Municipal solid waste is collected by street sweeping and community collection. Community collection is mainly conducted by:

1. House-to-house collection, where residential garbage is collected by apartment buildings in private bins and then offloaded onto Corporation or private vehicles which is modified van that make routine stops along particular routes; and

2. Communal collection, where residents bring their garbage to collection points such as round bins, sheds, and stationary containers, which are placed at various locations around the city.

2.3.3 Transportation of MSW

Primary wastage are collected by modified rickshaw from house and street sweeping and transported to specified site where bins are settled by City Corporation. About 350 vehicles transport waste from the various point of the city to dump station. A community based waste collection is driven accompanied with both city corporations. Mainly modified rickshaws are used for waste collection from the house to house by community.

2.4 Characteristics of MSW in Dhaka

2.4.1 Typical composition of MSW in Dhaka

Composition of solid waste depends upon a number of factors, such as food habit, cultural tradition, socio-economic and climatic condition. Composition of solid waste varies not only from city to city but even within the same city itself and also seasonally

The MSW collected in Dhaka consists of wet organics (primarily food waste), dry organics (straw, wood), inert materials (sand, soil, earth), and recyclables (plastics, metal, glass, paper).

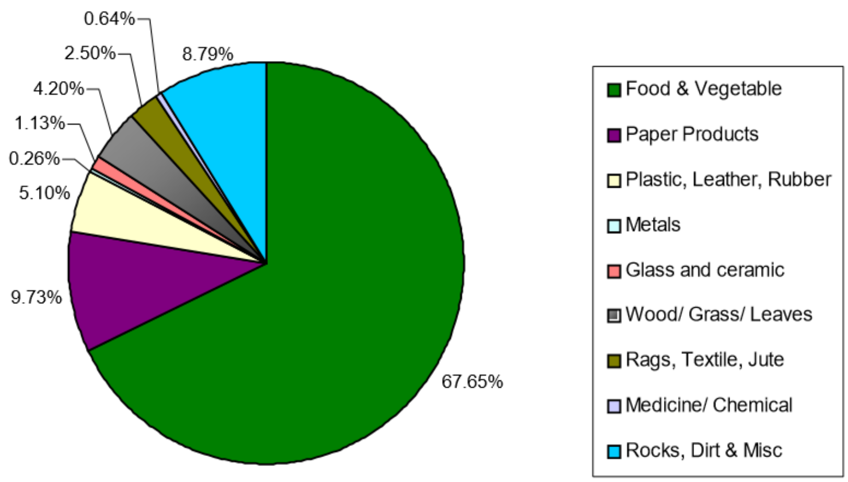


Figure-1: Physical composition of waste generated in Dhaka city

(Source: Waste Concern)

2.4.1.1 Organic Materials

The major component of waste generated in Dhaka is organic material which produced as the residue of food and vegetables. Main part of this component comes from household activity and a significant fraction comes from market of vegetable. Organic matter can be divided into wet and dry organic matter. Wet organic matter consists of kitchen wastes, fruit wastes, flower wastes, green grass, and other small organic material that is less than 1" in size. With regard to wet organic wastes, kitchen wastes constitute the majority of the waste, while green grass and flower waste make up less than 1% of organic waste. The largest components of dry organic wastes include dry grass and cotton waste, which together make up 81% of the total dry organic material found in the MSW in Dhaka. Around 67% of waste is organic materials.

2.4.1.2 Recyclable Component

Main recyclable part is paper product. 9.7% of total waste is paper product which comes as backdated newspaper, paper used by student and different government and nongovernment office. Other recyclable components are plastic, leather, rubber, metals, glass, ceramics which are all together about 6.94%. About 15% of total generated waste is recycled in Dhaka.

Figure-2: Recycling of waste in Dhaka

2.4.1.3 Inert Materials

The inert materials found in Dhaka MSW are sand, stone, silt, and bricks. A large Proportion of this comes from street sweeping and illegal dumping of construction and Demolition waste.

2.4.2 Types waste in Dhaka by Source

Main part of generated waste come from kitchen, house chores and market waste. Other remarkable waste is generated from construction. Others come from industry, mill-factory, textile, hospitals-clinics, tanning wastage, consumption of bottled food like can, bottled water, soft drinks and dust as street wastage.

2.4.2.1 Domestic Waste

Domestic waste is another big source of solid waste, which is about 1718 tons /day at a percentage of 49.08 %. These contain paper, vegetable peelings, onion seed coat, broken plastic and festal, spider net, soil and dust, pieces of thread, animal fasces, grasses, used shoes, pieces of cloth, small bottles, soot, used car parts, etc.

2.4.2.2 Industrial waste

There are many types of mills and factories in Dhaka. Large scale industries are textile, knit garments, medicine factories, detergent and soap factories etc. Medium scale factories are mainly confectionary. Moreover there are number of small scale factories. These factories produce much hazardous chemical waste which is not bio degradable.

2.4.2.3 Tanning Waste

Tanning waste is another type of industrial waste, which is polluting the environment dangerously. There are about 149 tanning industries in Hazaribagh area in Dhaka and they are producing 18,000 liters of liquid wastes and 115 tons of solid wastes. Wastes from tanneries contain sulfuric acid, chromium, ammonium sulfate, ammonium chloride, and calcium. Tanning wastes have harmful impactions on environment in terms of health, welfare, and environment like fever, headaches, respiratory and skin diseases and may also bring undesirable changes in land use and fisheries. It has also negative impact on groundwater, surface water, and the ecosystem in general

2.4.2.4 Hospital and clinic waste

There are more than 500 clinics and hospitals in Dhaka City, and all hospitals and clinics are producing huge amount of waste in every day. The present average of clinical waste generation in hospitals and clinics is calculated using 1kg/bed/day and an extra 200 kg/year for clinics. It is estimated that 20 percent of the whole hospital wastes (255 tons, 7.29 % of total solid waste generated per day) generated in the city is infectious and dangerous. Waste is collected from small bowls (plastic or metal) or plastic bins provided for each bed and emptied into larger containers. Wastes from operation theaters, laboratories, and kitchens are also dumped into these municipal bins. Since hospital wastes contain toxic and infectious materials, they are more unsafe than other types of wastes. In Dhaka, all types of medical wastes, like syringes and needles are thrown into the municipal dustbin. For this reason inflectional diseases spread out easily.

2.4.2.5 Market Waste

Other important sources are fish markets, butcher shop and vegetable market. There are numbers of market in the city. Karwan-bazer is the main wholesale vegetable and fish market in the city with approximate 1 km^2 area where 996 shops reside and 10 ton market waste is available from the market. But considering the future growth and possible inclusion of nearby other markets the design for anaerobic digester is made for 20 ton/day.[33]

2.4.2.6 Street sweepings, Drains, Toilets

Street sweepings, sludge from drain and human dungs from toilets is significant part of total waste generated in Dhaka. But these are remaining out of account.

2.5 Chemical Characteristics

The chemical characteristics of MSW in Dhaka were determined study by BCSIR in 1998. Note that the moisture content and heating value of wastage in Dhaka is very significant to produce energy.

Table-6 Chemical composition of solid waste in Dhaka

Constituents	Residential waste	Commercial waste	Mixed waste
Moisture	50	54	59
Carbon (C)	26.06	17.81	12.70
Hydrogen (H	3.53	1.92	2.25
Nitrogen (N)	1.62	0.46	0.62
Sulfur (S)	0.01	0.02	Minor
Ash	18	22	20
Oxygen (O)	0.78	3.79	3.43
C/N ratio	16:1	39:1	20.5:1
Calorific value KJ/Kg	6048	5343	4578

Source: BCSIR- 1998

2.6 Waste Collection in Dhaka

The Plan institutionalized community-based primary collection services. Dhaka created volunteer community groups tasked with educating residents about the new solid waste management system and engaged them to adapt the collection program as waste generation evolved. Residents, or Primary Collection Service Providers employed by the residents, transfer household waste to designated dust bins, containers, and transfer stations in Dhaka. The city also employs street sweepers to clean public areas and deposit waste in the containers. For the secondary collection, the government procured 132 modern waste collection vehicles, including 40 compactors and 27 container carriers, to retrieve waste from the collection points and transport waste to the disposal site.7 When the city's waste collection vehicles were inoperative, repairs typically took two years, thereby undermining collection efforts.8 To alleviate this bottleneck, Dhaka city government built a modern maintenance and repair shop that improved repair services. The Plan aims to reduce source generation by 5 percent and increase the waste collection rate from 44 percent in 2004 to 61 percent by 2015.[34,35,36]

2.7 Waste disposal in Dhaka

There are two operating dumps currently serving Dhaka. They are located in Matuail and Aminbazar. In some instances, slum encroachment at the City Corporation dumping grounds has reduced the amount of land actually available for MSW disposal. The trucks carrying garbage pass through residential areas to reach the dumps, thus creating noise, odor, traffic, and air pollution problems along the way. Residents living near the landfills often complain of odors, fires started by ragpickers, vermin, and scavenging animals. To combat these problems, the municipality sometimes sprays disinfectants on the waste.

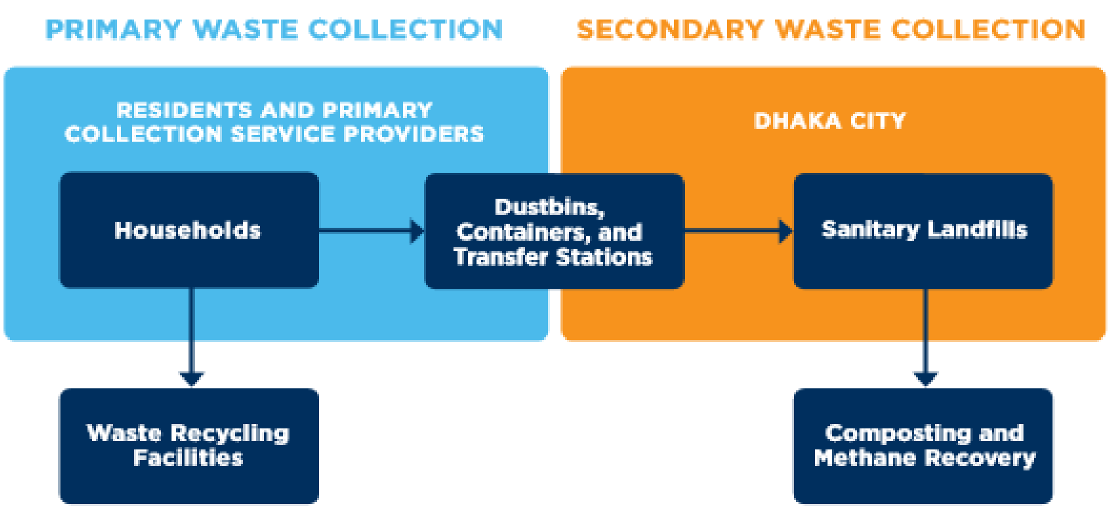


Figure-3: Dhaka Waste collection and Disposal. (Source: Dhaka City Corporation and JICA-2012)

2.7.1 Aminbazar Dump

Amin bazar dump is used by DNCC now. It situated at north east of Dhaka besides Dhaka – Tangail Road which is main gate to entrance Dhaka from north Bengal of the country. 1100 tons/day dumped at this site.Area of the disposal site is 20 hactre. Amin Bazar, and closed the open landfill, Berri Band. A Landfill Management Unit was created to monitor all activities at the landfills. Regular environmental monitoring is conducted to assess leachate, landfill gas, and surface water quality. Surveys also assess landfill impact on neighboring communities. Data collection at the weigh bridge allows planners to adapt collection and transport plans to suit the city's need. [4, 5, 34, 35, 36]

2.7.2 Matuail Dump

Matuail is the first waste dump station in Bangladesh. It possesses area of 40 hectare and the only disposal site of DSCC. Matuail landfill and upgraded the site into a sanitary landfill with leachate collection and treatment facilities designed to clean the water that percolates out of the landfill, and a gas venting system. It also modernized operations through construction of a weigh bridge, a truck-scale to weigh incoming waste; a carwash facility to avoid contamination of roads by vehicles leaving the landfill; and a waste compaction and monitoring facility [4, 5, 34, 35, 36]

CHAPTER 3

TEST CASE STUDY WASTE TO ENERGY IN DHAKA

3.1 Background

There are over 600 waste-to-energy facilities worldwide that convert around 155 million tons of MSW per year to electricity or district heating (cooling) [63]. Over the last two decades, the waste-to-energy industry has been highly effective in reducing the volume of waste being sent to landfills, decreasing the amount of air pollution generated by WTE facilities, and increasing the efficiency of energy recovery from MSW. Waste-to-energy is highly beneficial for areas that are very populated and short on space (such as islands), as well as to provide a renewable source of energy and decrease the amount of fossil fuels used for the same [1].

3.2 What is Waste to Energy (WtE) and Different Technologies

Waste to energy is a process of generating energy in the form of electricity or heat from the primary treatment of waste. WtE is a proven, environmentally sound process that provides reliable electricity generation and sustainable disposal of post-recycling MSW. WTE technology is used extensively in Europe and other developed nations in Asia such as Russia, Japan, Singapore, and Taiwan. New policies to encourage WTE can also have a meaningful impact in reducing dependence on fossil fuels and increasing production of renewable energy. WTE technology has significantly advanced with the implementation of the Clean Air Act.

Technologies used for generating power from waste: The technology options are given below

MSW processing divides depending on technology in two classes

1) Thermal processing, 2) Chemical Processing.

1) Thermal processing:

a) Combustion, b) Pyrolysis, c) Gasification, d) Plasma arc e) Refused derived fuel.

2) Chemical Processing:

a) Composting, b) Biomethanation, c)Land fill gas.

1) **Thermal processing**

a) **Combustion**

In which the residual waste is burned at 850 C and the energy recovered as electricity or heat. The principle in combustion is direct and complete oxidation in which carbon in biomass is oxidized to carbon dioxide, hydrogen to water, Sulphur to Sulphur dioxide, and nitrogen to nitrogen oxide. The useful scale of combustion is very large in heat production. In power Production the smallest commercial technologies are about 50 kW. However, combustion is about quit ineffective way to gasification, and even unfavorable in purpose to produce liquid or gaseous fuels. [40]

Mass –burn incineration is a large – scale incineration process with typical volumes of waste between 10 and 50 ton/h. Complete combustion or oxidation takes place in a single – stage chamber unite. Fluidized bed, cyclonic rotary kiln and liquid and and gaseous incinerators are examples of other types of combustion processes. They are usefully small scale and volumes are between 1 and 2 ton/h. [43]

Bubbling, turbulent and circulating bed types are the main type of fluidized beds. They are all are composed of a bed of sand refractory- lined chamber trough which combustion air is blown from the bottom of the chamber. The sand particles are fluidised by adjusting the air flow. The incoming fuel are dispresed rapidly and heated up to ignition temperature. Fludised beds have high Heat- storage and heat transfer rates. Therefore these bed types permit fast ignition of low combustable wastes. Flow diagram of apower plant is represented in Figure [43]

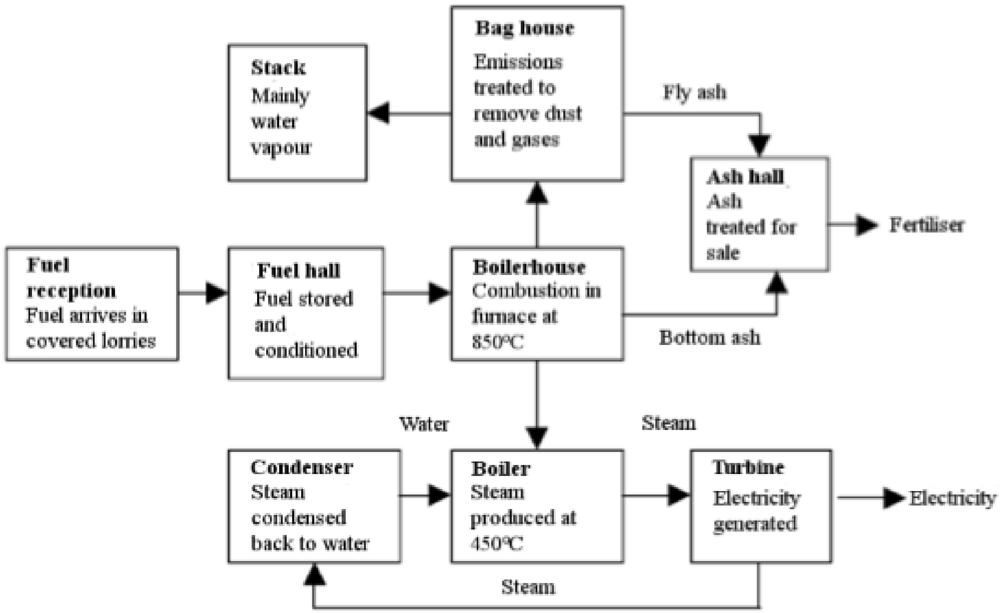


Figure-4: Flow Diagram of a Power Plant [43]

The moiture content is a very significant factor when considering direct combustion. Also high moiture waste may burn in a co- incineration plant but the minimisation of moiture content at low cost is apparentely desirable. In addion it is worthy for all combustion techniques [43].

In addition to understanding implementation, the role of government in supporting

a) Pyrolysis:

Pyrolysis is a process in which organic material is heated at high temperature in the absence of oxygen. The products are gases, liquids, (pyrolysis oil) and solids (char)Figure . Usually the gases are used to produce heat for drying and pyrolysis reactions. Pyrolysis oil often called a bio-oil can be used to replace heating oil, or it can be refined to secondary fuels such as crude oil [40].

Temperature in the pyrolysis process is between 400-800 C. The characteristics of bio mass , the reaction parameters and the pyrolysis method affect the relative portions of pyrolysis products . Pyrolysis can be roughly divided to fast and slow pyrolysis. The slow pyrolysis produces mainly char. The fast and flash pyrolysis process reach greatest oil yield usually a very heating rate. The yields of fast pyrolysis are 40-65% of organic condensates 10-20 % gases and 5-15% water based on dry feed. The lower heating value of pyrolysis oil is 15-18 MJ/kg, the gas is around is very flammable and therefore hot char must be handled with caution [42].

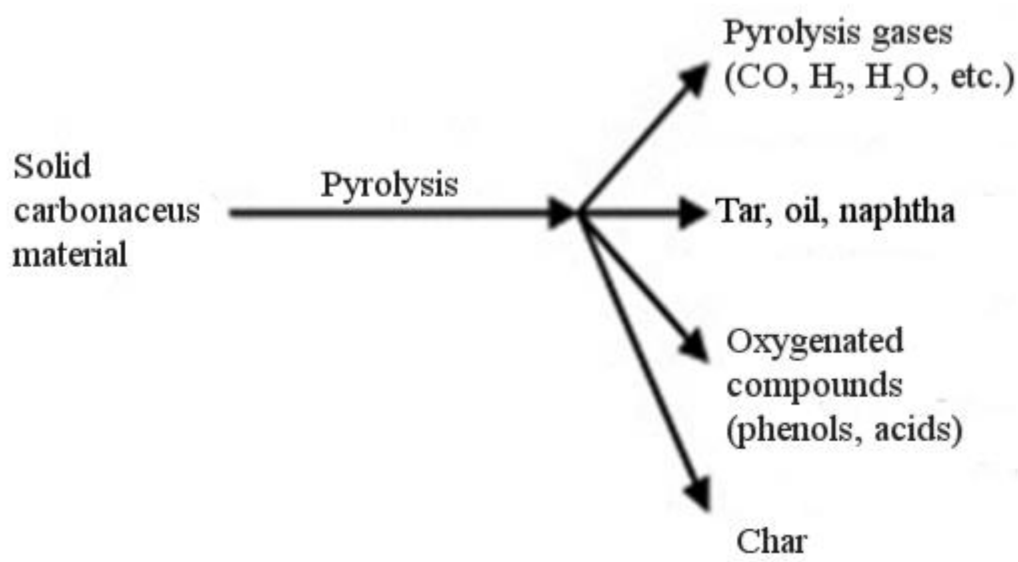


Figure-5: Pyrolysis Pathways [39]

Bubbling Fluid Bed (BFB) pyrolysis are commonly referred as fluidized beds. Fgure - illustrates a typical configuration with electrostatic preceptors (ESPs) which are widely used to remove particles from gases. Fluidized bed reactors are well understood technology which is simple in construction and operation. Their good temperature control and very efficient heat transfer to biomass particles due to high solid density are also advantages. Heating can be in a variety of ways especially in small scale while some heat transfer methods are not suited to large – scale plants [41]

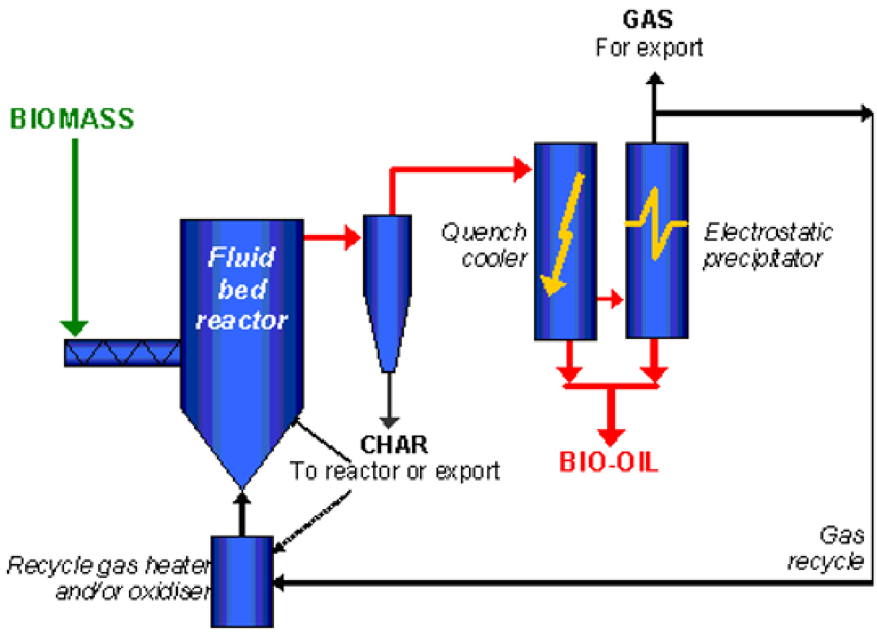


Figure-6: Fluid bed rector With ESP [41]

Fluidized bed pyrolysis give good and consistent with high pyrolysis oil yield (usually 70-75% from wood and dry basis). Feedstock particle sizes of less than 2-3 mm are required to achieve high heating rates and the rate of particles heating is generally the rate limiting step. The fluidizing gas flow rate controls residence time of solid and vapors and time are higher for char than for vapors. Rapid and effective char separation is significant because char acts as an effective vapor cracking catalyst at fast pyrolysis reaction temperatures. [41]

Circulating fluidized bed (CFB) and transported bed reactor systems have many similar features than BFB reactor systems except that the residence time for the char is almost same as for vapors. Gas and char are also in better contact with each other due to the higher velocities which can lead to higher char content in produced bio-oil. A typical CFB rector configuration is presented in Figure- Heat needed in a pyrolysis is usually from recirculation if heated sand from a secondary char combustor, which can either be a bubbling or circulating fluidized bed. The rotating cone reactor (RCR) systems have many similarities to the CFBs except that the sand and feed stock transport is boosted by centrifugal forces operating in a rotating cone. [41]

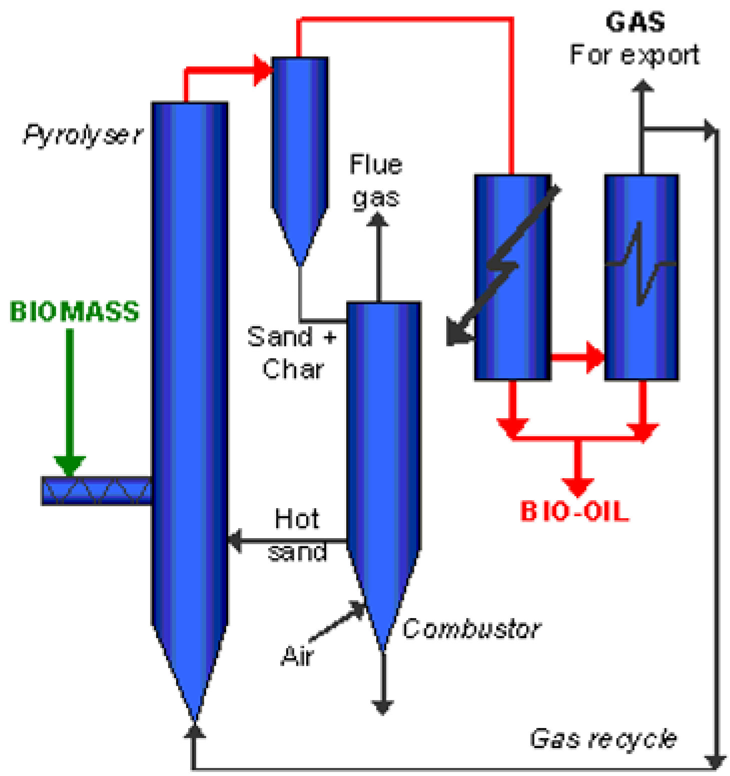


Figure-7: Circulating fluid bed reactor [41].

Ablative pyrolysis reactors are notably different compared to the other methods of fast pyrolysis. In all the other methods, the rate of heat transfers through a feedstock particle limits the rate of pyrolysis reaction and therefore small feedstock particles are required. Ablative reactors can handle also large particles and there are no upper limits to size that can be processed. In ablative pyrolysis heat is transferred from hot reactor wall to feed material that is in contact with it under pressure. As the materials is mechanically move forward, the residual oil film both provides lubrication for successive particles and also rapidly evaporates to give pyrolysis vapors. [41]

The rate of reaction in ablative systems is strongly affected by pressure, the surface temperature and the relative velocity of feedstock on the heat exchange surface. The high pressure is achieved due to centrifugal or mechanical forces. The limiting factor in the ablative process is the rate of heat supply to the rector rather than the rate of heat absorption by the pyrolysis feedstock in other reactors. [41]

Fast pyrolysis of biomass is on demonstration stage in power production. Fluidized and transported bed reactors have proven reliable to produce bio-oil with relatively high yields. Also other reactor types such as ablative, rotating cone and vacuum reactors are concealed. Bubbling fluidized bed reactor is commercially available with capacity of 20-400Kg/h. and circulating fluidized bed reactor with the capacity of 20-1700 kg/h.

Though it is suitable for small scale power plant it has a major disadvantage of fluidized bed rectors is their requirement for very feedstock particles size (1-2mm). Ablative reactors can handle feedstock sizes up to 20mm but not enough small for waste of Dhaka. Beside it is low yielding process (30-45%).

b) Gasification:

Gasification is a process that converts organic or fossil fuels carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide. This is achieved by reacting the materials at high temperatures (>700^{0}c), without combustion, with a controlled amount of oxygen and/or steam. The resulting gas mixture is called syngas (from synthesis gas or synthetic gas) and is itself a fuel.

The combustion products from complete combustion of biomass generally contain nitrogen, water vapor, carbon dioxide and surplus of oxygen. However in gasification where there is a surplus of solid fuel (incomplete combustion) the products of combustion are (Figure-8) combustible gases like Carbon monoxide (CO), Hydrogen (H2) and traces of Methane and non-useful products like tar and dust. The production of these gases is by reaction of water vapor and carbon dioxide through a glowing layer of charcoal. Thus the key to gasifier design is to create conditions such that a) biomass is reduced to charcoal and, b) charcoal is converted at suitable temperature to produce CO and H2

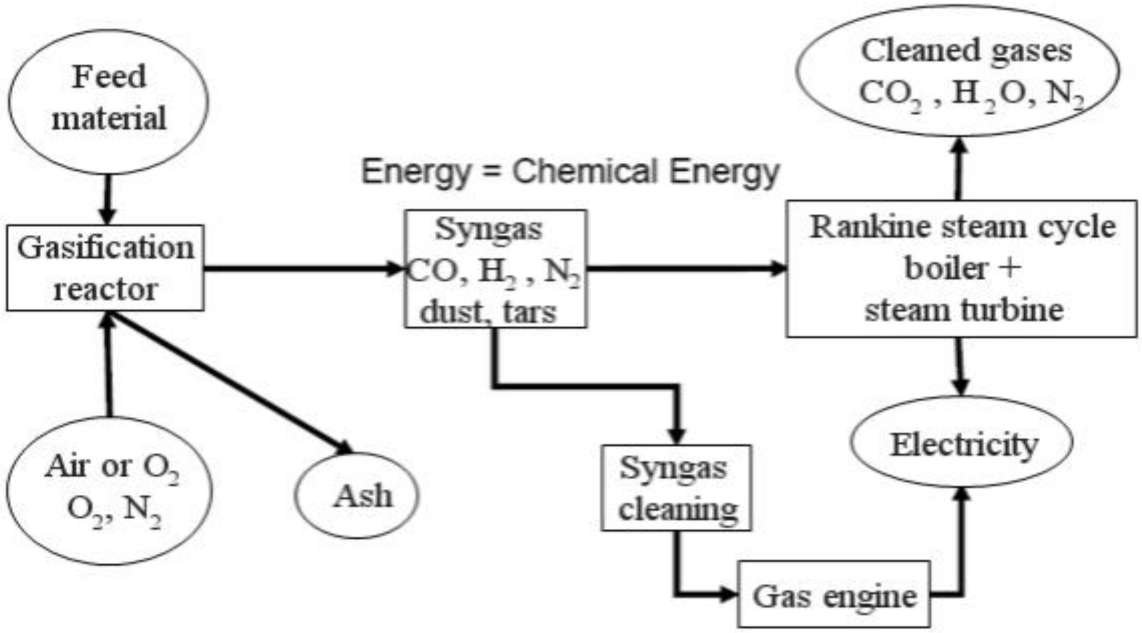


Figure-8: Schematic representation of a gasification process (Austerman and Whitinng 2007)

Gasification technology can be used for heat and power production beginning from 1 kW micro –scale application. In Figure – the gasification process and electricity generator from syngas is presented. Partial oxidation in the reactor occurs with air or by reaction with steam. Using air as oxidant is the cheapest option and results in product gas with relatively low energy content. The product gas contains up to 60% nitrogen and the lower heating value is 4-6 MJ/Nm^3 while oxygen supply which heating value is 10-18MJ/Nm^3 but requires an oxygen supply which is expensive [44].

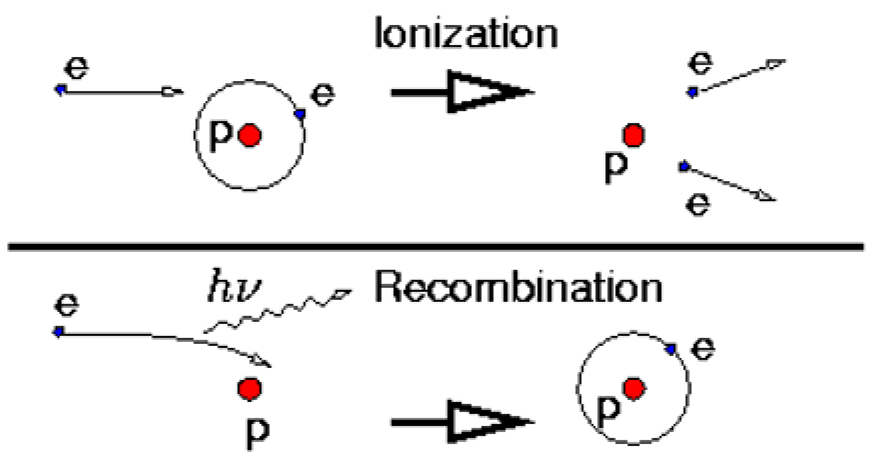
Various parameters have an influence on the gasification process reaction and the distribution of products. For example, feedstock particle size and particle size range, moisture content, mode of gas – solid contacting, pressure heating rate, temperature and temperature profile, and residence time may have to be taken into account.

As gasification needs dry content of biomass it is not suitable for the generating power using waste produced in Dhaka which contains mainly wet content.

c) Plasma arc

Plasma is the fourth state of matter. About 99% of the matter in the universe is in the plasma state. Plasmas exist in astronomical bodies with temperatures in millions of degrees. Plasma is a gas in which an important fraction of the atoms is ionized, so that the electrons and ions are separately free. This occurs when the temperature is hot enough to overcome ionization threshold energy, about 13.6eV

Balance between collisional ionization and recombination



Figgure-9: Ionization and Recombination

Plasmas are said to be quasi neutral as Electrostatic force >> Kinetic Pressure Force. This is one aspect of the fact that, because of being ionized, plasmas exhibit all sorts of collective behavior, different from neutral gases, mediated by the long distance electromagnetic forces E, B. In plasma, the Debye length,

$$\lambda_D \equiv \left(\frac{\epsilon_0 T_e}{e^2 n_\infty} \right)^{1/2}$$

<< Size of the plasma

Plasma technology was developed and employed in the metal industry during the late 1800s to provide extremely high heat. Plasma Arc heaters received renewed attention when the United States NASA Space program, during the early 1960s, evaluated and selected Plasma Arc Heating technology for simulating and recreating the extreme high heat of reentry into the earth's dense atmosphere encountered by spacecraft from orbit. Utilizing the same plasma physics, scientists who previously worked for NASA, have refined and improved the plasma arc technology in efficiency, cost, and wider user applications; the lead NASA scientist, Dr. S.L. Camacho used this technology to convert waste to energy. The gaseous emission to the atmosphere were limited and very much under control. Waste materials are processed without any fly ashes that would require to be sent to a landfill. The environmental regulations are becoming more stringent and landfills are becoming outmoded. The harmful attributes of landfills to environment were predicted. They suggested that Sustainable and successful waste management should be safe, effective, and environmentally friendly. Plasma technology adaptation to large-scale solid waste disposal via gasification and recovery of energy from the generated gas is relatively new. Plasma gasification of municipal solid waste (MSW) is a fairly new application that combines well-established sub-systems into one new system. The sub-systems are waste processing and sorting, plasma treatment, gas cleaning, and energy production.

Plasma physics applied to gasification represents a clean and efficient option to manage waste in an environmentally responsible manner. The plasma gasification technology is ideally suited to process wastes such as Municipal Solid Waste (MSW), common hazardous waste, industrial waste, chemical waste, sediment sludge and biomass. It can also vitrify fly ash from incinerators and any other types of ash. Converting waste into various energy outputs reduces reliance on the use of conventional fossil based fuels by using readily available waste. In Nigeria like most developing countries, wastes are commonly dumped in open dumps uncontrolled landfills where a waste collection service is organized. Open dumping of waste is not a long-term environmental method of disposal. The dangers of open dumping are numerous; health hazard, pollution of ground water, spread of infectious diseases, highly toxic smoke from continuously smoldering fires, foul odors from decomposing refuse and emission of greenhouse methane gas. Several million tons of wastes have been deposited in open dumpsites across the country over the years. A new technology such as Plasma Physics applied to Gasification of MSW may prove to be an environmentally friendly and sustainable solution for wastes disposal and power generation.

The gasification reaction for MSW is generally written as follows:

$$CHxOy + wH2O + mO2 + 3.76mN2 \rightarrow aH2 + bCO + cCO2 + dH2O + eCH4 + fN2 + gC$$

Where waste material is described by its global analysis, CHxOy), w is the amount of water per mole of waste material, m is the amount of O2 per mole of waste, a, b, c, d, e, f and g are the coefficients of the gaseous products and soot (all stoichiometric coefficients in moles). This overall equation has also been used for the calculation of chemical equilibrium occurring in the thermal plasma gasification with input electrical energy. The concentrations of each gas have been decided depending on the amount of injected O2, H2O, and input thermal plasma enthalpy. The H2 and CO generated during the gasification process can be a fuel source for power generation.

Plasma gasification is an efficient and environmentally responsible form of thermal treatment of wastes which occurs in oxygen starved environment so that waste is gasified, not incinerated. Westinghouse Plasma Corporation (WPC) has developed a plasma gasification system [9],[7],[10] which uses plasma heat in a vertical shaft cupola adopted from the foundry industry. The plasma gasification process is illustrated in Fig. 2 below. The heart of the process is the Plasma Gasifier a vertical refractory lined vessel into which the feed material is introduced near the top along with metallurgical coke and limestone. Plasma torches are located near the bottom of the vessel and direct the high temperature process gas into a bed of coke at the bottom of the vessel. Air or oxygen is introduced through tires located above the torches. The high temperature process gas introduced through the torch raises the temperature of the coke bed to a very high level to provide a heat reservoir and the process gas moves upward through the gasifying vessel to gasify the waste. The power of plasma gasification makes it environmentally clean technique. Plasma Gasification Plant projects are being developed by many gas plasma companies, with real benefits obtained from this technology. Additional heat is introduced from the reaction of the carbon in the waste with the oxygen introduced through the tuyres to produce carbon monoxide in the gasification process. The hot product gas, passing upward though the wastes, breaks down organic compounds and dries the wastes at the top of the ―gasifier‖. As the waste moves downward through the ―gasifying‖ vessel, inorganic materials such as metal, glass and soil are melted and produce a two phase liquid stream consisting of metals and a glass-like (vitrified) residue that flows to the bottom of the vessel. Discharge of the molten material into water results in the formation of metal nodules and a coarse sand-like material.[45]

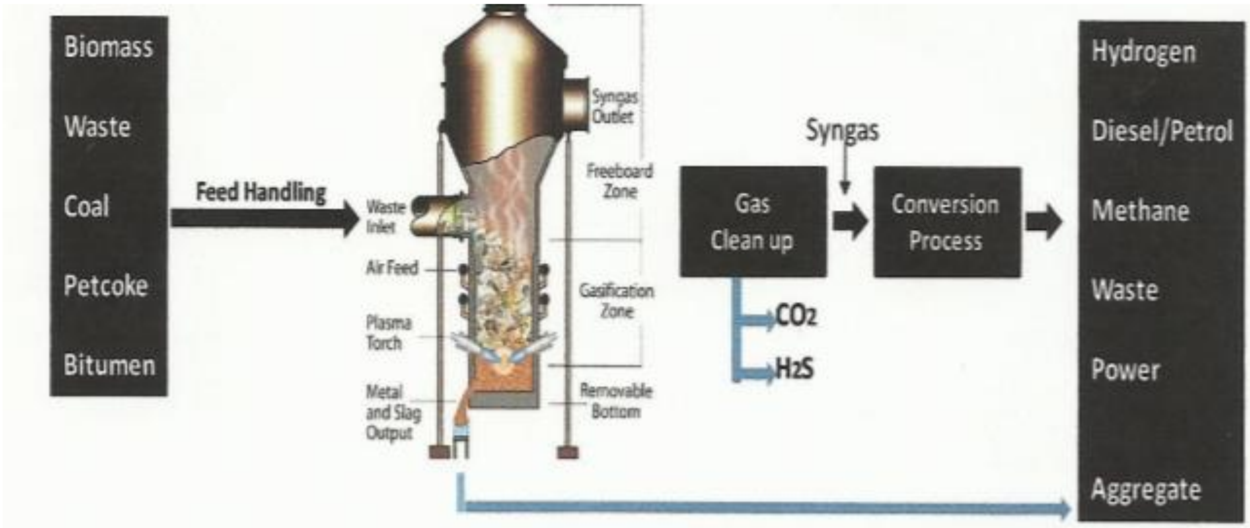


Figure-10: Plasma gasification process (Anyaegbunam F. N. C-2013)

d) Refused derived fuel.

In an RDF system, MSW is processed, most commonly by shredding, prior to combustion. Noncombustible materials, such as glass and metals, are removed before the MSW is converted into pellets or briquettes by densification or compression. The RDF can be used on its own or combined with other fuels to produce energy. Although this process creates a uniform fuel, a considerable amount of energy is used in the creation of RDF, and hence the energy benefits derived from it need to be analyzed in detail before this method is chosen as a waste processing option.

Refuse derived fuels cover a wide range of waste materials which have been processed to fulfil guideline, regulatory or industry specifications mainly to achieve a high calorific value. Waste derived fuels include residues from MSW recycling, industrial/trade waste, sewage sludge, industrial hazardous waste, biomass waste, etc.

The term ‘Refuse Derived Fuel (RDF)’ in English speaking countries usually refers to the segregated high calorific fraction of processed MSW. Other terms are used for MSW derived fuels such as Recovered Fuel (REF), Packaging Derived Fuel (PDF), Paper and Plastic Fraction (PPF) and Processed Engineered Fuel (PEF). The terms ‘Secondary Fuel’, ‘Substitute Fuel’ and ‘Substitute Liquid Fuel (SLF)’ are more commonly used in reference to industrial waste fractions such as tyres or solvents processed to achieve consistent quality compatible with particular process requirements.

The assessment of the environmental impacts of the production and use of RDF has been undertaken using a multiple approach including:

• An LCA type system analysis that considers general benefits or disadvantages of the total recovery system of RDF;

• An EIA type estimation of local impacts of the production and use of RDF; and

• An assessment of impacts on the products from industries co-incinerating RDF.

Refuse derived fuel (RDF) from municipal solid waste can be an alternative form of energy to replace fossil fuels. RDF is the component of MSW that has higher calorific like paper, plastics and textile.[64]

2) Chemical Processing:

a) Composting:

Composting is a simple way to convert organic material to carbohydrate (aerobic process) and gases (anaerobic process).In aerobic process, mainly compost fertilizer is produced and anaerobic process different gas are produced such as methan , carbon di-oxide , sulpher di-oxide etc.

b) Biomethanation:

Anaerobic digestion is a biological process where organic material is decomposed by anaerobes in absence of air to yield methane rich biogas. The general technology of bio-methanation of complex organic matter is well known and has been applied for over 60 years as part of domestic sewage treatment to stabilize organic wastes [49]. Anaerobic process is more advantageous than aerobic process in solid waste treatment because of high degree of waste stabilization, low production of excess biological sludge, low nutrient requirement and high production of methane gas as a useful by-product. Various studies have been conducted for evaluating different process parameters and model equations on biomethanation process [50] but only few are reported on catalytic bionethanation process . In the microbiological analysis of methanogenic process four different bacterial groups are identified as being responsible for carrying out the anaerobic digestion of complex organic matter. These are (i) the hydrolytic (hydrolysis of carbohydrates), (ii) acetogenic & homo acetogenic (monomer compounds to organic acid) (iii) acidogenic (organic acids to acetic acid) (iv) methanogenic bacteria (acetic acid to methane and carbon dioxide). However, the bio gas production is mainly depends on different parameters such as substrate concentration, pH of the substrate, temperature, stirring speed C/N ratio etc. It has been reported that the presence of some organic material may enhance the biogasproduction as the enzymatic part of the concern bacteria is activated. It has been further observed that some metal as well as some organic compound including green biomass may enhance the bio-methanation process.[48]

c) Land fill- gas

LFG is a natural byproduct of the decomposition of organic material in anaerobic (without oxygen) conditions. LFG contains roughly 50 to 55 percent methane and 45 to 50 percent carbon dioxide, with less than 1 percent non-methane organic compounds and trace amounts of inorganic compounds. Methane is a potent greenhouse (heat trapping) gas with a global warming potential that is 25 times greater than carbon dioxide.1 When municipal solid waste (MSW) is first deposited in a landfill, it undergoes an aerobic (with oxygen) decomposition stage when little methane is generated. Then, typically within less than 1 year, anaerobic conditions are established and methane-producing bacteria begin to decompose the waste and generate methane. [51]

3.3 Environmental Benefits of Waste-to-Energy

Given the amount of concern over the environmental risks of waste-to-energy, this section discusses the general trend of emissions from WTE facilities, dioxin emissions from WTE facilities, and dioxin emissions from open burning, which is currently practiced in Bangladesh. Waste-to-energy has historically been thought of as a major source of air pollution due to the presence of dioxins, mercury, lead, and other harmful substances. Although harmful pollutants were emitted by WTE facilities in the eighties, the technology and pollution control equipment has advanced so rapidly that the US EPA regards it as “a clean, reliable, renewable source of energy,” and one that has “less environmental impact than almost any other source of electricity.” [53]

Contrary to many assertions made by environmental groups, waste-to-energy facilities have a number of environmental benefits. According to the Intergovernmental Panel on Climate Change,

> "Net GHG emissions from WTE facilities are usually low and comparable to those from biomass energy systems, because electricity and heat are generated largely from photosynthetically produced paper, yard waste, and organic garbage rather than from fossil fuels. Only the combustion of fossil fuel based waste such as plastics and synthetic fabrics contribute to net GHG releases, but recycling of these materials generally produces even lower emissions." [54]

3.3.1 Emission Trends from Waste-to-Energy Facilities

Emissions from waste-to-energy facilities worldwide have decreased dramatically since the eighties as a result of a stricter regulatory environment and continuous improvements in technology. Tables-7 show the percentage decrease in emissions from WTE facilities within a decade for the US and Germany, respectively. Today approximately 26 million tons of MSW are diverted to waste-to-energy facilities in the US each year [55]. The waste incineration capacity in Germany increased from 9.2 million tons in 1990 to almost 14 million tons in 2000 even as emissions have decreased across the board [54]. In addition, Table-8 compares emissions per unit of heating value from coal-fired and WTE plants in the US. Emissions of sulfur dioxide, nitrogen oxides, particulate matter, and cadmium are higher from coal-fired plants than waste-to-energy facilities, while emissions of hydrogen chloride, lead, and mercury are higher from waste-to-energy facilities than coal-fired plants [56].

Table-7: Emission Reductions from WTE facilities between 1990 – 2000 in the US [134]

Pollutant	Reduction (%)
Dioxins/Furans	99.7
Mercury	95.1
Cadmium	93.0
Lead	90.9
Particulate matter	89.8
Sulfur dioxide	86.7

Table-8: Emission Reductions from WTE facilities between 1990 – 2001 in Germany [120]

Pollutant	Reduction (%)
Mercury	98.7
Lead	99.8
Particulate matter	<88

Table-9:Emissions per unit of heating value of plants in the US (kg/GJ) [134]

Pollutant	Coal-fired plants	WTE facilities
Sulfur dioxide	0.452	0.013
Nitrogen oxides	0.194	0.151
Hydrogen chloride	0.017	0.087
Particulate matter	0.03	0.002
Lead	$2.6 * 10^{-6}$	$15 * 10^{-6}$
Mercury	$2.6 * 10^{-6}$	$7 * 10^{-6}$
Cadmium	$1.9 * 10^{-6}$	$1.1 * 10^{-6}$

3.3.2 Dioxins from Waste-to-Energy Facilities

Dioxins are a group of compounds that have similar chemical characteristics. Approximately 30 compounds fall into three groups: chlorinated dibenzo-p-dioxins (CDDs), chlorinated dibenzofurans (CDFs) and some polychlorinated biphenyls (PCBs). The term 'dioxin' is also used to refer to one of the most toxic of these compounds, 2,3,7,8 tetrachlorodibenzo-p-dioxin (TCDD). The toxicity of dioxins are measured in terms of Toxic Equivalents or TEQs, which is the equivalent amount of TCDD in a mixture of dioxin compounds. Dioxins are carcinogenic and lipophilic, which means that they can easily dissolve in fats, oils, and lipids, and hence bio accumulate in humans and wildlife, causing significant concern about the risks associated with them. Dioxins are commonly formed when organic material is burned in the presence of chlorine.

According to the US EPA, some of the major sources of dioxins are coal-fired plants, metal smelting plants, diesel trucks, and trash burning. However, in a span of twenty years, from 1987 to 2007, dioxin emissions from waste-to-energy facilities in the US decreased from 10,000 g/year to 12 g/year. At present, dioxins from waste incineration constitute less than 0.05% of the total US inventory [59]. In comparison, backyard burning of municipal waste in some rural areas where it is still allowed results in emissions of 580 g/year of dioxin, as shown in Figure-11 [56]In many cases, the stack gas from WTE facilities is found to be cleaner than the ambient air in some US cities [56, 57]. With regard to Germany, it is estimated that residential fireplaces emit 20 times more of dioxins than do the most modern WTE facilities in Germany [57]. It is interesting to note that a study conducted at Oak Ridge National Laboratory, Tennessee in 1989, when WTE facilities were still considered to be 'dirty,' concluded that emissions of dioxins and furans from WTE plants (1.2*l0-5 ng TEDFs/m3) were no greater than background levels (1.3*$l0^{-5}$ ng TEDFs/m^3) [61].

In addition to measuring the decreasing trend of dioxin emissions, health risk assessments are conducted to measure the risk to human health from various industrial and manufacturing facilities. Typically the goal of these assessments is to predict the potential of excess lifetime cancer risk (ELCR), which is the probability of cancer incidence in a population, and hazard index (HI), which is the noncarcinogenic health risk.

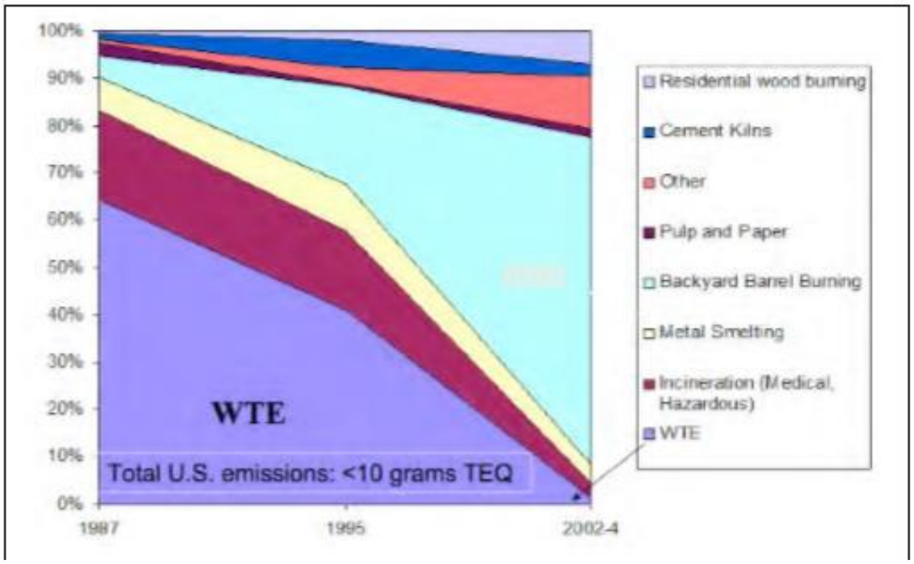


Figure-11: Dioxin emission in US between 1987 and 2002

As specified by the US EPA, the ELCR for combustion facilities is 10 chances in 1 million, and the HI is 1. Independent health risk assessments of WTE facilities in the US show exceedingly low values of ELCR and HI. For example, a health risk assessment for a municipal waste resource recovery facility in Montgomery County, Maryland in 2003 showed that the worst-case ELCR scenario from TCDD TEQs was 0.5 chances in 1 million. This is 20 times less than the national standard for combustion facilities. The worst-case total HI scenario calculated for the 19 compounds selected for the study was 0.029, which is almost 35 times less than the national standard.

In addition to measuring the decreasing trend of dioxin emissions, health risk assessments are conducted to measure the risk to human health from various industrial and manufacturing facilities. Typically the goal of these assessments is to predict the potential of excess lifetime cancer risk (ELCR), which is the probability of cancer incidence in a population, and hazard index (HI), which is the no carcinogenic health risk. As specified by the US EPA, the ELCR for combustion facilities is 10 chances in 1 million, and the HI is 1. Independent health risk assessments of WTE facilities in the US show exceedingly low values of ELCR and HI. For example, a health risk assessment for a municipal waste resource recovery facility in Montgomery County, Maryland in 2003 showed that the worst-case ELCR scenario from TCDD TEQs was 0.5 chances in 1 million. This is 20 times less than the national standard for combustion facilities. The worst-case total HI scenario calculated for the 19 compounds selected for the study was 0.029, which is almost 35 times less than the national standard [62].

3.3.3 Dioxins from Open Burning

Although waste-to-energy facilities have a bad reputation of producing harmful emissions, studies show that they are much less harmful than landfilling or uncontrolled burning. Studies conducted to quantify emissions from open burning of MSW show high levels of dioxins and PCBs. One study in particular, by Minh, et al. (2003), looked at concentrations of polychlorinated dib Enzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and PCBs at an MSW dump site.

In general, the study found higher concentrations of dioxins and other compounds at the MSW dump site than at control sites, i.e., agricultural and urban areas located far away from the dump sites studied.

3.3.4 Health Effects of Uncontrolled Burning at Landfills

A number of health effects have been recorded on rag pickers and local residents who live near landfills, which are aggravated by certain factors:

• Emissions tend to be at ground level (as compared to tall stacks), which inhibits the dispersion of gases and particulate matter;

• Emissions tend to be localized and higher at certain times of the year;

• Uncontrolled burning at landfills constitutes non-point sources and hence is harder to regulate than point sources.

CHAPTER 4

WHY ANAEROBIC DIEGESTION IN DHAKA

4.1 Background

There are many technologies to convert waste to energy. But they have some drawback. Such as for direct combustion dioxin (toxic material) emission is a problem to environment as well as to public health. Though Pyrolysis is a suitable technology for converting biomass to energy but it has a major problem of fluidized bed rectors is their requirement for very small feedstock particles size (1-2mm). Ablative reactors can handle feedstock sizes up to 20mm but not enough small for waste of Dhaka. Beside it is low yielding process (30-45%).For gasification it is convenient to use dry content of biomass but it is only 24 -26% of total waste production in Dhaka. Besides it has another disadvantage of pretreatment process to gasify which increases cost.

Besides an organization named Waste Concern started a community-based composting project in 1995 to promote the concept of the ‘4 Rs’ – reduce, reuse, recycle and recover waste – in urban areas. It is based on the idea that the organic content of Dhaka’s household waste, which accounts for more than 70% of total waste, can be efficiently converted into valuable compost. This reduces disposal costs and prolongs the lifetime of landfill sites. It also reduces the harmful environmental impact of landfill sites, because organic waste is responsible for groundwater contamination and methane gas emissions. By turning the organic waste into compost, the soil in urban areas can be improved. [3]

4.2 Anaerobic Digestion

Anaerobic digestion (AD) is a microbial decomposition of organic matter into methane, carbon dioxide, inorganic nutrients and compost in oxygen depleted environment and presence of the hydrogen gas. This process, also known as bio-methanogenesis, occurs naturally in wetlands, rice fields, intestines of animals, manures and aquatic sediments, and is responsible for the carbon cycle in the ecosystems.

Natural and anthropogenic sources account for 30 and 70 %, respectively, of the total methane released in the atmosphere every year. Major natural sources of methane are the wetlands and animal guts (mainly insects and ruminants) while the main anthropogenic sources have been identified in the fossil fuel processing industries, rice fields and landfills. Biological activity has been identified to be the cause for more than 80% of the flux of the atmospheric methane [70].

In general there are three different methanogenic ecosystems in the nature (Figure) : (a) in lacustrine and marine sediments, marshes, swamps, rice soils, sludge and digesters where the organic matter is completely degraded; (b) in ruminants and intestinal tracts of almost all living creatures (e.g. humans, insects, termites), where the process of mineralization is incomplete and most of the intermediate products (e.g. volatile fatty acids) are absorbed into the bloodstream; (c) in absence of organic matter (e.g. hot springs) where methanogenesis occurs only from geochemical hydrogen formed as part of the geological process [65].

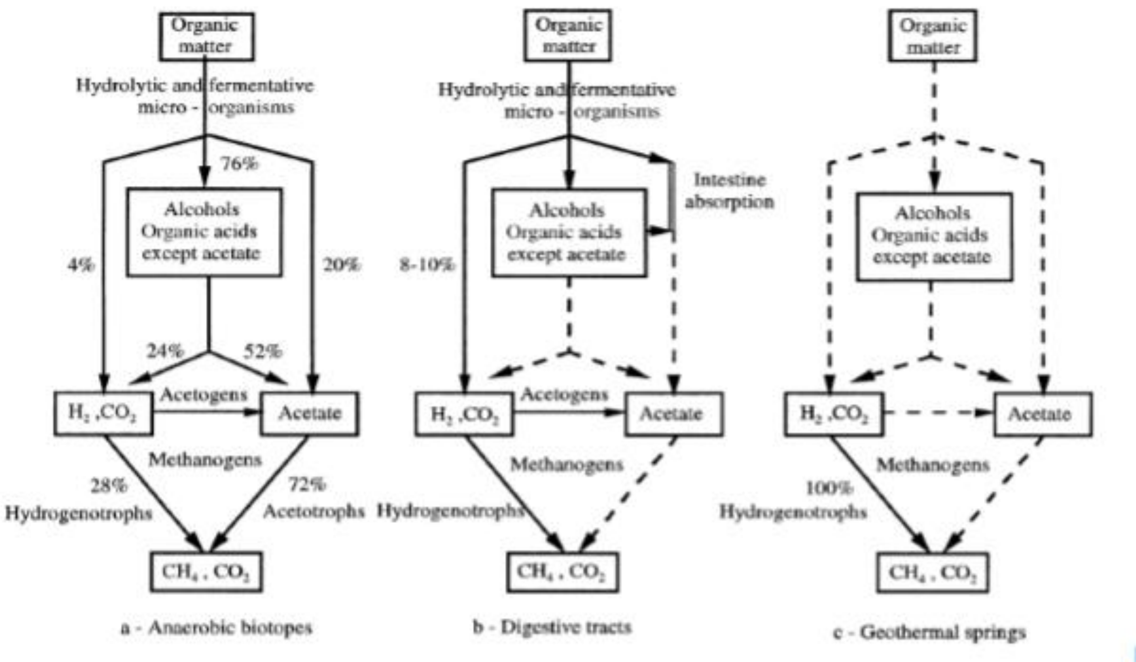


Figure-12: Schematic diagram of three different methanogenic ecosystems in nature (Garcia et al. 2000)

In Figure 1, the solid arrows show the reactions that occur and the dashed arrows show the reactions that do not occur in the specific ecosystem.

Humans have harnessed bio-methanogenesis for rapid and controlled decomposition of organic wastes and biomass feedstock to methane, carbon dioxide and stabilized residue. In the generalized scheme of the anaerobic digestion, the feedstock is harvested or collected, coarsely shredded and placed into a reactor with active inoculums of methanogenic microorganisms. Since the methane is a significant greenhouse gas, anaerobic digestion has higher control over the methane production and contributes to lower the carbon footprint of the food waste management in the way that the fugitive emissions are lower than then the emissions in the cases of the landfilling and aerobic composting [66].

Generally three main reactions occur during the entire process of the anaerobic digestion to methane: hydrolysis, acid forming and methanogenesis. Although AD can be considered to take place in three stages all reactions occur simultaneously and are interdependent. In the experimental study to be described later, we shortened the AD process at the end of the acid forming stage, because the goal was to produce volatile fatty acids and avoid methane production. Methanogenesis was not important in our experimental study but is described below in order to provide the complete picture of the AD process.

4.2.1 Hydrolysis

Hydrolysis is a reaction that breaks down the complex organic molecules into soluble monomers (constituents), Figure 2, Stage 1. This reaction is catalyzed by enzymes excreted from the hydrolytic and fermentative bacteria (cellulase, protease and lipase). End products of this reaction are soluble sugars, amino acids; glycerol and long- chain carboxylic acids [68]. Approximate chemical formula for the organic fraction of the municipal solid waste (MSW) is C6H10O4 (Shefali & Themelis 2002). Hydrolysis reaction of the organic fraction of the MSW can be represented by the following reaction:

$C_6H_{10}O_4+2H_2O= C_6H_{10}O_6+2H_2$ (Ostrem & Themelis 2004)

4.2.2 Acid-forming stage

This stage is facilitated by microorganisms known as acid formers that transform the products of the hydrolysis into simple organic acids such as acetic, propionic and butyric acid as well as ethanol, carbon dioxide and hydrogen. Acid forming stage comprises two reactions, fermentation and the acetogenesis reactions. During the fermentation the soluble organic products of the hydrolysis are transformed into simple organic compounds, mostly volatile (short chain) fatty acids such as propionic, formic, butyric, valeric etc, ketones and alcohols. [67]

The acetogenesis is completed through carbohydrate fermentation and results in acetate, CO_2 and H_2 , compounds that can be utilized by the methan is of critical importance in acetogenesis of compounds such as These reactions can only proceed [68]. Thus the presence of hydrogen scavenging bacteria is thermodynamic feasibility of this reaction.

4.2.3 Methanogenesis

Methanogenesis is a reaction facilitated by the methanogenic microorganisms that convert soluble mater into methane. Two thirds of the total methane produced is derived converting the acetic acid or by fermentation of alcohol formed in second stage such as methanol. The other one third of the produced methane is a result of the reduction of the carbon dioxide by hydrogen. Considering that the methane has high climate change potential the goal is to find an alternative in order to lower the environmental foot print of the organic waste treatment. Therefore in the experimental part we avoided this stage and instead of methane we targeted the production of volatile fatty acids. The reactions that occur during this stage are as follows [67] :

4.3 Anaerobic Digestion as WtE Technology

Anaerobic digestion is a biochemical process in which microorganisms consume organic waste materials in the absence of oxygen.[71] This process results in three primary end products: methane, carbon dioxide, and “digestate,” a solid residue similar in form to soil or compost.[72] Waste designated to undergo anaerobic digestion is commonly referred to as “feedstock.”18 The following is a general description of the steps involved in anaerobic digestion in small community digesters and larger industrial facilities.

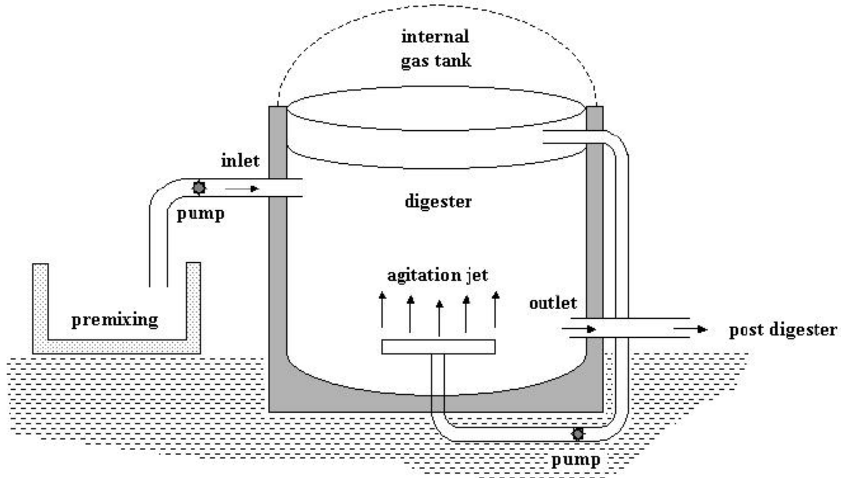


Figure-13: A typical digester.

4.3.1 Pretreatment of the Feedstock

To produce energy most efficiently, feedstock should be pretreated before undergoing anaerobic digestion [73]. “Municipal solid waste” is a general term describing the overall waste stream produced by a typical community.[74] Subcategories of municipal solid waste include the following: residential waste, generated by households; institutional waste, generated by facilities such as hospitals and universities; and commercial waste, generated by stores, tourism, and markets[16]. The fraction of municipal solid waste best suited for anaerobic digestion is identified broadly as “organic waste,” which includes materials such as food waste, garden waste, and paper products[16]. Organic waste accounts for over 65% of all municipal solid waste produced by the Dhaka City. Pretreatment of feedstock consists of separating nonorganic materials from organic waste.[75] Nonorganic materials commonly found in municipal solid waste include metal, glass, plastic, and rocklike debris such as stones, concrete, and sand[76].Anaerobic digestion facilities employ, to varying extents, mechanical sorting technologies that physically remove nonorganic materials from the waste stream[77]. This process may involve the use of magnets, passable screens, or conveyor systems staffed by personnel who visually identify nonorganic materials and remove them manually [78]. Once nonorganic materials have been removed, the remaining waste is ground or shredded to reduce the size of the feedstock that will be fed into the anaerobic digester [16] Reduction in the size of the feedstock increases the surface area of waste and speeds the ability of the anaerobic bacteria to digest the incoming feedstock [79] After reduction, the feedstock enters an anaerobic digester—a silolike container made of metal or concrete.30 Inside the digester, the feedstock is mixed and diluted with water[16] Different types of water may be used, including fresh water, sewage water, or “effluent.”[16] The primary benefit of using sewage water or effluent is that the liquids already harbor colonies of anaerobic microorganisms that may immediately begin digesting the feedstock [16]. “Slurry” is the industry term for a mixture of water and feedstock. The “total solids content” of slurry refers to the percentage of the slurry comprised of waste material [16] Total solids content can range from 10% to 40% depending upon the design of the digester [16]

4.3.2 Temperatures inside the Anaerobic Digester

Perhaps the most important parameter to control within an anaerobic digester is temperature [81] Different strains of microorganisms perform optimally in different temperature ranges [16] Variations in temperature of only a few degrees can have devastating effects on the colonies of anaerobic bacteria, their ability to digest the feedstock, and their production of methane[16] To produce methane most efficiently, digester operators need to maintain optimal temperature levels for the particular kind of microorganism employed[16] Generally, reactor operators use one of two types of bacteria.40 A “mesophilic” bacterium is a microorganism that performs best between 95^0 F and 105^0 F [81] A “thermophilic” bacterium is a microorganism that performs best between 125^0 F and 135^0 F[16]. Mesophilic bacteria and thermophilic bacteria bring distinct benefits and detriments to the anaerobic process. Reactor operators need to be mindful of these differences when deciding which strains of bacteria to employ. Thermophilic bacteria allow a more efficient and complete digestion of the feedstock, and reduce the number of harmful pathogens that survive digestion. Some operators, however, disfavor thermophilic bacteria because they are more sensitive to temperature deviations. Minute temperature shifts can result in major disruptions to methane production and significant deaths of thermophilic bacterial colonies. Mesophilic bacteria are much more tolerant of temperature shifts than thermophilic bacteria.46 However, the mesophilic bacteria do not digest feedstock as efficiently as thermophilic bacteria. Furthermore, the optimal temperature level for mesophilic bacteria is not high enough to destroy all of the harmful pathogens [16]

4.3.3Slurry Retention Time and Mixing

After digester operators introduce feedstock into the anaerobic digestion vessel and mix it with water, the slurry remains within the vessel for a period of days. The retention time for an anaerobic digester varies based on numerous factors including the type of bacteria used, the specifications for the particular digester technology utilized, and the preferences of management. Some anaerobic digesters mix slurry with paddle devices that increase the rate of bacterial digestion. Paddles, however, are prone to mechanical breakdowns. Other anaerobic digesters employ gas jets that use compressed oxygen or biogas injected into the slurry to provide a mixing action. Like the paddle, these jets help to increase the rate of bacterial activity. Finally, some anaerobic digesters do not use any form of mechanical mixing, but rely instead upon gravity to slowly pull solid particles through the reactor from top to bottom, enabling the complete digestion of particles along the way. Such "gravity" or "plug flow" models produce less overall biogas than reactors using mechanical mixing, but are less technologically complex and, therefore, less expensive to build and maintain.[16]

4.3.4 Biogas Production

As anaerobic bacteria digest organic waste, they produce a mixture comprised mostly of carbon dioxide and methane called "biogas." The percentage of methane contained within biogas can vary dramatically based on a myriad of factors including the type of feedstock digested, the type of bacteria used, the design of the digesters, and the retention time for the slurry. The amount typically ranges between 50–70% [16]. Average biogas production at an anaerobic digestion facility falls between 3.2 and 4.8 standard cubic feet per wet pound of waste. The methane produced by anaerobic digestion may be used as an energy source in several ways. Historically, anaerobic digesters burned biogas in electrical generators onsite or nearby with only minimal treatment of the biogas to remove impurities. Due to the high costs of maintaining generators, digester operators have moved away from burning biogas in recent years and towards refining biogas for sale on the natural gas market. Before it can be sold on the natural gas grid, biogas must undergo sufficient purification to remove all impurities except for methane. Many facilities divert biogas for onsite energy usage [16].

4.3.5 Digestate Production

After the anaerobic bacteria finish digesting feedstock, physical bi-product remains called digestate. Digestate is rich in nutrients and can be used as an odor free fertilizer 67 or soil enhancer.68 unlike typical fertilizers, digestate is nearly free of pathogens, including those that may be harmful to plants, animals, and humans [16].

4.4 Model of an anaerobic power plant using organic fraction of Waste Produced in Dhaka City

4.4.1 Key Consideration for this Model

-Collection of Waste

-Land (site selection)

-Transportation

-Segregation

-Feeding waste to Digestion tank

-Design of Digestion Tank

-Separation of SO_2

-Collection of gas (CH_4)

-Bi-Product Disposal

4.4.1.1 Collection of Waste

For anaerobic digestion we need organic wet materials. About 65% of total waste generated in Dhaka City is organic. Waste will collect from the site where it accumulated i.e. dustbin, dumping station.

4.4.1.2 Land Requirements and Siting of a WTE Facility in Dhaka

Lack of availability and high price of land in Dhaka City it is difficult to implement this model. But we can implement this model besides the two dumping station, where wastes of Dhaka city are accumulated for disposal. For the purposes of this study, an area of 6 ha (0.06 km2) is estimated for a WTE facility in Dhaka. This value was chosen based on a survey of approximately 20 WTE facilities and their daily capacities around the world. [1]

The siting of a WTE plant is a key component of the overall waste-to-energy strategy. The location should be such that garbage transportation costs and times do not increase substantially, i.e., the plant should be located near areas that generate the maximum amounts of waste. However, the plant should be at a sufficient distance from residential areas to minimize public opposition to its construction and reduce the impact of dump truck traffic, noise, and emissions through these areas. For this project we can use the two dump site in Dhaka.

4.4.1.3 Transportation:

Collected waste will transport through DSCC and DNCC vehicles or by private transport system.DSCC and DNCC have its own fleet for garbage collection and also hire contractors to collect and transport MSW to transfer stations and dumps. The city corporations and private contractors use compactors, dumper placers, trucks, and other refuse vehicles for garbage collection. Based on data made available by DSCC and DNCC, the municipal corporation uses approximately 350 vehicles per day for garbage collection, while the private contractors have about 1000 modified rickshaw vehicles.

The average distance from collection points to the dumping grounds ranges from 15-28 km. [DSCC] as mentioned above, the collection vehicles make multiple stops along the route to the dump or refuse transfer station, and multiple trips to the dump each day. The total cost for a modernized fleet for a per year is estimated to be Tk 91.25 million Small one-ton vehicles will be used in slum areas to navigate the narrow alleys. They will be unloaded into large six-ton compactors that will go directly to the dump.'Mini' compactors, having a capacity of 2.5 tons, will be used to transport MSW to transfer stations, and will haul garbage a distance of approximately 5-10 km. From the transfer station, large six-ton compactors will then transport the compacted MSW to the dump. Current budget for waste Management of DSCC is and DNCC is together Tk 262 million. [83, 84]

4.4.1.4 Segregation:

In composting systems there are three objectives for materials separation: 1) recover recyclable or combustible materials as marketable by-products, 2) reduce the levels of visible inert materials (e.g., plastics and glass), and 3) reduce the levels of chemical contaminants (e.g., heavy metals and HHW). Many of the separation technologies now applied to MSW composting were originally developed to recover recyclable or combustible materials from solid waste. While some of these technologies have been adapted for reduction of inserts, they have rarely been optimized for reducing chemical contaminant levels. There are number of technique to segregate of waste such as a) screening b) manual separation c) magnetic separation d) air classification e) wet separation f) ballistic separation g) eddy current separation. [17]

a) Screening

Most MSW composting facilities first convey the waste into a bag-opener and screen or trommel to separate different sizes of waste (Figure-14). Fine materials, including soil, grit, and much of the organic wastes, fall through the screen as "unders". Plastic films and large paper products are retained on the screen as "overs" and may possibly be recycled or marketed as a refuse derived fuel (RDF), which is burned for energy recovery. But the main purpose of size segregation in a composting plant is to facilitate further separation. It is much easier for either people or machines to further separate materials of a similar size, as small items are not buried under large ones. Size fractionation also takes advantage of the size distribution properties of different waste components, generating streams in which certain recyclables or contaminants are concentrated.[17]

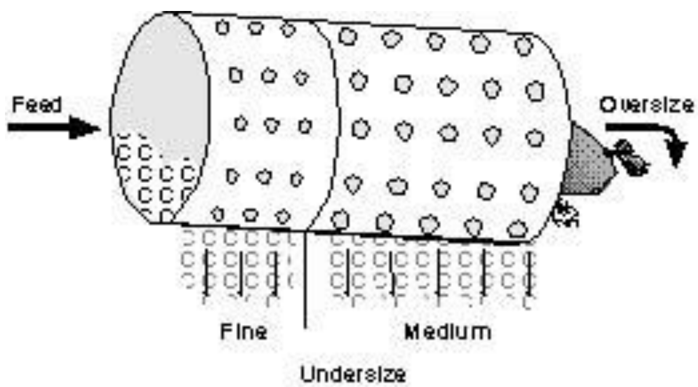


Figure-14: Trommel

b) Manual separation

With materials segregated to a relatively uniform size, it becomes much more practical to hand separate recyclables and contaminants as they move along conveyor lines. As manual separation of MSW can be an unpleasant task, worker comfort and safety are very important. Ergonomic design can help workers function at their best, and issues such as conveyor speed, reach, and placement of containers, flooring material, lighting, ventilation and dust control should all be considered. Here, as throughout the plant, it is recommended that workers wear safety glasses, gloves and adequate clothing to protect against injury from sharp objects, and hearing and respiratory protection wherever appropriate Conveyors and other materials handling machinery are critical to the operation of a plant. While this equipment may seem mundane, proper materials handling can minimize downtime and cleanup, and contribute to the overall efficiency of the facility. Steady materials flow will improve the efficiency of all the separation devices described below. [17]

c) Magnetic separation

As materials are conveyed from one separation system to another, the conveyors can utilize magnetic belts, rollers or overhead magnets to separate the ferrous metals from the rest of the stream. Magnetic separation efficiency is sensitive to the depth of waste, as small ferrous items will not stick to the magnet if they are buried in non-ferrous materials, while larger ferrous items can drag non-ferrous items like paper and plastic along. Air classification to remove the light paper and plastic fractions prior to magnetic separation minimizes the contaminants in the scrap ferrous. Pre-shredding and screening can also enhance ferrous recovery. Because magnetic separation is relatively inexpensive, it can sometimes be found at several locations in the composting facility. A minimum of two stages of magnetic separation are usually needed to achieve efficient ferrous recovery. Magnetic separation is effective with iron and most steel, but does not separate aluminum, copper, and other non-ferrous metals. Consumer electronics can be difficult to separate magnetically, depending on the ratio of ferrous to non-ferrous material. [17]

d) Air classification

Air separation is an additional separation technology used in some MSW composting facilities, and is commonly used to generate a marketable RDF. This technology has been used in the combustion industry for many years. The heart of an air classification system is an air column or "throat", into which the waste stream is fed at a gradual rate. The air column is usually oriented vertically. A large blower sucks air up through the throat, carrying light materials such as paper and plastic, which then enter a cyclone separator where they lose velocity and drop out of the air stream. Heavier materials, such as metal, glass, and food waste, fall directly out of the throat (Figure 3). These two streams tend to be different sizes as well as densities, facilitating further separation. Glass and metal can be sorted out of the heavy fraction by systems such as the wet separator described below. The light fraction can be marketed directly as an RDF, or sorted for recyclable paper or plastic prior to composting. [17]

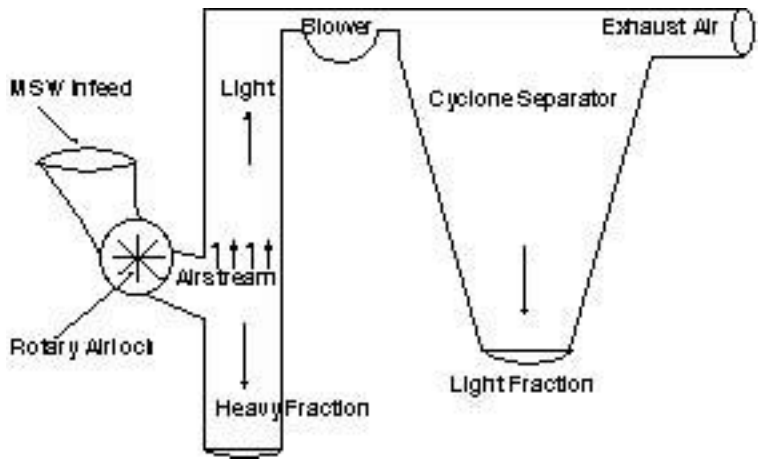


Figure-15: air classification

e) Wet separation

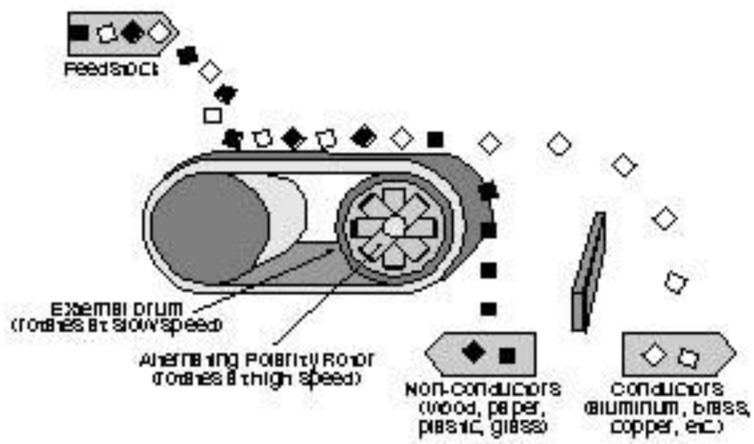
Wet separation technologies, while taking advantage of the same sorts of density differences as air classifiers, use water rather than air as the floating medium. These units are usually used to separate particles of glass, sand, and other heavy particles from organic materials prior to composting. A hammermill or other size reducer is needed prior to wet separation to minimize the potential for air pockets in the heavy fraction. After entrainment in a circulating water stream, the heavy fraction drops into a sloped (and sometimes vibrating) tank where it moves to a removal zone. This heavy fraction may be marketable as an aggregate substitute in construction applications. The less dense organic matter floats and is removed from the recirculating water using screening systems similar to those employed by wastewater treatment facilities. Wet separation is particularly effective at removing glass fragments and other sharp objects, which tend to be heavier than organic materials. [17]

f) Ballistic separation

Ballistic separation takes advantage of both density and elasticity differences to separate inert and organic constituents. This method can be used in either initial processing or in the refinement of the final compost product. Compost is dropped on a rotating drum or spinning cone, and the resulting trajectory differences bounce glass, metal and stones away from the compost. [17]

g) Eddy current separation.

Eddy current separation systems have been developed to separate non-ferrous metals. This technology works by exerting repulsive forces on electrically conductive materials. These systems should be located after magnetic separation to minimize contamination by ferrous materials. Aluminum is the primary metal recovered from MSW, although some copper and brass will also be separated. Cans literally jump off the conveyor into a waiting bin (Figure). Eddy separators, while they do not achieve perfect removal of aluminum, do produce a relatively marketable aluminum by-product. [17]



Adapted with permission from Eriez Magnetics

Figure-16: Eddy Current Seperator.

4.4.1.5 Feeding waste to Digestion tank

Even after the removal of much of the non-compostable material, municipal solid waste needs further processing before composting. Large pieces of paper, cardboard, food and yard waste will break down slowly if not reduced to a smaller size. Reducing particle size increases surface area, enhancing composting rates because the optimum conditions for decomposition occur on the surfaces of organic materials.

There are three major types of size reducing devices available for municipal waste processing: hammer mills, shear shredders, and rotating drums.

For any composting system and material there is an optimum range of particle sizes, and for MSW this is usually between 0.5 and two inch diameters (1.2 - 5 cm).

After achieving suitable size it feed to the tank which composted for 20-25 days.[16]

4.4.1.6 Design of Digestion Tank and gas production

Design of digestion tank is very important for production bio-gas in anaerobic digestion process because disposal of bi- product is related to the design of digestion tank. After optimizing the particle size we will put waste into digester through a pipe. After 15 days it will become slur which produces methane gas as well as carbon di-oxide Sulphur di-oxide etc. Gas will stored at the top of the tank from where we can collect the gas through an outlet pipe to a gas reservoir. [16]

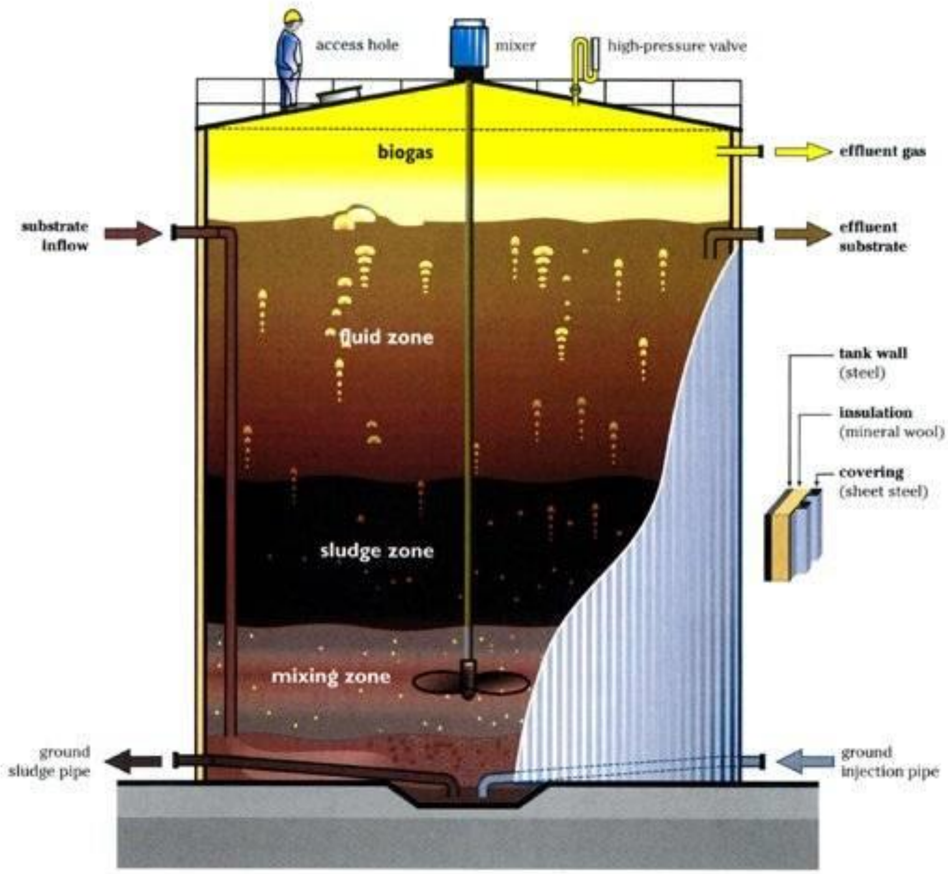


Figure-17: A typical Anaerobic Digester

4.4.1.7 Desulphurization:

SO_2 scrubbing pr0cess typically uses a calcium or sodium base alkaline regent. The regent is injected in the flue gas in a spray tower or directly into the duct. The SO_2 is absorbed, neutralized and /or oxidized by the alkaline reagent into a solid compound, either calcium or sodium sulfate. The solid is removed from the waste gas stream using downstream equipment. . Using this gas we can generate a gas generator which produces electricity that can be feed to the national grid.[16]

4.4.1.8 Bi-Product Disposal:

Bi-Product will dispose through bottom of tank after collecting the gas into gas reservoir. The dispose digested uses as compost fertilizer which will add revenue to the project.

CHAPTER 5

COST ANALYSIS

5.1 Cost analysis:

Cost of the model can be dividing into two sections i.e. capital cost and operating cost

5.1.1 Capital cost

One of the main deterrents for setting up waste-to-energy facilities is the high capital cost. In the US, the initial capital costs range from $114,000 to $326,000 per daily ton of capacity. However, experience in China has shown that by using native manufacturing resources the cost of a WTE facility in China can be as low as $40,000 per daily ton of capacity. Furthermore, new alternative processes, such as the Zhejiang Circulating Fluidized Bed process, being developed in China are apparently even less costly[1]. On the basis of the China experience, this report assumes a capital cost of $50000 per daily ton of capacity for Dhaka. If a WTE facility were set up in Dhaka using AD technology to treat 1000 tpd of MSW, the capital cost would be approximately $50 million. It is assumed that the total capital expenditure takes place in first year, i.e., Year 0. For the purposes of this study, an area of 6 ha (0.06 km2) is estimated for a WTE facility in Dhaka. This value was chosen based on a survey of approximately 20 WTE facilities and their daily capacities around the world. [29]

Since the project will constructed at the dump site so it can be assumes that land will be lent at 12,000,00 Tk per annum from government and not increased for the first 5 year and then every year it will increased by 5% .

5.1.2 Operating Cost

The main operating cost of this project will be maintenance and labor costs. The maintenance cost assumes that $ 7 million i.e. tk56 crore based on maintenance costs of a Covanta Energy WTE Facility in Essex, New Jersey. It is assumed that maintenance costs increase by $0.75 million i.e. tk6 crore every 10 years for this project.

Labor costs are calculated for a team of 35 workers, as shown in Table-10. It is assumed that labor costs for the first year are $95400, and increase annually by 5%.

Table-10: Monthly Salary estimation of working team.

Position	Number	Monthly Salary	Total Payment(Tk)	Annual payment(Tk)
Manager	1	50000	50000	600000
Assistant Manager	1	40000	40000	480000
Foreman	3	25000	75000	900000
Admin Assist.	3	22000	66000	792000
Worker	27	15000	405000	4860000
Total Annual Payment=7632000 Tk				

5.1.3 Transportation of Waste to Site:

The project will set up at the either of the two dump site and could be use City corporation's transport facility. Waste will collect from different collection point to the project site. Average distance from the different point of collection site to the dump site is 15-25 km. The project firm will pay 50% of cost to transport 1000 ton waste to the dump site. Per ton transport cost estimated 94.625 tk. So daily cost will be 94625 tk and the annual cost will be 34538125 tk. As firm will pay 50% of it that is 17269062.5 Tk and it will increase 5% every year.

5.2 Revenues:

5.2.1 Revenues from Electricity Sell

For the organic fraction of municipal solid waste and animal manure biogas yields of 80-200m3 per ton and 2-45 m^3 per m3 are reported.(T.Z.D. de Mes, A.J.M. Stams, J.H. Reith and G. Zeeman).

Organic fraction is 65% of total waste generated in Dhaka city. As mentioned earlier 6700 ton/day waste is generated in Dhaka city. So organic materials are 4355 ton/day generated in Dhaka city. By using food waste and organic waste from cafeterias and canteens around the campus, this mini biogas power plant will digest all the waste and turn it into methane in order to produce electricity. With the total amount of 1000kg of mixed food waste per day, there is about 180 cubic meter of methane can be produced and about 600kW electricity can be generated. [88]

Box no.2

Let,

We compost 1000 ton solid waste and150m^3 bio-gases generate per ton.

So total gas generation= 1000*150= 150000 m^3

0.01011 Mcf produces 1kWh electricity (US Energy Information Administration)

1 Mcf = 1000 cubic feet.

0.01011 Mcf= 1000*0.01011= 10.11 cubic feet

1 m^3 = 35.31 cubic feet

150000 m^3= 35.31* 150000= 5296500 cubic feet

10.11 cubic feet produces 1 kWh electricity

6355800 cubic feet produces 523887.24 kWh electricity or 523.88 MWh

Per ton production will be 523.88 kWh

If consider 15% of total generated electricity feedback to operate the system then the system provide 445.3 kWh electricity to the grid.

Highest Residential tariff rate is 9.98tk per unit in Dhaka in2015.

Dhaka Power Distribution Company Limited (DPDC), which is the agency responsible for setting tariffs related to power purchase, transmission, and distribution, determined the tariff, or electricity rate in Dhaka. The could give a guideline to materialize the project such a wayCity Corporation would have provided land for waste to energy power plant free of cost to a waste to energy operator. The operator will receive a sales tax benefit of no more than 50% of the total investment cost.

5.2.2 Revenue from selling compost fertilizer:

We will get bio-gas fertilizer with almost complete retention of the fertilizer nutrients like N, P and K. This would be useful for our farmers. In Bangladesh, farmers usually use Urea, TSP, DAP and MOP as fertilizer. Acting Agriculture Secretary SM Nazmul Islam said that Bangladesh's current fertilizer imports stood at 1.75 metric tons against a yearly requirement of 2.45 metric ton. Commonly used fertilizer Urea's price is 16Tk per Kg and adjustment in Urea prices would cost the government an additional Tk 6.8 billion per year for subsidy.[89] (bdnews24.com-25/08/2013). If we consider price of compost fertilizer will 6Tk per Kg which is only 37.5% of Urea's price total revenue would be tk12 million which could extra support for the model. 500 kg compost is produced from 2 ton of MSW processing [3]. So from 1000 ton of MSW will produced 250 ton compost.

Box no. 3

250 ton compost fertilizer is produced from 1000 ton waste after anaerobic digestion.

Total price= (amount of fertilizer in ton)*(1000)*(price per Kg)

Saving for using same amount of compost fertilizer instead of urea= (total price of urea)-(total price of compost)

Table-11: Price of compost fertilizer

Amount of compost	Price per Kg tk	Total price Tk (millions)	Price of same amount of Urea tk (million)
250000	6	1.5	4

So the total savings will be 2.5 million tk

5.2.3 Revenues from Greenhouse Gas Emission Credits

Clean Development Mechanism (CDM) of the Kyoto Protocol is a potential revenue sources for the WtE facilities. Reducing greenhouse gas emission, developing country could get help from the developed country under CDM is setting by Kyoto Protocol. This can either be done through Certified Emission Reductions (CERs), projects registered under the UN Framework Convention on Climate Change, or Voluntary Emission Reductions (VERs), projects that do not fall under CDM for technical reasons. Each CER or VER refers to a reduction of 1 ton of carbon dioxide that would have been emitted had the project not been implemented. We have to set our revenue carbon reduction rate. The city's composting facility was the first ever to receive CDM approval, and was projected to reduce 177,000 tons of CO_2 -equivalent per year upon completion. [35, 36]

CHAPTER 6

BENEFITS

6.1 Benefits

6.1.1 Land Required for MSW Disposal in Open Dumps

Dhaka has been unable to maintain proper disposal of waste due to the severe shortage of land. With millions of people living in slums or whole families often having to live in one room, the priority has been to develop areas for housing and development. Based on the assumptions made and calculations show in Box 3,calculates the estimated land requirement for landfill disposal of waste in Dhaka from 2007 to 2030. Assumption made on base a case study for the similar problem in Mumbai, India. [1]

Box no.4

The area required for MSW disposal can be calculated using the following formulas (based on Tchobanoglous):

$Vol_{req} = G_w \div \rho_w$

Area required/year = (Vol_{req}* 365 days/year) ÷ D_w

Where:

G_w = Amount of MSW sent to landfill per day

ρ_w = Density of MSW

D_w= Depth of compacted MSW

Vol_{req} = Volume of space required per day

Assumptions:

1. Amount of MSW generated per day taken from calculations in Table -5
2. In 2001, ragpickers removed approximately 15% of the waste before it was landfilled. [154] As consumption of recyclable material increases, the amount of waste that is recycled or removed by ragpickers increases by roughly 13% over 23 years.
3. Amount of waste destined for dump Gw = Amount of waste generated per day * (1 – amount removed by ragpickers)

4. Various sources have different estimates of waste density at the landfill, ranging from 260 kg/m3 [154] to 1 ton/m3. A density of 550 kg/m3 was chosen for the calculation.

5. Average depth of dump site is chosen 8m.

Result:

Table-12:Calculations for future land required for MSW disposal in open dumps in Dhaka

Year	Waste generated (tpd)	Amount removed by ragpickers (%)	Waste sent to dump (tpd)	Volume of space required (m3/day	Area required for waste disposal (ha/year)
2007	5340	15%	4539	8252.72	37
2015	8165.72	20%	6532.576	11877.41	54
2020	10654.48	23%	8203.95	14916.27	68
2025	13901.77	25%	10426.33	18956.96	86
2030	18138.78	28%	13059.92	23745.31	108

6.1.2 Direct Benefits of Waste to Energy to Dhaka

Dhaka will receive extra 628 MWh electricity from this model. This will mitigate energy crisis of dwellers in Dhaka. Most of garments and other industry situated in Bangladesh around the Dhaka city like Gajipur, Narayongonj which extended to Munshigonj and Mtmensingh This section focuses on the advantages of having a WTE facility in Dhaka's backyard. Contrary to public opinion and environmental opposition in Dhaka, introducing a WTE facility would decrease pollution from waste that would otherwise have been landfilled, free up land so.

6.1.3 Environmental Benefits

The MSW dumps in Dhaka are a significant source of air, surface, and groundwater pollution in the city and surrounding areas. Since emissions from WTE facilities have been discussed in great detail in Section 3.5.1, the following sections highlight the various forms of environmental pollution from landfills. Needless to say, a WTE facility in Dhaka would decrease or eliminate many of these problems. It is important to note that European countries with more stringent environmental regulations than most other countries in the world commonly use WTE technology to treat their waste and are phasing out the use of landfills.

6.1.3.1 Air Pollution

Air pollution is primarily caused by odor, methane emissions, and landfill fires. MSW in Dhaka is deposited without any soil cover, thus allowing odors to permeate to nearby housing complexes. In addition, rag pickers often start fires in order to retrieve metals and glass. This not only harms their health but also causes significant air pollution, including emissions of dioxins and furans. Industries cause air pollution through smoke emission. Agro based industries like sugar, pulp, paper, tanneries and value added industries like textile, garments, pharmaceutics, oil refineries, fertilizer and chemical industries are the major contributors for air pollution [85]. The air pollution percentage of most five industrial sectors of Bangladesh in the year 2001 is shown below:

Table-13: Air Pollution Percentage of most Five Industrial Sectors of Bangladesh in the Year 2001

Industry	Emission (tons/year)	Pollution (%)
Food Industry	146356.05	38.7
Cement/Clay	62725.88	16.6
Pulp and Paper	51963.92	13.7
Textile	39831.01	10.5
Tobacco	16992.22	4.5

Source: Research Work by Islam Faisal on “Industrial Pollution in Bangladesh” in the year 2002.Pollutants in the Air of Dhaka City

6.1.3.2 Surface Water Pollution

Dhaka is situated on the bank of river Buriganga. On the other side river Turag divides Dhaka and Gajipur. Both rivers are heavily polluted by municipal wastage and industrial waste. The Buriganga is one of most Polluted River in the world. The major portion of water pollution of Buriganga river occurred by man-made causes. Industrious wastes, agricultural wastes, domestic wastes, excess use of fertilizer, pesticides etc. are notable manmade pollutants. Water is seriously polluted by these pollutants. Water, polluted by such types of pollutants, is very harmful for both human and aquatic lives in the cities of Bangladesh. In Dhaka at Tejgaon area, food processing industries are situated along with chemical and heavy metal processing industries. In Tongi a pharmaceutical industry is situated near a pesticide producing industry. Tannery industries of Hazaribagh also situated in a heavily populated residential area. Severe pollution has reduced the river Buriganga into a 'dumping drain' of toxic refuse, threatening millions of people living on its banks with serious health hazards and a loss of their livelihoods. That the river is dying is clearly evident from its stench.[86]

All industrial, municipal (700-1100 tonnes daily) and urban wastes of Dhaka city (population 1989 about 6.5 million and expected to grow in year 2000 to 11.1 million) are flushed into the Buriganga River. It is estimated that total organic waste load discharged into the river will be around 250 metric tonnes per day (Reazuddin, 1994). The following description of Hazaribagh leather industry explains the present status of industrial pollution in Bangladesh:[86]

- pH, ………………………………….. 4-10
- Total alkalinity as CaC03 , mg/l ……670-1850
- Electrical conductivity……….. 670-2200 (Micromhos/cms)
- Chloride, mg/l ………………1300-5000
- Chromium, mg/l …………...3-36
- COD, mg/l ……………...3200-21000
- BOD,mg/l……………….200-650

- DO,mg/l……………………o.8-5
- Ammonia nitrogen, mg/l………. 12-1970 [86]

6.2 Decreases Costs and Emissions Related to Transportation of MSW and Land require in Dhaka

Diesel emissions from trucks and other vehicles can be particularly harmful to public health because they emit dioxins, polycyclic aromatic hydrocarbons, and particulate matter. In fact, it is estimated that diesel trucks emit five times more particulate matter per ton of waste than waste-to-energy plants. These emissions worsen asthma and other respiratory diseases because they are a major source of fine particles and cause high smog levels.

If the city chooses to continue landfilling the majority of the waste generated, it will need to transport the waste longer distances to neighboring towns that will accept the waste for disposal. This would not only increase the costs of trucking the waste, but also increase air pollution from vehicle emissions.

Table 7 shows the land require in future for Dhaka City. At Dhaka disposes its wastage at two dumped site named Aminbazar dumping station and Matual Dumping station. Area of these two dump station is together 60 hactre (see Table -2). The area is not enough for dumping of wastage of Dhaka City. It would also minimize the costs of transporting the residue for disposal if the residue could be used as fertilizer which increases fertility of land and will be useful to farmer.

CHAPTER 7

WASTE TO ENERGY IN DHAKA IS A SOLUTION TO WASTE MANAGEMENT

7.1 Economic Analysis

We consider capital cost will be $50 million i.e Tk400 crore and the maintenance cost $7 million i.e. 56 crore per year. Salary of working team for this project estimated Tk 7632000 per year. Revenues earn from electricity sell for the first year is Tk 146.65 crore and at last year it will be Tk169.77 crore and from fertilizer selling Tk 4200000 at first year and for last year it will be Tk 4862025(Appendix-3). Net revenue will be Tk 247.87 crore for life time of the project and payback period will be 7.1 years (Appendix-5)

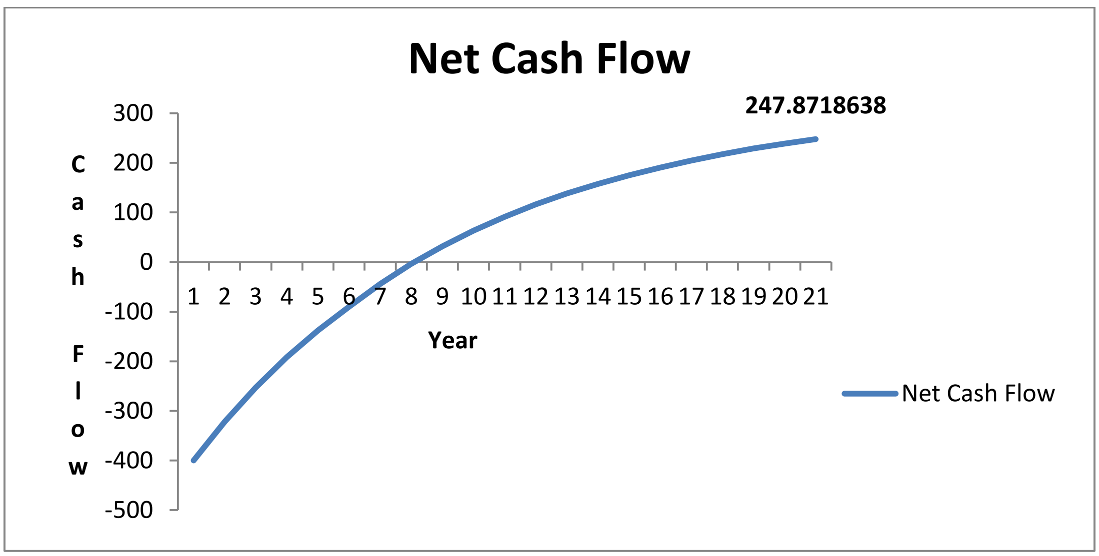


Figure-18: Cash Flow diagram

Table-14: Economical Status of the model

Interest Rate	13%
NPV	Tk247.8718638
IRR	22.3158%
Payback Period	7.102141783 Years

7.2 WTE is an Integral Part of Dhaka Life

The previous sections show the numerous benefits Dhaka can derive from waste-to-energy technology. Waste-to-energy is not only a solution to reduce the volume of waste that is generated and provide a supplemental energy source, but also yields a number of social benefits that cannot easily be quantified. For citizens who live or work near dumps, it provides a cleaner, less polluted, and less congested neighborhood. In addition to all these reasons, a waste-to-energy facility in Dhaka could serve as an example of how a municipality can adopt a successful solid waste management strategy for the benefit of all its citizens. A WTE facility in Dhaka can provide leadership and encourage other cities in BD to adopt similar waste management solutions. As other cities have done, Dhaka can create a WTE facility that is a highlight of the city

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

As described in this report, Bangladesh, and in particular Dhaka city is facing significant solid waste management challenges. These challenges present numerous opportunities to improve methods in waste collection, transport, and disposal. Given that solid waste management directly affects public health, land use, and the environment, stringent waste management regulations need to be formulated, enforced, and monitored.

Although the Bangladeshi economy has been growing over the last decade or so, it still lacks sanitary landfills. Like other developing countries, the majority of MSW disposal takes place in open dumping grounds. These dumping sites have to tackle for landfill gas capture or leachate collection, thus contributing to both increased greenhouse gas emissions as well as environmental pollution. The average waste generated in Dhaka is 0.42kg/person/day, which is very low compared to developed countries. However, it is estimated that the amount of MSW generated will increase by 1.8% annually. Bangladesh is also similar to other developing countries in terms of its general waste characteristics, it has a high fraction of organic matter and inert materials and moisture content between 45-55%.

Dhaka is capital of Bangladesh, highest number of employment opportunities it provides for the country. Although it attracts thousands of people every day, it has been unable to maintain and upgrade its infrastructure, including roads, water supply, electricity supply, housing, and solid waste management. Dhaka city generates 6700 tons of MSW, 4000 tons of C&D waste, and 100 tons of biomedical waste daily. The collected waste is taken to three dumping grounds, either directly or via transfer stations.

Following the creation of two City corporations in Dhaka it has adopted a number of approaches to improve its waste management services.

The goal of this report is to highlight the suitability and benefits of introduction of waste-to-energy technology in Bangladesh, and uses in Dhaka as a case study. Since Bangladesh's GDP increasing, the amount of waste generated will also increase correspondingly. The Government of Bangladesh recognized bio-gas as a renewable technology and provides various funding mechanisms for development of WTE facilities.

Although there is strong environmental opposition to waste-to-energy, it offers a more environmentally friendly option of waste disposal compared to landfilling. It reduces the amount of greenhouse gas emissions by diverting MSW from landfills and providing a renewable source of power. Emissions of pollutants from waste-to-energy, such as dioxins, will mitigate. Finally, waste-to-energy prevents surface and groundwater and air pollution from landfills. From an economic standpoint, an integrated waste management approach that includes waste-to-energy is also favorable for a city like Dhaka. The revenues generated from selling electricity, greenhouse gas emission reduction credits and selling fertilizer byproduct waste-to-energy would be a profitable venture.

In terms of future work, two important topics stand out: more research and more outreach. More research is needed to quantify various aspects of the solid waste management sector. A number of key statistics, such as the value of recyclables, the amount of environmental pollution from waste sources, and the quantity of industrial waste generated, need to be computed to get a better understanding of this sector. In terms of research related to waste-to-energy, detailed analysis of costs and available funding is needed. In addition, investigating the suitability and quantifying the costs and benefits of combined heat and power for Dhaka would be useful. Independent researchers or consultants should carry out such research in order to prevent any bias decision that may otherwise occur.

Outreach to both environmental groups as well as the public at large is important in order to demonstrate the benefits of waste-to-energy technology to the community, city, and local government. This can be achieved by educating the public through campaigns, workshops, town hall meetings, university lectures, and so on. Creating an open dialogue with environmental groups is an essential first step of sharing information and collaboration to create better environmental conditions. Furthermore, it would be useful to develop a methodology for incineration to be included in the approved CDM methodologies. This would make incineration a more viable option for local promoters and encourage funding from foreign companies in developed countries. Before any final decision the case of technology should be carefully evaluated for the suitability of our environment.

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Appendices

Appendix-1

Year	Projected population	Projected waste	Per capita waste
2007	11	5340	0.485
2015	14.6	8165.72	0.56
2020	17.42	10654.48	0.62
2025	20.79	13901.77	0.67
2030	24.81	18138.78	0.73

Appendix-2

Year	Tarrif Rate	Electricity per ton	Daily MSW Treated	Daily revenue	Revenue per Anumm
	Tk	KWh	ton	Tk	Tk
1	9.98	445.3	1000	4444094	1466551020
2	9.98	445.3	1000	4444094	1466551020
3	9.98	445.3	1000	4444094	1466551020
4	9.98	445.3	1000	4444094	1466551020
5	9.98	445.3	1000	4444094	1466551020
6	10.479	445.3	1000	4666298.7	1539878571
7	10.479	445.3	1000	4666298.7	1539878571
8	10.479	445.3	1000	4666298.7	1539878571
9	10.479	445.3	1000	4666298.7	1539878571
10	10.479	445.3	1000	4666298.7	1539878571
11	11.00295	445.3	1000	4899613.635	1616872500
12	11.00295	445.3	1000	4899613.635	1616872500
13	11.00295	445.3	1000	4899613.635	1616872500
14	11.00295	445.3	1000	4899613.635	1616872500
15	11.00295	445.3	1000	4899613.635	1616872500
16	11.553098	445.3	1000	5144594.317	1697716125
17	11.553098	445.3	1000	5144594.539	1697716198
18	11.553098	445.3	1000	5144594.539	1697716198
19	11.553098	445.3	1000	5144594.539	1697716198
20	11.553098	445.3	1000	5144594.539	1697716198

Appendix-3

Year	Capital cost	Maintainence cost	Salary	Transport	Land	Total Cost	Revenue(Electricity)	Revenue(Fertilyzer)	Total Revenue
0	400								
1		56	0.7632	1.73	0.12	58.6132	146.65	0.42	147.07
2		56	0.8014	1.8165	0.12	58.73786	146.65	0.42	147.07
3		56	0.8414	1.907325	0.12	58.86875	146.65	0.42	147.07
4		56	0.8835	2.002691	0.12	59.00619	146.65	0.42	147.07
5		56	0.9277	2.102826	0.12	59.1505	146.65	0.42	147.07
6		56	0.9741	2.207967	0.126	59.30803	153.98	0.441	154.421
7		56	1.0228	2.318365	0.1323	59.47343	153.98	0.441	154.421
8		56	1.0739	2.434284	0.1389	59.6471	153.98	0.441	154.421
9		56	1.1276	2.555998	0.1459	59.82945	153.98	0.441	154.421
10		56	1.184	2.683798	0.1532	60.02093	153.98	0.441	154.421
11		62	1.2432	2.817988	0.1608	66.22197	161.69	0.46305	162.15305
12		62	1.3053	2.958887	0.1689	66.43307	161.69	0.46305	162.15305
13		62	1.3706	3.106831	0.1773	66.65472	161.69	0.46305	162.15305
14		62	1.4391	3.262173	0.1862	66.88746	161.69	0.46305	162.15305
15		62	1.5111	3.425282	0.1955	67.13183	161.69	0.46305	162.15305
16		62	1.5866	3.596546	0.2052	67.38842	169.77	0.4862025	170.2562025
17		62	1.666	3.776373	0.2155	67.65785	169.77	0.4862025	170.2562025
18		62	1.7493	3.965192	0.2263	67.94074	169.77	0.4862025	170.2562025
19		62	1.8367	4.163451	0.2376	68.23777	169.77	0.4862025	170.2562025
20		62	1.9286	4.371624	0.2495	68.54966	169.77	0.4862025	170.2562025

Appendix-4

	Cash Flow Chart		
Year	Negative CF	Positive CF	CF
0	-400		
1	58.6132	147.07	88.4568
2	58.73786	147.07	88.33214
3	58.868753	147.07	88.20125
4	59.0061907	147.07	88.06381
5	59.1505002	147.07	87.9195
6	59.3080252	154.421	95.11297
7	59.4734265	154.421	94.94757
8	59.6470978	154.421	94.7739
9	59.8294527	154.421	94.59155
10	60.0209253	154.421	94.40007
11	66.2219716	162.15305	95.93108
12	66.4330701	162.15305	95.71998
13	66.6547236	162.15305	95.49833
14	66.8874598	162.15305	95.26559
15	67.1318328	162.15305	95.02122
16	67.3884245	170.256203	102.8678
17	67.6578457	170.256203	102.5984
18	67.940738	170.256203	102.3155
19	68.2377749	170.256203	102.0184
20	68.5496636	170.256203	101.7065

Appendix-5

	NPV, IRR and PB		
Year	Cash Flow	Present Value	Net Cash Flow
0	-400	-400	-400
1	88.4568	78.28035398	-321.719646
2	88.33214	69.17702248	-252.5426235
3	88.201247	61.12788855	-191.414735
4	88.063809	54.01118351	-137.4035515
5	87.9195	47.71918209	-89.6843694
6	95.112975	45.684524	-43.9998454
7	94.947574	40.35847673	-3.641368661
8	94.773902	35.65013796	32.0087693
9	94.591547	31.48809147	63.49686077
10	94.400075	27.80916207	91.30602284
11	95.931078	25.00900702	116.3150299
12	95.71998	22.08316293	138.3981928
13	95.498326	19.49736829	157.8955611
14	95.26559	17.21225825	175.1078193
15	95.021217	15.19301396	190.3008333
16	102.86778	14.55540397	204.8562373
17	102.59836	12.84715211	217.7033894
18	102.31546	11.33781321	229.0412026
19	102.01843	10.00433439	239.045537
20	101.70654	8.826326846	247.8718638

Interest Rate	13%
NPV	247.8718638
IRR	22.3158%
Pay back Period	7.102141783