Feasibility of Waste to Energy Conversion in Bangladesh

A Thesis

Submitted to the Department of Electrical & Electronics Engineering, BRAC University

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DECLARATION

This is to declare that this thesis titled "Waste to Energy Conversion in Bangladesh" is submitted to the department of Electrical and Electronics Engineering of BRAC University for the partial fulfillment of the degree of Bachelor of Science in Electrical and Electronics Engineering. We hereby affirm that the theoretical research and result was conducted solely by us and has not been presented previously elsewhere for assessment. Materials of the study and work found by other researchers have been properly referred and acknowledged.

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Abstract

Bangladesh is one the fastest developing countries with lots of opportunities due to its rich natural resources and human power. With the governments vision of digital Bangladesh the usage of electronic equipment is increasing day by day. Not only that due to huge population in the capital city Dhaka the wastage is increasing day by day. According to various sources the current population of Dhaka city is around 14.7 million. The total amount of waste developed in Dhaka city per day is around 4,634.52 tons. The contributions of different sectors to the total generation of Dhaka city, where nearly 76% of generated waste came from the residential sector, 22% came from the commercial sector, 1% from the institutional sector and rest from other sectors. The per capita waste generation rate is computed as 0.56 kg/capita/day. And it will increase more day by day. It is estimated that around 2030 the per capita waste will be around 0.78 kg per day.

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 rapidly going solid waste management problem. The solution needs to be cost effective, sustainable, useful, climate change impacts and etc. Waste-to-energy (WtE) is a strategy that is effective, environmentally sound, and economically beneficial.

There are many ways to produce energy from waste. For example direct combustion, gasification, pyrolysis, composting, plasma arc, refused derived fuel etc. The feasible methods for Dhaka city would composting that is Biogas, also direct combustion and pyrolysis. Along with that the important part is how to manage the electronic wastes.

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Chapter 1

1.1 Introduction:

A critical increment of municipal solid waste (MSW) generation has been provoked to by Overpopulation, consumerism, urban and modern improvement and the variables like these are consistently driving an exponential increment in rate of solid wastes to such a degree to the point that it postures genuine risk to the regular habitat and putting weight on national assets. Absence of appropriate transfer and frustrating condition of waste administration has now turned into a worldwide concern which must be tended to taking effect right now.

To dump filths transparently and wildly close destinations without appropriate supervision hinders the whole urban seepage mechanism as well as it creates stationary water in this way, which accelerates the pollution of water supply. This stances risk to the strength of inhabitants of significant city enterprises of improving and recently promoted to developing countries like ours.

The database in regards to the sorts, amount and attributes of waste alongside gathering, activity, stockpiling, administration design and transfer are worse than average that it needs work to a reasonable administration mechanism which requires instructive, institutional and ecological maintainability.

With developing requests of power for the mass, industrial facilities, workplaces all through the city and overly significant urban communities in Bangladesh there is an open door utilizing the MSW to produce impressive quantity of power by methods for burning and thermal plasma arc gasification which should not be underestimated. Because of fluctuating expenses of energizes and flammable gas, this procedure can be an option and reasonable choice to determine the issue immediately and in the long run, for the upcoming days [35].

1.2 Objective:

To discover new ways and choices of legitimate disposal of waste accumulation in mass and overseeing those for controlling the production effectively is the main reason for this research. This investigation will in the end help in sort of decision making forms as to receive the accompanying techniques or not. This observation includes managing measure of waste production, attributes, administration mechanisms and conceivable cures of various city organizations with respect to Bangladesh alongside the relative effects of the surroundings. The factors that can be used are:

- Estimation of energy produced utilizing Municipal Solid Wastes as an information.
- Estimation of the density of waste produced in various parts the all over the country.
- Estimation of the offshoot created that can be reused for different purposes and create techniques to check natural impacts if there is any.

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.

1.4 Literature Assessment:

1.4.1 What is Solid Waste?

Solid waste stands for municipal waste and falls under the following classes: residential (household waste), industrial, institutional, street sweeping, construction, sanitation and business [30]. Moreover, municipal strong or solid waste refers to solid wastes from homes, streets and public locations, shops, workplaces, and hospitals, which might be extra frequently the obligation of municipal or different governmental authorities. Solid waste from commercial approaches is normally no longer taken into consideration as municipal. However, in view that this waste ultimately ends up within the municipal waste flow, it need to be taken into consideration whilst managing solid waste.

1.4.2 Primary Operational elements of Solid Waste control device:

The actions associated with management of SWM from the factor of production to proper disposal are compiled into some simple practical factors [32]:

- Waste production
- Waste managing, sorting and processing at the unit
- Gathering
- Handling and transformation
- Disposal

Practical elements are quite interconnected however they are not always presented in all municipal solid waste management process.

In lots of underdeveloped or growing nations the process is limited to-

- Waste production
- Handling wastes at the unit
- Gathering
- Disposal at landfills

On the other hand, in most developed countries almost every functional elements are determined in the system.

Chapter 2

An Overview of Solid Waste Management in Bangladesh

2.1 **Background**

Humans and waste are directly proportional to each other. The more the humans the more waste is produced. Bangladesh is a small country approximately 130,170 Km^2 of land and an estimated population of **165,998,382** which is 2.18% of the world population. [38] And it is a developing country so its standard of living is increasing day by day for which the consumption of goods and energy is increasing.

Solid Waste management is the least prioritized sector not just in Bangladesh, but also in developing countries. Solid Waste management is an important sector for the developing countries. Due to poor solid waste management in Bangladesh it leads to health, environmental problems and lowers the living standard of people. This happens due to lack of proper management, knowledge, practices and funds. Government and both the people give less or no attention to Waste Management.

Here, an overview of how wastes are produced, collected, disposed and types of wastes produced in main cities of Bangladesh are given. Along with the comparison between other countries are made where appropriate to show the condition of Bangladesh Solid Waste Management. Suggestions on how Bangladesh should do or take steps for solid waste management and how Bangladesh can be benefit through better solid waste managements. Furthermore, better solution that is Waste to Energy process is discussed how it can help Bangladesh to generate energy and dispose wastes in an effective manner while discussing the current condition of electricity and renewable energy sectors in Bangladesh.

2.2 MSW Generation in Bangladesh

Not just humans and waste are directly proportional but also their economic growth and living standard are directly proportional to waste. Normally higher per capita countries consume more goods and produce higher wastes compared to the lower per capita countries. But the lower per capita countries normally produce less renewable materials compared to the higher per capita countries.

Dhaka, the capital city of Bangladesh is one of the most densely populated city Worldwide. Around 19 million people are living in Dhaka city that is 2900 people approximately live in a square kilometer [39] . The highest waste is generated in Dhaka compared to other major cities which is shown in table 2.

In the table below the growth rate and production of solid waste in Dhaka from 1991 to 2025.

Table 1. Urban solid waste production in Bangladesh.

Year	**Total urban 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

The table show how dangerously waste is increasing day by day. 7690 tons of municipal solid waste (MSW) is generated in the major cities of Bangladesh. [40]

Table 2

	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/day)	0.485	0.360	0.347	0.378	0.325	0.430	0.387

DCC = Dhaka City Corporation, CCC = Chittagong City Corporation, KCC = Khulna City Corporation, RCC = Rajshahi City Corporation, BCC = Barisal City Corporation, SCC = Sylhet City Corporation

2.3 MSW in Dhaka City:

As mentioned, Dhaka is one of the densely populated cities and by 2020 the population will rise above 20million.[41] . Only around 50% waste is collected properly and transported to the two landfills available and other wastes are disposed in unorganized and unhygienic manner in different parts of the city. Dhaka annually generates around 1.7million of waste. 80% of the wastes are organic wastes such as food, cloth, agriculture etc. The problem is Dhaka is growing at the higher rate and in an unplanned manner for which the city is facing trouble with the waste management. In recent reports Dhaka is marked as the most polluted city in the world according to the US Air Quality Index (AQI). The AQI showed that the Dhaka city's air has an index of 387, the most hazardous city.[42] . In Dhaka around 0.29kg to 0.60 kg is generated per capita by person in a day. The more the income the higher the tendency to generate more waste[43] Due to rapid increase in Urban population and industrialization waste management have become the top priority for the government.

2.3.1 Waste Collection overview

Initially, Dhaka had only one governance body to look after the wastes that was Dhaka City Corporation. Later, due to rapid increase of population and waste management problems Dhaka City Corporation has been divided in two parts. Dhaka North City Corporation (DNCC) and Dhaka South city Corporation (DNSC). DNCC covers around 75 square kilometers and DSCC covers around 42 square kilometers. Moreover DNCC has 32 wards and DSCC has 56wards both are responsible to collect and supervise the waste produced in the wards.

Dhaka city generates around 4000-5000tons of waste per day. DNCC and DSCC collects around 40%-60% of the waste generated in the city. And the remaining is not collected due to lack of proper transportation and funds, mainly the slums are neglected by the city corporations. [44] . As the wastes are not collected properly bad odors, rodents and sewer drains. Mainly in the rainy seasons, the condition gets worst due to this lack of concern of proper collection. But the condition has improved a bit and is improving due to two major plan. First plan was innitiadted by Japan International Cooperation Agency (JICA) in 2005 with the objectives of formulating a master plan of Dhaka City and to develop capabilities

and management skills of the Dhaka City Corporation. And the second plan 3R Strategy was undertaken in 2010 by Department of Environment (DoE), Ministry of Environment and Forestry of the Government. The principle of reducing, reusing and recycling of resources and products is often called the 3Rs.[45].

DNCC and DSCC follow the same method for collection and transportation of the wastes. Small vans are used to collect wastes from the households and then those are transported to the local nearby stations or dump yard. City Corporations workers collect rest of the waste from the roadsides as much as possible and takes to the nearest dump yard or sites where big bins are put by the City Corporation. Later big trucks or known as waste transportation truck of city corporations transports the waste from the various big bins from part of the city to the two main dump station which are located at the Amin Bazar and Matuail Landfill. And the remaining wastes remains on the roads, sidewalk and in the slam areas. As city corporations do not collect waste due to insufficient man force and budget from the slam areas were around 30% of the population of Dhaka lives.

Table 3: Basic Information of Solid Waste Management at DNCC and DSCC

Items	DNCC	DSCC
Total Zones	5	5
Total Wards	36	57
Amount of Waste Generated (2012)	2186 t/day	1938 t/day
Amount of Waste collected (2012)	1100 t/day	1400 t/day
Waste Disposal Site	Amin Bazar	Matuail
Area of Disposal Site	20 hectare	40 hectare
Number of Waste management Officials	257	352
No. of Ward SWM Offices	7	10

Number of cleaners	2661	5300
Waste Collection Vehicles	115	235

Source: [46]

The transportation of the waste is not done in proper manner, the condition of the vehicles are too poor. The vehicles were brought for safe and hygienic transfer of the wastes around the city. But due to lack of proper management, the condition of the vehicles have become poor. So, the wastes are transferred in unhygienic and improper manner. While transferring the wastes the truck liters the wastes in the roads. Not only that due to poor trucks/vehicles many types the wastes are not collected on proper time so wastes are piled up and the conditions gets worst.

Few NGOs are working informally to solve the crisis created by the city corporations in the slums by not collecting wastes from there properly. NGO's are focusing on recycling process in the slums.

Table 4 : Waste Management in DNCC (Source: DNCC 2016/2017 annual report)

Month	**Waste(Ton)**
July (2016)	65,966
August	74,853
September	67,408
October	66,485
November	63,493
December	66,200
January	69,142
February	63,446

March	72,948
April	71,780
May	84,076
June(2017)	86,594
TOTAL	852,391

2.3.2 Waste Disposal in Dhaka

Proper Waste disposal is a big challenge for not only Dhaka or Bangladesh for the World. Improper waste dumping causes hazardous problems like environment and health problems. Dumpsites for municipal solid waste are situated on low-lying, flood-prone land. They are not managed as sanitary landfills, apart from efforts by JICA and Waste Concern at Matuail site. The wastes are transferred to the two location as mentioned. Most of solid waste was disposed of at landfill sites without any intermediate treatment in Dhaka. [47] The dumped solid wastes are dressed irregularly by pay-loaders, excavator, tyre dozer, chain dozer etc. Though through the intervention JICA the present condition of the landfills have improved. JICA build the Amin Bazar landfill and improved the Matuail landfill. Major clean landfill segments presented under the project of JICA. Steps like leachate collection and gas venting systems, surface drainage improvement, proper collection of waste, waste transporting vehicles being washed properly.[46] Both landfills now facilities the same way but still not enough to tackle the waste disposal problem of Dhaka.

2.3.3 Waste Recycling in Dhaka.

It is said that only 6% of the wastes are being recycled though mainly through informal sector like waste pickers, plastic bottle collectors etc. The informal sector is playing a great part in

recycling the waste. This has huge scope of improvement. DNCC and DSNC also need to work on the recycling. [47].

Table 5 : Estimated Volume of Recycled Wastes in Dhaka City (48)

Material	a) Estimated generation of recyclables (t/d)	b) Estimated recycled waste (t/d)	c) Recycle rate	d) Contribution to waste reduction (b / 3,200)
Plastic	124	103	83%	3.2%
Paper	260	168	65%	5.3%
Glass	46	24	52%	0.8%
Metal	27	41	N/A	1.3%
Compostable	2211	6	0%	0.2%
Others	99	94	95%	2.9%
Total	2767	436		13.6%

2.4 Solid Management in Other major Cities of Bangladesh

Not only in Dhaka but other major cities are now growing up with the waste problems. On average all the major cities produce 0.40kg/day of wastes. None of the cities Chittagong, Khulna, Sylhet, Rajshahi, Comilla none of them have proper solid waste management and which has been resulted into environment problems. Along with Dhaka city's waste management the government needs to work on with the waste management of the other major cities.

Chapter 3

Waste to Energy

3.1 WtE Overview:

Around 2500 WTE plants are active all over the world and the disposal capacity has been 300 million tons per year. Moreover, around 280 thermal plants with a capacity of almost 75 million annual tons were constructed between 2011 and 2015. Again, there are various ways of waste to energy conversion technologies and among more traditional approach is direct incineration of solid wastes. Considering that 70s [29] advanced thermo-chemical processes which include pyrolysis, gasification and plasma arc gasification are quite evolved and experimentally carried out to choose waste streams on a minimal extent in a particularly designed closed chamber with temperatures and pressures used to control the parameters. Moreover, every generation makes use of various kind of requirements for the input operating in particularly designed system configurations in special modes to generate extensive variable products on different particular scales. towards the WtE facilities. China has developed new CFB technology incineration method to burn waste to produce energy which is better than the old incineration method. There are currently 28 CFB power plants in china and there research for suitable waste to power plant energy is ongoing. Not only the WtE is beneficial for the environment but also economically beneficial for the countries. The global WtE market was valued at US$25.32 billion in 2013, a growth of 5.5% on the previous year. WtE technologies based on thermal energy conversion lead the market, and accounted for 88.2% of total market revenue in 2013. [49]

The sections stated below state the thermo-chemical transformation technologies for calorific waste treatment and a brief passage of situations mentioned in the table 3.1.

Incineration is all about full oxidative combustion. Also similar process like coal combustion.

Gasification is mainly partial oxidation

Pyrolysis is related to thermal degradation of natural material in situations where oxygen isn't present

Plasma Arc Gasification is a combination of the organic fraction and vitrification of the inorganic fraction of the waste feed and it is applicable to both pyrolysis and gasification. About vitrification it can be said that it is responsible for impermeability of water

Table 6: Reaction conditions and products from various thermos-chemical approaches (based on Kolb and Seifert)

	Pyrolysis	**Gasification**	**Combustion**	**Plasma Treatment**
Temperature [°C]	250-900	500-1800	800-1450	1200-2000
Pressure [bar]	1	1-45	1	1
Atmosphere	Inert/Nitrogen	Gasification Agent:O_2 , H_2O	Air	Gasification Agent:O_2 , H_2O Plasma Gas:O_2, N_2, Ar
Stoichiometric Ratio	0	<1	>1	<1
Products From The Process				
Gas Phase	H_2, CO, H_2O, N_2, hydrocarbons	H_2, CO, CO_2, CH_4, H_2O, N_2	CO_2, H_2O, O_2, N_2	H_2, CO, CO_2, CH_4, H_2O, N_2
Solid Phase	Ash,Coke	Slag,Ash	Slag,Ash	Slag,Ash
Liquid Phase	Pyrolysis oil and water	N/A	N/A	N/A

3.1.1 Pyrolysis

3.1.1.1 Records of Thermal Plasma Gasification system:

Gasification has turned out to be one of the first industrial thermo chemical methods. Towards the termination of the 19th century all through the industrialization of Europe gasification process was discovered, in general for producing oil and gas from coal, which consists of mostly carbon. Using gasifiers decreased for petroleum was now simply more available soon after WWII ended. Between mid 70s and 80s, using gasification for generating alternative fuels started out. Even today, this utility has been the biggest use of gasification. In the 80s, United States, Europe and Japan has centered at the improvement of gasification for the elimination of rock-hard wastes. Today, there are around 150 industrial gasifiers all over the world. Those are specifically used to deal with coal and biomass. Using gasification for MSW has been often implemented in Japan, in which their shortage of area compelled them to discover options to landfilling. Additionally, Japan has the only business plasma arc facility that treats municipal solid wastes, in Utashinai where Hitachi metals is one of the operators. The thermo-select is a procedure made by the Germans but due to a few technical problems it was shut down later on. Siemens faced similar problems with waste gasification at their Fürth plant which brought a critical twist of fate, ensuing in plug of waste shaped in the pyrolysis chamber which created an overpressure and get away of pyrolysis gas. Reputedly, this problem was the result of processing mattresses that aren't shredded at all and this problem instantly faded away in later versions of the gasifier. But Germany is not thinking about the use of it. Other than Germany, gasification is usually considered as a better opportunity compared to grate combustion because it isn't related to the old and polluting incinerators. Therefore, there may be a market for gasification in competition to grate combustion. Gasification is the breakdown of the natural a part of the waste into synthesis fuel or syngas, which is a combination of CO and H_2, through carefully control and screen of the amount of oxygen gift. The important thing difference from combustion is that the overshoot will be useful, partly oxidized and the sub-stoichiometric quantity of oxidant permits preserving CO and H_2 as very last products instead of the completely oxidized CO_2 and H_2O. [37]

3.1.1.2 An Introduction to Plasma Arc Gasification Operation & basic concepts:

Plasma Arc Gasification is an upgraded version of pyrolysis that requires high-temperature where the organics of waste solids are converted into syngas and inorganic materials and minerals of the waste solids yield a rock alike glass referred to as vitrified slag. The syngas is typically composed of H_2 and CO and it is not a hydro-carbon product. The process containing a reactor with a plasma torch processing organics of waste solids is called plasma arc gasification. Commercially, the process is operated using an infusion of a carbonaceous material like coal or similar material made of coal into the gasification reactor. This material rapidly reacts with oxygen to create heat for the pyrolysis responses in an oxygen-insufficient surrounding. Equation (3.6) demonstrates the carbonaceous materials as C that can react with oxygen to create controlled burning yet with the sufficient warmth required for the syngas reactions (Equations [3.1, 3.2, 3.3, 3.4 and 3.5]). Likewise, steam is added to the plasma arc gasification reactor to advance syngas responses. The ignition responses (exothermic responses) supply warm with extra warmth from the plasma circular segment lights for the pyrolysis responses (endothermic responses), yielding a temperature normally within 4000ºC and 7000ºC. The inorganic minerals of the waste solids create rock-like offshoots.

Since working conditions are high these minerals are changed over into a vitrified slag regularly involving metals and silica glass. This vitrified slag is essentially non-filtering and surpasses Environmental Protection Agency scales, shortly known as EPA scales. Metals can be recuperated from the slag and the slag can be utilized to deliver other offshoots, for example, shake fleece, floor tiles, rooftop tiles, protection, and arranging pieces and besides that, vitrified slag, being naturally adequate as a recyclable result, is one of the more positive qualities of plasma arc gasification process for the administration of MSW contrasted with others. Another affirmative way of the gasification process is that advancements in the outline of the reactor/chamber have enhanced tremendously and diminished the requirement for pretreatment/preprocessing. [33]

$$C_nH_m + nH2O \leftrightarrow nCO + (n+ 1/2m)\ H2;\ -205kj/mol\ (exothermic) \qquad (3.1)$$

$$C + 2H_2 \leftrightarrow CH_4; +172kj/mol \text{ (endothermic)} \quad (3.2)$$

$$C + H_2O \leftrightarrow CO + H_2; +131kj/mol \text{ (endothermic)} \quad (3.3)$$

$$C + O_2 \rightarrow CO_2; -393kj/mol \text{ (exothermic)} \quad (3.4)$$

$$C + CO_2 \leftrightarrow 2CO; -74kj/mol \text{ (exothermic)} \quad (3.5)$$

$$CO + H_2O \leftrightarrow CO_2 + H_2; -41kj/mol \text{ (exothermic)} \quad (3.6)$$

3.1.1.3 An example of pyrolysis which can be implemented in Bangladesh

Alter NRG(Westinghouse)Plasma Corporation:

The accompanying matter talks about the foundation of Alter NRG and the diverse phases of their task of plasma gasification and determination rule of the reactor.

3.1.1.3.1 Background

Westinghouse Plasma Corporation's plasma innovation was created over a period more prior to 20 years and investing more than hundred million dollars in Westinghouse research and development financing. In 80's decade, Westinghouse and the Electric Power Research Institute built up a reactor utilizing plasma for recovering divided pieces of metal. Moreover, Westinghouse expanded the plasma vault innovation for the treatment of unsafe –solid wastes including sullied landfill objects, PCB-defiled electrical equipment, transformers and capacitors and steel industries' till late 1990.

A progression of tests were executed at the WPC Plasma Center in Madison utilizing an assortment of sustain materials and at different dampness substance.

WPC and Hitachi Metals have joined endeavors finished in the exhibition to the Japanese government that the Yoshii WTE institute was equipped for utilizing plasma vitality to dependably and financially gasify remains for vitality generation. In September 2000, The Westinghouse Plasma Gasifier was conceived right after when the Japanese Waste Research Foundation granted a procedure confirmation of the innovation.

Full scale offices in Mihama-Mikata and Utashinai Japan were connected to the lessons learned at Yoshii, which both started business task in 2002 and 2003 and keep working till now. In 2007 Westinghouse Plasma Corporation was procured by Alter NRG. Different undertakings were embraced by the organization to manage waste administration which were at first illustrated, enhanced and in the end popularized in various parts over the world. That office treats unsafe wastes from less than 50 distinct enterprises.

Today air Products obtained a plasma gasification reactor from Westinghouse for Air Products' thousand tons for every day plant to be worked in England [34]. The accompanying figure 3.3 denotes the business history of this Plasma Corp Technology.

As indicated by them the plasma gasification process notwithstanding power can likewise create ethanol, gas, diesel fuel and is the best option accessible to fight shy of landfilling. These provide many crucial features that include:

- governments are embracing this plasma arrangement because of energy independence
- Exclusive IP, specialized mechanism and dynamic licenses around the world
- Pilot tests are performed over a hundred times on various feedstock at their reality class plasma core with a normal of 48 tons for every limit
- Scale-30 to 1000TPD for every gasifier [34]

They have designed quite a few product line of models depending upon demand and supports distinct market verticals described in the figure 2 -

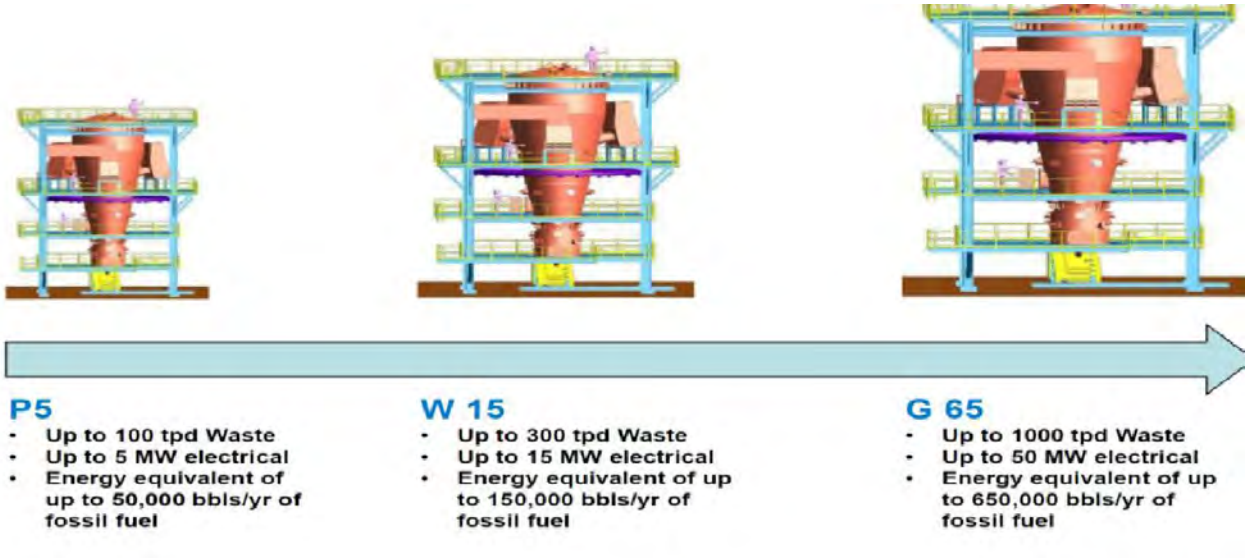


Figure 2: Gasifier reactor models [39]

Point to be noted:

- Ground level to syngas exit flange. Ductwork height excluded as it is project specific.
- MSW calorific value (C.V) range -14 MJ/kg (4000-6000 Btu/lb) HHV basis.
- Hazardous waste (C.V) range -14.0-23.3 MJ/kg (6000-10,000 Btu/lb) HHV basis

Point to be noted:

The real results from a WPC gasification space will rely upon the amount of particular feedstock being utilized and the real design of the plant. Gasifiers can be introduced in parallel to make a plant with the ability to suit any requirements. The above Table 3.5 records the amount of syngas, gross and net power age from various models.

3.1.1.3.2 Mechanism:

Inside the gasification chamber the unchanged plasma burn comprises of chilled water run through a pair of copper tubes. The working gas is infused through the little spaces between the terminals. Pressurized air through the electric bend will change over the air stream into a plasma crest which will be known as ionized gas with a temperature around 5800 °C. These lights are utilized to make massive heat inside the gasifier. These lights help temperatures as

well as they give critical capacities in devastating dangerous waste and vitrification of WTE slag.

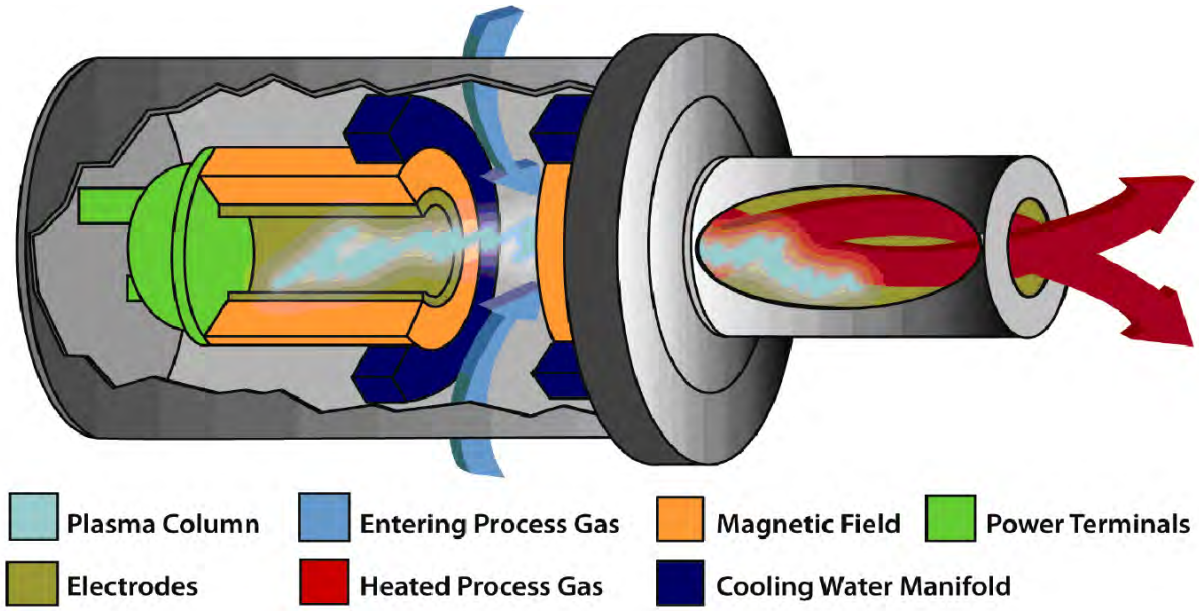


Figure 3 WPC plasma torch [43]

WPC has built up a gasifier based on plasma where the plasma planes are situated at the base of the gasifier. Six plasma lights at their peak are utilized at the base to give adequate warmth to the gasification to occur. A streamlined chart demonstrating the internals of a plasma burn is being appeared in figure 3 that is stated above. Inside the dome a bed coke is made utilizing metallurgical coke (met coke) to assimilate and hold the warmth vitality from the plasma burns and give a "structure" that backings the MSW bolster as it slides through the gasification reactor and is changed over to gas and fluid slag, this activity is like the marvels happening in an impact heater. The met coke is sustained at the same time as the MSW and is vital for the activity of the gasifier. The real speed of the plasma fly leaving the lights is about Mach2, so we better put restriction towards the gas speed and permits appropriation of warmth equally. A decent basic trustworthiness has been earned by the met coke and can bolster the heaviness of the waste on its own. This procedure can deal with any dampness content in the MSW since it fades away alongside the syngas. The waste coming in ought to be around 10” in terms of dimension.WPC accommodates the gasification island, which incorporates the gasifier and the plasma burn framework and the rest units are accessible

independently.The procedure is totally controlled by the observing of the temperature of the gases that come out eventually. The last ought to be between 982ºC to 1093ºC, keeping in mind the end goal to keep the tar arrangement and that little particles blend into those gases. Consequently, the keys for the procedure control are the plasma lights. Pretty much warmth will be included through them depending whether we need to turn up or down the syngas temperature. As the blend of waste and met coke is going down through the gasifier, the waste will begin gasifying while the met coke will stay strong. The bed coke will gradually gasify yet will stay at the base. The bed waste will lie over it. The main materials that will get away from the bed coke are the slag and liquefied metals. They will be recovered toward the end. Metals are isolated from the slag through an extreme rapid method.After the procedure is unfaltering, lights are running consistently, and the power supply can be adjusted. Each power burn is alimented independently, subsequently one light can be closed down and adjusted without the need to close down the entire procedure. As it is conceivable to entirely evacuated one of the plasma burn while the framework is running, a few valves are particularly outlined with the goal that within vessel gases don't escape while this procedure. The gasifier is working at marginally negative strain to stay away from vaporous holes. The accompanying figure 4 gives a delineation of the diverse phases of working temperatures inside a gasifier chamber.

The vessel into which the plasma burn is embedded is really the exclusive plan of WPC appeared in figure 5, and it is the component permitting the great activity of the gasifier. Some air needs to circumvent the plasma burn since it is vital that the plasma stream does not touch the dividers, else they would liquefy. [34]

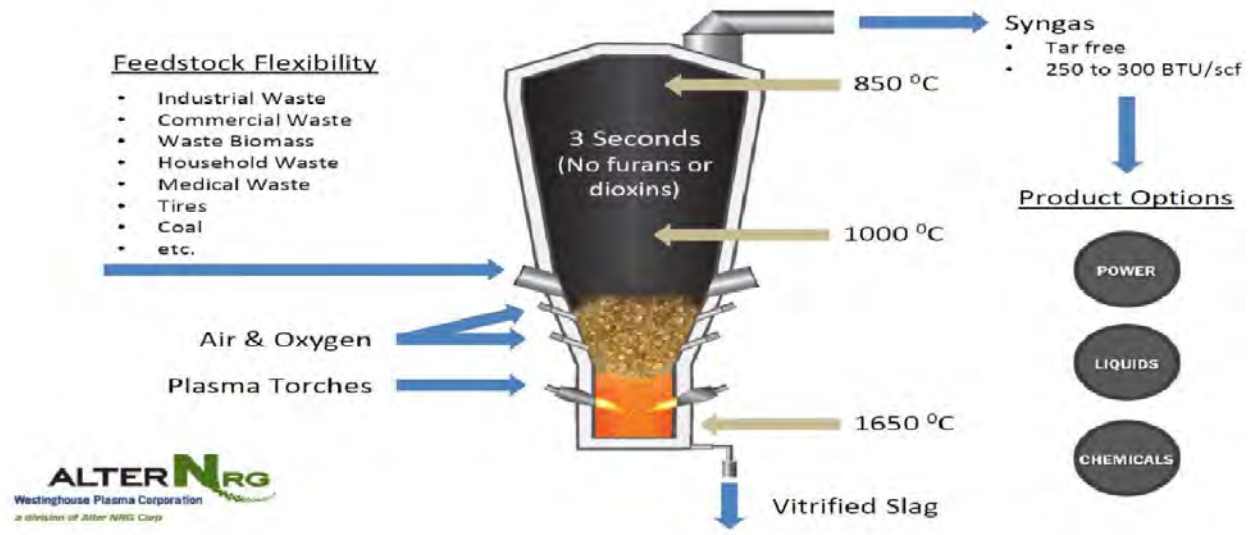


Figure 4 Internal structure and operating temperatures inside a gasifier [43]

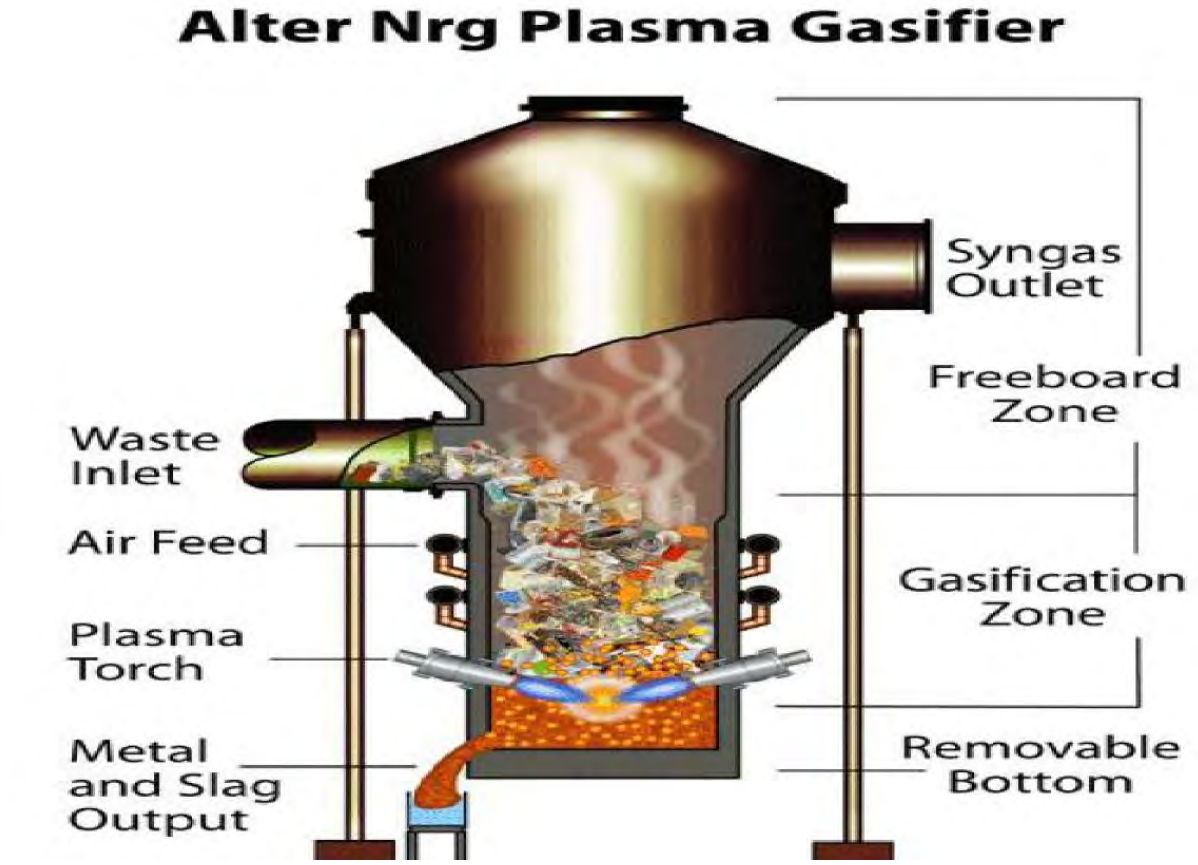


Figure 5 Input & output of a typical gasifier [37]

Within the vessel is walled with recalcitrant which is a rigid material and can give some sort of insulation at the base. The width and stature are figured relying upon the residency time, the stream rates, satisfactory temperature, and warmth misfortunes.

The syngas will have, best case scenario 33% of the power substance of gas. Consequently, the turbine utilized must be perfect with a lower power gas or gaseous petrol must be added to influence it to work suitably. WPC right now has an organization with Solar Turbines to examine the utilization of their turbine that is good with the low vitality substance of the WPC syngas means can a shot at 100% syngas can be taken conveniently and the main reason for existing is to pitch to customers both the gasifier and the turbine of sun powered turbine at the same time. Nonetheless, if the customer rather includes petroleum gas, WPC will work with them to pick another mechanism. In this survey, an approach can be taken on the Integrated Plasma Gasification Combined Cycle, shortly known as IPGCC, where MSW is gasified with expanding metallurgical coke which needs to be 4% w/w to create syngas and followed by power production by means of a gas turbine. Met coke is added to the heterogeneous stream keeping in mind the end goal to raise the calorific estimation of the sustainability. This IPGCC configuration is a definitive objective of Alter NRG, alongside an entire sustain of MSW. The fundamental distinction between the traditional steam cycle and the consolidated cycle is the nearness of turbines that pack the syngas as opposed to combusting everything in a steam heater and in the end, combustion is undeniably worthier than the other process to recover more power.

The Air Product Tees Valley Renewable Energy Facility is a venture arranged as an IPGCC. Plasma gasification can be utilized to create syngas which can be molded and afterward changed over to a particular type of gasoline or energy through innovation stages like energy units and moreover, for those practical implementations, most of the plant, the segment which is devoted to preparing waste and making clean syngas, will be relatively comparative. [34]

3.1.1 Conclusion:

Despite people who are concerned about waste to energy conversion and views plasma arc gasification as one of the traditional combustion processes, plasma arc gasification has the potential to convert the increasing quantity of waste into some serious quantity of energy that can help us to deal with our power outage problem and alleviation of unwanted waste as well. Burning fuel is not a healthy as well as beneficial way to ensure high temperature and pressure unlike plasma arc gasification. Utilizing a controlled air and creating a moderately minimum quantity of gas accelerates the gas cleaning mechanism. Besides, controlling the measure of heat contribution can tweak the structure of syngas and H-CO ratio according to the operator's convenience. [37]The process has been well received by many countries because of the viability but it is a matter of regret that the process is not economically beneficial due to the immense variation of the expense of post-waste management program, which is known as the treatment. In any case, unmistakably the reuse of vitrified slag and vitality generation from syngas will enhance the business practicality of this procedure, and there have been proceeded with progresses towards facilitate advancement. [40]The upcoming ten or twenty years should perceive how this process will develop. Hopefully the chance is good as many plants are being constructed and will be operational within a matter of time.

3.1.2 Anaerobic digestion

Anaerobic digestion (AD) is a biological process of the break-down of organic matter by naturally occurring bacteria in the absence of air, and this produces biogas and a solid digestate. Biogas comprises of mostly methane and carbon dioxide with a small amount of hydrogen sulphide and hydrogen. Depending on the type of input material, the residual solid matter or dig estate can be a nutrient-rich bio-fertilizer [15]. According to a report by the Bangladesh Centre for Advance Studies [16], the 8.44 million households of Bangladesh have 22.29 million cattle and buffalo, and there are 116,000 poultry farms which produce 22,139 t of litter per day. Traditional use of dung and litter has a big impact on the environment and cultivable land in Bangladesh because when it is dumped on low ground adjoining dwelling areas it causes them to be affected by smell, dust and surface water pollution [17]. Bangladesh already has nearly 40,000 domestic biogas plants using cow dung or poultry litter, but the full potential has been estimated at 3 million plants [6]. The traditional use of biomass for cooking or the burning of renewably harvested fuel wood has

often been assumed to be greenhouse gas neutral as eventually all the CO_2 will be recycled and taken up by vegetation in the next growing season.

Bangladesh has a suitable climate for biogas production. The ideal temperature for biogas is around 35°C. The temperature in Bangladesh usually varies from 6°C to 40°C, but the internal temperature of a biogas digester in Bangladesh usually remains at 22°C to 30°C, which is very near to the optimum requirement [18]. Suitable raw feed stocks for biogas such as cow dung and poultry litter are easily and cheaply available throughout the country.

The potential for mass deployment of domestic AD plants is very promising. Government and micro-finance companies already support such schemes [1]. The use of AD could supply a much-needed energy resource for domestic consumption for cooking, as well as bio fertilizer to enrich the farm land [3-5]. It would also reduce deforestation by displacing wood fuel, and improve air quality in rural homes by avoiding contributions caused by incomplete combustion of solid fuels. These AD plants would be situated in rural farm areas where there is no realistic option for extending natural gas supply, on smallholdings where the energy would be directly used.

The common use of AD biogas in Bangladesh would also make a significant contribution to the reduction of greenhouse gases, which could provide some income via the Clean Development Mechanism (CDM). However, this approach would require appropriate calculation of baseline carbon emissions. The focus of this study is the determination of the potential energy contribution and energy patterns of small and medium AD systems in Bangladesh from common feed stocks and common scenarios [1-5].

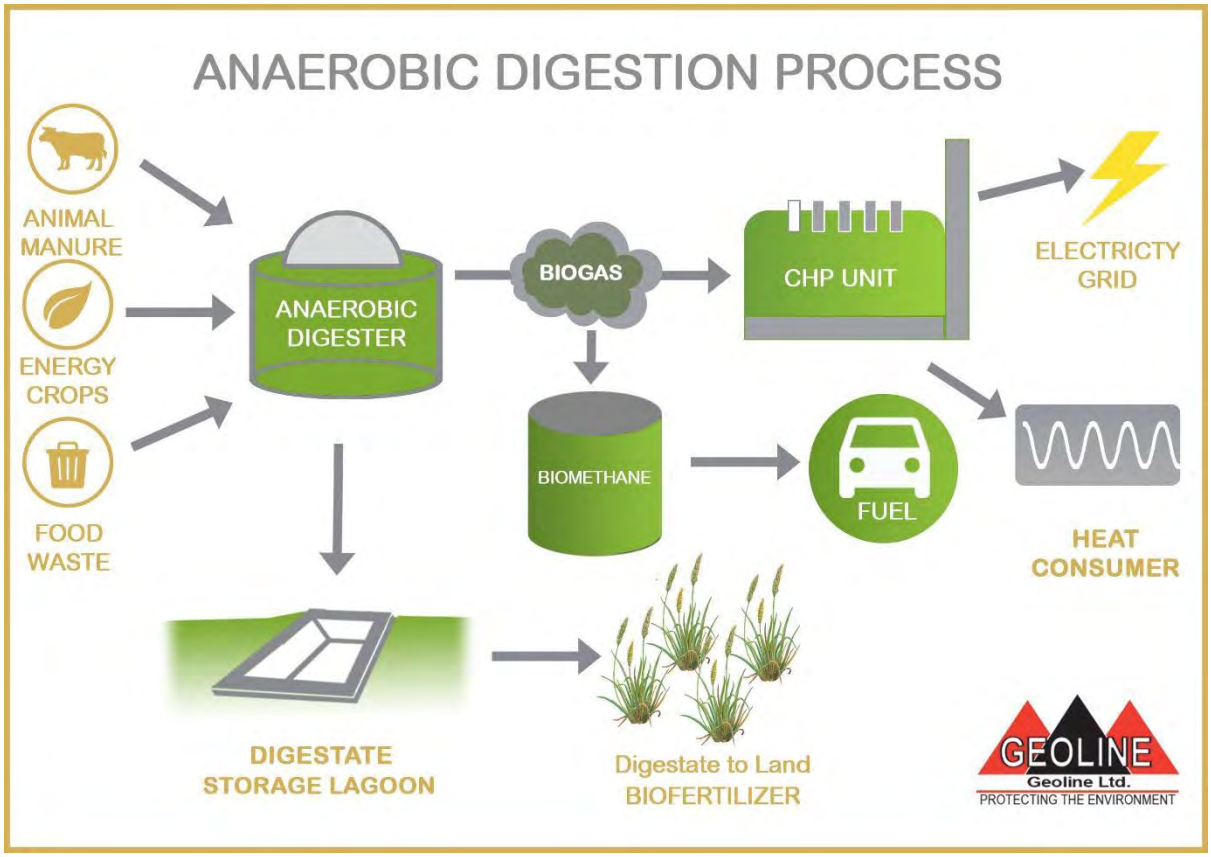


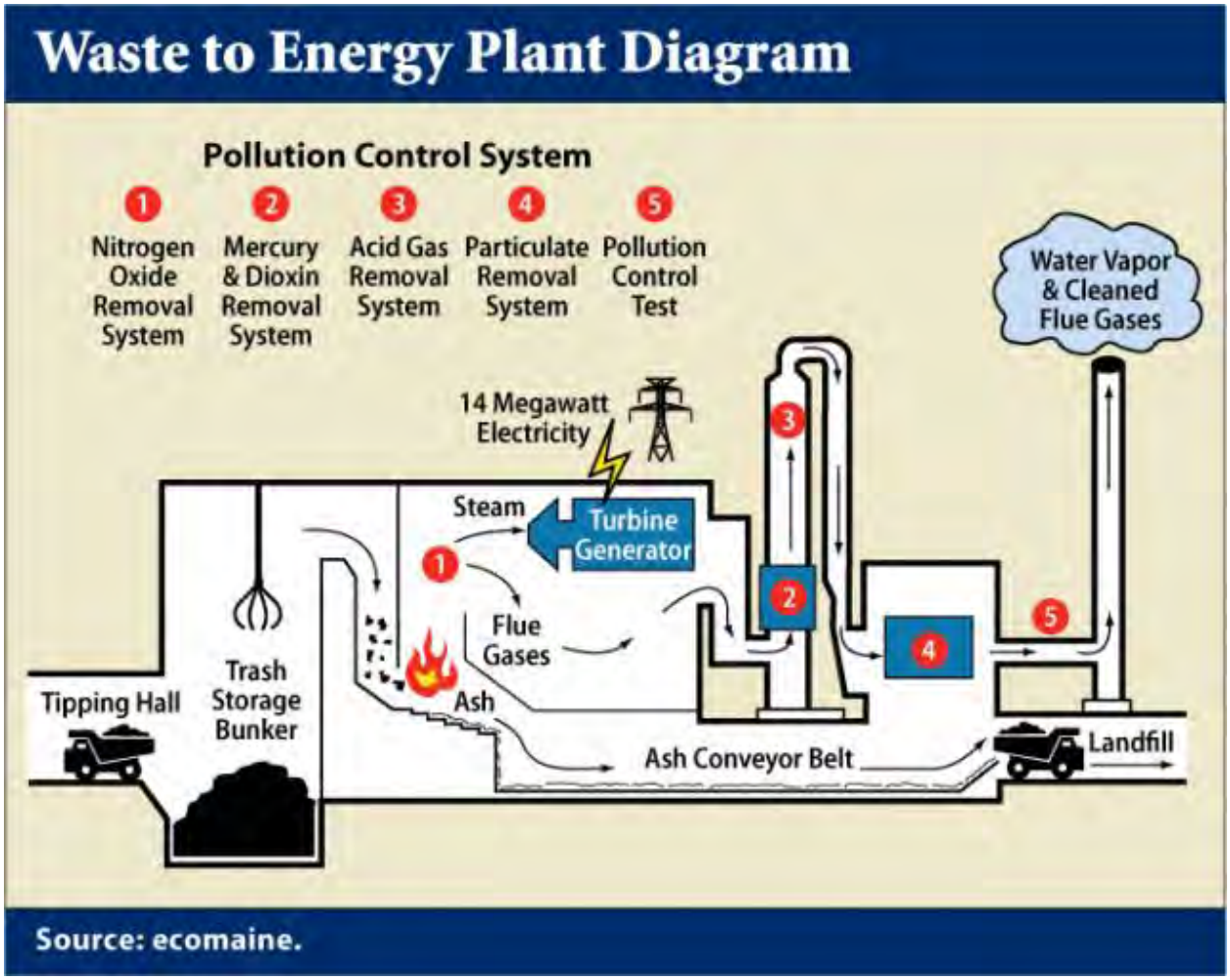
Figure 6: Anaerobic Digestion Method to produce Electricity

3.1.3 Incineration method to produce energy

Incineration is an alternate method of landfilling of the waste. From incineration technique the combustion technique came in to produce energy. Such WtE plant burns the waste in control condition to generate steam that is used to run the turbine and generate electricity. Around 500MWh to 700MWh energy is generated by per ton of waste by MSW combusted. [57]

The method is simple but the complication occurs while maintain and controlling the harmful materials, compounds produced. The below diagram is an example of a WtE mass burner.

Figure 7: Waste to Energy Plant Diagram

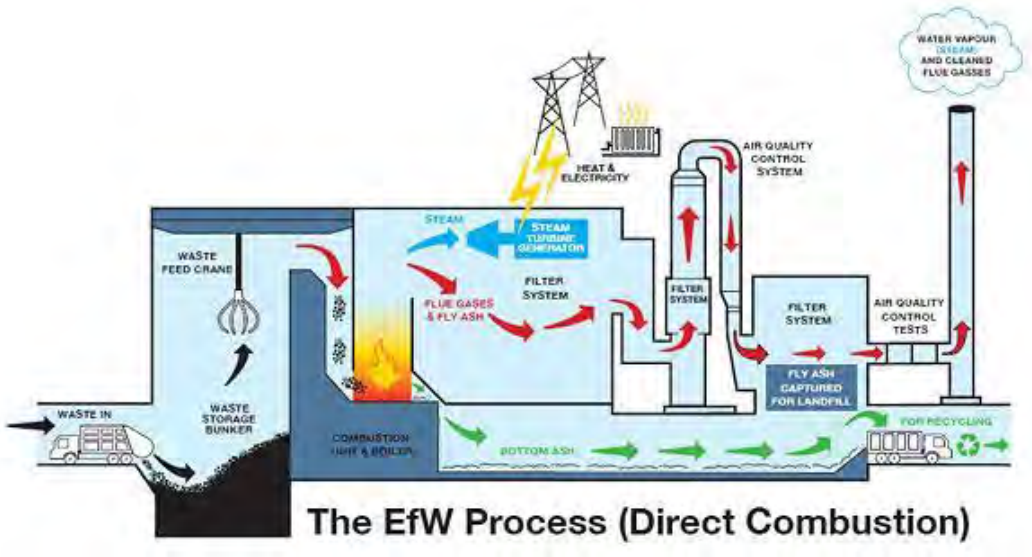


It works by burning waste that cannot be recycled. In the above figure it is shown that the trash is stored in a bunker and later it is burned and the steam is used to generate electricity and this electricity can be fed into the national grid or supplied to the local community and the flue gases are sent for treatment. And the ash produced from the burning of the waste is collected. The ashes can be used to for constructions. The plants can also produce high-pressure hot water or steam that can be used by industry or domestic heating. These plants are highly efficient and are encouraged by UK Government policy. [56]

The electricity produced by the mass burner can be used for the plan itself. More advanced technologies are being implemented to control the flue gases. In Uk , Germany strict rules and regulations are followed and maintained for the combustion method. Not just that the combustion system provides heat service in many countries. 30% of Denmark's district heating comes from the 28WtE facilities. [57] The below image shows average emission of ten WtE facilities, it is said that WtE has lower carbon emission equivalent to landfilling and

coal burning.

Figure 8: Direct combustion Plant



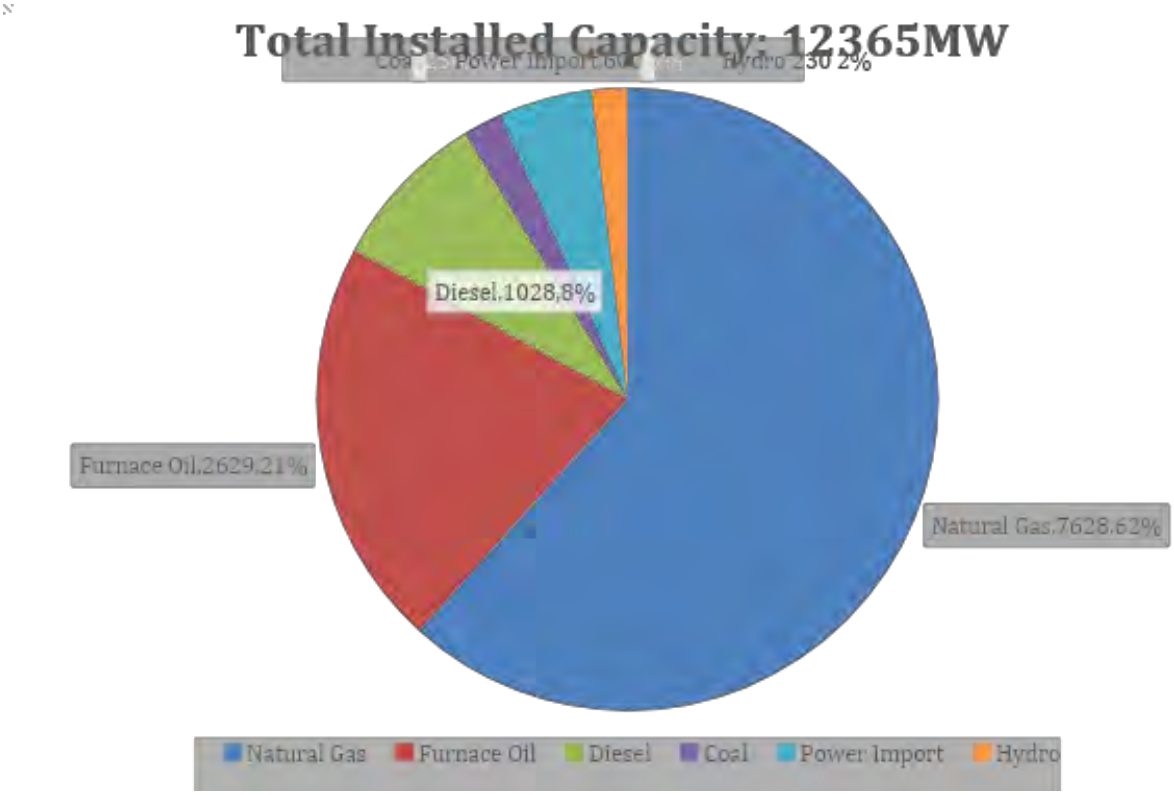
CHAPTER 4

Environment Impacts

4.1 Overview of Power generation and impact on the environment in Bangladesh.

Bangladesh is a developing country, the power demand is rising day by day. The government is facing huge challenge to meet the demand of the power. Average daily demand is around 12MW and the power board is able to produce around 8MW in 2017. Where as in 2009 only around 4MW was produced [50]. In the figure 1 it shows the composition of installed generation capacity by fuel type as on June 30, 2016. [Source System Planning, BPBD]

Figure 9 : Total Installed Capacity of Bangladesh



As said, the demand is on the rise i.e 7% per approximately per year and the government have taken many plans to meet the demand. Government previously used Quick Rental method to meet the demand later the quick rental methods were reduced but government is again planning for quick rental along with other major plans. Nuclear power plant is one of those major plans by government. The first phase of the plant is supposed to start the generation on 2023/2024 which will have a gross of 1200MWe and the second phase on 2024/2025 and have same gross 1200MWe.[51] .

The problem arises when the plan of establishing 23 coal power plant to generate 20MW of electricity through the coal power plants by 2030. Coal based power plants produce around 41% of the electricity of the World. This is because Coal based power plants are one of the cheapest ways to produce electricity. Moreover, coal based power plants are one of the main reasons for greenhouse gases and global warming. According to a report in 2011 coal based power plants in USA emitted a total of 1.7 billions of CO_2. A typical coal power plant generates around 3.5million of CO2 per year. According to reports BNCS on June 2016 Bangladesh generated a total power of around 12,365MW. And of that 2.02% came from Coal Based Power Plants. Coal based power plants are managed by private organizations and both by governmental organizations. Bangladesh plans to build few numbers of coal power plants and one of them in Sundarbans named Rampal Powerplant. There are many controversies regarding it on how it can harm the largest mangrove forest and the environment. Coal based power plants are lower in costs but the opportunity cost is higher that is the environment. The first thing needed to run a Coal based power plant is coal. For that coal needs to be extracted from the surface or needs to be imported from other countries. Coal mining causes hefty amount of damages to the environment. When coal mines move in, whole communities are forced off their land by expanding mines, coal fires, subsidence, and overused and contaminated water supplies. Mines are quick to dig up and destroy forests and soils. But once the coal is gone, the problems they leave behind, like acid mine drainage, can persist for decades. Around the world, Greenpeace campaigns to help communities stop coal mines, and speed up the shift to 100 percent clean, safe renewable energy. Underground mines, which provide the majority of the world's coal, allow coal companies to extract deep coal deposits. About 40 percent of the world's coal mines are the more damaging strip mines (also called open cast, open pit, mountaintop or surface mining). After coal is found from mining it is then burned in the coal based powerplant to generate electricity through the mechanism. Burning coal results into producing various harmful gas which is the leading

cause of smog, acid rain, toxic air pollution and climate change. Some emissions can be significantly reduced with readily available pollution controls. The list of gases, materials produced and how it harms the environment.

Carbondioxide (CO_2): carbon dioxide emission from power plants contributes to the global warming and climate change.

Sulfur dioxide (SO_2): Coal plants leading source of SO_2 pollution, which takes a major toll on public health, including by contributing to the formation of small acidic particulates that can penetrate into human lungs and be absorbed by the bloodstream. SO_2 also causes acid rain, which damages crops, forests, and soils, and acidifies lakes and streams. A typical uncontrolled coal plant emits 14,100 tons of SO_2 per year. A typical coal plant with emissions controls, including flue gas desulfurization (smokestack scrubbers), emits 7,000 tons of SO_2 per year. Which is still harmful for the environment.

Nitrogen oxides (NO_2): NO_2 pollution causes ground level ozone, or smog, which can burn lung tissue, exacerbate asthma, and make people more susceptible to chronic respiratory diseases. A typical uncontrolled coal plant emits 10,300 tons of NO_x per year. A typical coal plant with emissions controls, including selective catalytic reduction technology, emits 3,300 tons of NO_x per year. In order to reduce NO_x, emission, low NO_x burner firing system should be installed in all power plants.

Particulate matter: Particulate matter (also referred to as soot or fly ash) can cause chronic bronchitis, aggravated asthma, and premature death, as well as haze obstructing visibility. A typical uncontrolled plan emits 500 tons of small airborne particles each year. Baghouses installed inside coal plant smokestacks can capture as much as 99 percent of the particulates. To control flue gas dust from coal power plants, electrostatic precipitator (ESP) will help to reduce dust emission to a desired level.

Mercury: Coal plants are responsible for emissions of mercury, a toxic heavy metal that causes brain damage and heart problems. A typical uncontrolled coal plants emits approximately 170 pounds of mercury each year. Activated carbon injection technology can reduce mercury emissions by up to 90 percent when combined with baghouses.

Some few more harmful pollutants are emitted from the coal based power plants like lead, cadmium, uranium, carbon monoxide and etc.[49,52-54]

It is said that the emission of CO_2 emission will be tripled by the year 2030 due to the coal power plants and other fossil fuel plants. Dhaka is already the most polluted city in the world. This increase in CO_2 emission will not just impact Dhaka and Bangladesh rather the world.

4.2 Comparison between fossil fuel plants and WtE plants

4.2.1 In terms of biogas (an anaerobic digestion) plant:

A biogas plant's design mechanism can be defined by its attributes of raw materials. These raw materials can be of two kinds, one type of materials come straight out of farms and the materials include manure, sludge and grass. Another type of materials are labelled as external raw materials that may cost some money in order to get due to the solid configuration. In every process some toxic materials that are pretty much harmful for the environment hence in terms of plants that deal with biogas, the materials are highly dependent on the equipment of treatment and feedstock. Biogas is nothing but the mixture of the gases like carbon-dioxide (CO_2) and methane (CH_4) so it needs to be kept in mind that methane is a highly flammable gas as it is proven to be explosive while getting in touch with spark, oxy-acetylene flame (C_2H_2 at 3200 ^{0}C) or while reacting with oxygen (O_2) hence safety measures need to be taken to keep the environment as well as the individuals safe. In terms of anaerobic digestion, it may create products along with biogas that are heavily metallic. Biogas combustion can produce gases like nitrogen oxides (N_xO_y) that are proven inconvenient to lung and can cause serious allergy. Besides that, both methane and carbon dioxide are the parts of biogas which are also known as greenhouse gases that help to increase the overall temperature of our planet and hence responsible for the icebergs of both north and south poles being melted down. Moreover, anaerobic digestion plants tend to produce water which is not good for the soil because of the level of nitrites dissolved in that and last but not the least, plants like these cause other environmental problems like odor and pollutants as huge amount of methane being burnt for the sake of power generation.

4.2.2 In terms of plasma arc gasification:

There is a difference between traditional waste to energy conversion technique and plasma arc gasification in terms of the timing of syngas cleaning. In plasma arc gasification process syngas is cleaned before the combustion as it saves money and it makes the process more efficient. During power generation process, oxides of nitrogen gas will also be produced. Elements like furans and dioxins keep coming back while getting back to the normal state even if they are alleviated by dint of plasma treatment as well as high heat and in this case, drastic cooing process may help a lot to get rid of those elements. After done with the cleaning process water will come out of the syngas and chlorine will be in that water in a very mild quantity.

4.2.3 In terms of incineration method for combustion:

Incineration method is an old technique to burn wastes but with the technologies available. Through incineration we are able to produce energy just like the same mechanism of coal but with more control and less harm to the environment. The incineration method produces two type of ashes bottom ashes and fly ashes. Bottom ashes comes from the furnace and fly ashes from the stacks of hazardous components. Bottom ashes are around 10% and only few percent of fly ashes. [55]. But there are technologies to render the hot flue gases and safe and harmless release to the environment.

UK follows a strict monitoring of the emission of the plants. European Waste Incineration Directive objective is to minimize the impact from emissions on the environment and human lifes. It is said that the Dutch cities which have WtE power plant has cleaner emissions than the people who breathe air at ground level. [58]

4.3 CO_2 Emission for grid power Generation

CO_2 emission from power plants causes global warming and climate change. The following table shows the current and future trend of co2 emission in Bangladesh

Table 6: CO_2 Emission present and future condition

		2015(Actual)	2021	2030
1.	Net Electricity Generation(GWh)	45836	99838	190752
2.	Fossil Fuel based Electricity Generation(Gwh)	41890	77925	133145
3.	CO^2 Emission (Million ton)	24.85	42.4	79.2
4.	Emission Factor(Grid)(t/MWh)	0.54	0.43	0.42
5.	Per Capita CO_2 Emission (Ton/annum)	0.16	0.24	0.40

Source: Derived from BPDB energy and financial modelling data and PSMP

This much emission will create an imbalance in the environment the technology to mitigate CO_2 is highly expensive so the coal and fossil power plant seems to be an unhealthy concept for Bangladesh.

The average coal-fired power station will annually emit over 100 times more sulphur dioxide and nitrogen oxides compared to a typical EfW facility. The air quality for people living and working around a site will not suffer as a result of an EfW plant.[58] So opting out of coal power plant and shifting to WtE power plant is a necessity.

Chapter 5

Electronic Waste

5.1 Definition of E-waste:

Used electronic households like laptops/desktops, phone sets/cell phones, fridge, television, video camera, copy machines which have been sold or about to get sold or discarded by the owners are normally known as E-wastes or Electronic wastes and goods like these are either can be functional or partially functional or on the verge of the life cycle or non-functional fall into such category. Based on their conditions they can be refurbished, reused, regarded and recycled as well.

To be more specific, according to Waste Electrical and Electronic Equipment directive, e-wastes can be classified as [59]:

- Entertainment electronics like LCDs, TVs, CD players etc.
- E-tools like electric lawnmowers and drilling machines
- Communication appliances of the office like printers, phones, computers
- Both small and large appliances like ovens, fridges, toasters etc.
- Surveillance equipment
- Medical instruments
- Sports equipment like training machines
- Lighting materials like fluorescent lights and so on

5.2 Mass and findings of the appliances related to E-waste:

E-waste's hotspot or concentration of highest disposal of e-waste in Dhaka are Islampur, Dholai Khal, Gingira, Elephant Road and Mohammedpur. It was a matter of regret that the people who were in charge of the official details of the weight and findings of the

components related to e-waste could not be interviewed they were quite busy with the tasks they were appointed to hence the only way of getting enlightened was interviewing the random workers named Monir and Asad who work at Dholai Khal as well as Shopon and Habib who work somewhere near the Elephant road and after talking to them for quite a while it had been unofficially confirmed that around .27 million metric tons of e-wastes were being collected on a daily basis and .83 million metric tons of e-wastes were being collected on a monthly basis. Around 90% of the e-wastes were being processed and then being sent to Chittagong shipyard and nearly 5%-3% go through recycling and regarding process and 5%-7% fail to serve any purpose hence those components end up in the landfills unfortunately.

	Amount of E-waste(in million metric tons)
On daily basis	0.27
On monthly basis	0.83
On yearly basis	7.91

Table 7: Amount of E-waste in a year

Treatment	Mass of E-waste (%)
Processing	90
Recycling	5-3
Unusable	5-7

Table 8: Disposal of E-waste

According to the workers who had been interviewed, processed and recycled e-wastes include-

- Television
- Computer
- Cell phones
- CFL bulbs

- Medical wastes
- Junkyard of the ships, normally known as ship breaking yard
- Mercury bulbs

It had been also confirmed by the workers that the highest amount of waste came from ship breaking yard which was around 0.192 million metric tons per month and the least amount of waste came from medicals allover Bangladesh.

5.3 Recycling and reusing e-wastes:

It is told to us that the discarded computers are often recycled at recycling stores or those devices are given to local schools or many non-profit Christian missionary organizations for a negligible amount of money. It is difficult to distinguish the mottos behind recycling e-wastes in the developing countries due to estimated gross and domestic recycling as both types of recycling are proven to be indistinguishable due to the betterment of the environment. Moreover, recycling is way better than landfilling. It is a matter of regret that here in South Asian countries especially, workers are often exposed to toxic atmosphere while dismantling and restoring multiple elements from a device that has gone through and entire lifecycle. Situations like dumping and burning of toxic materials have been witnessed near Dholai Khal as the workers and even the concerned authorities are getting frustrated about how to recycle the important parts of a device without doing so.

Based on how the electronic materials are being reused, the entire process can be summed up in the way exhibited below-

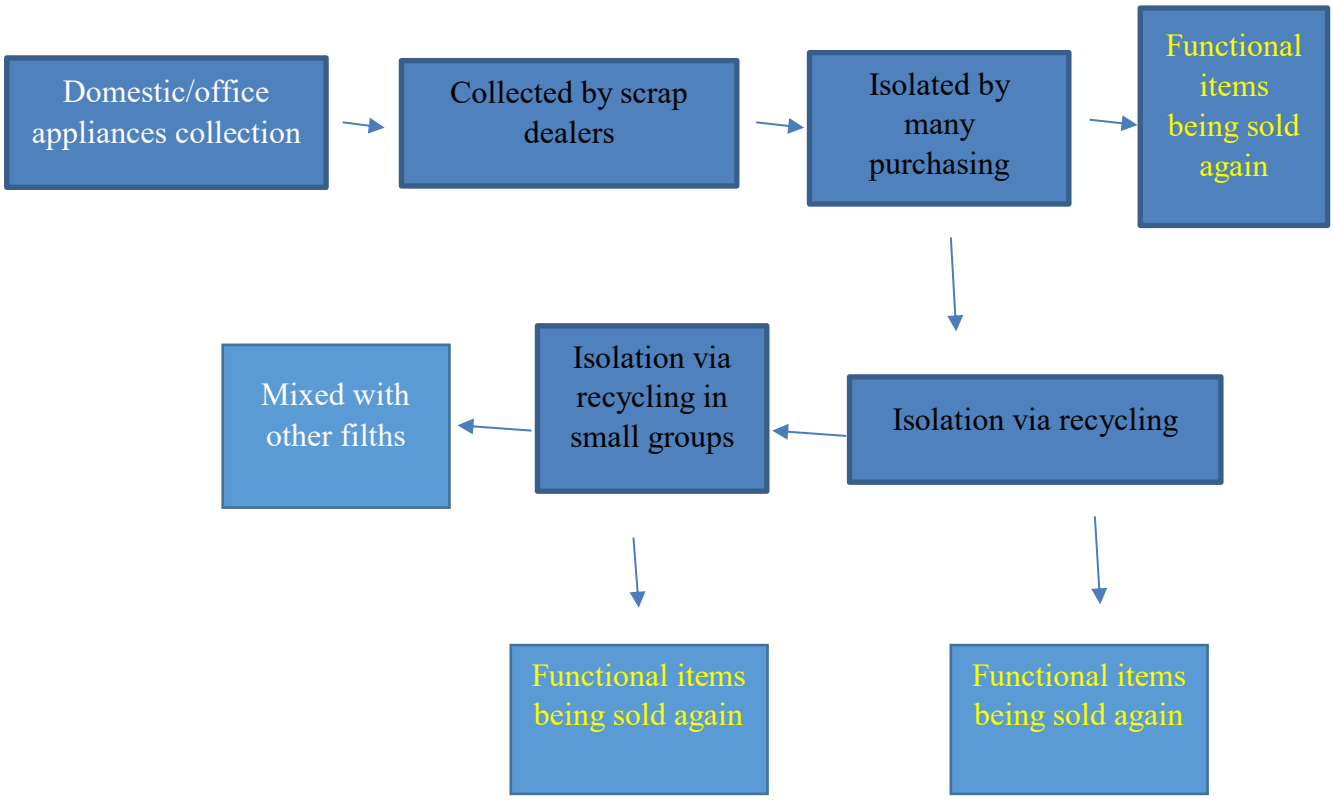


Fig 10: How E-wastes get recycled around Dhaka

5.4 Chemical compositions of the E-wastes:

Chemicals found in e-wastes can be categorized based on their quantity overall and the category is stated below [60]-

- Things that can be found in quite a negligible amount, things like Barium(^{56}Ba), Nickel(^{28}Ni), Gallium (^{31}Ga), Indium (^{49}In), Cobalt (^{27}Co), Germanium (^{32}Ge), Gold (^{79}Au), Antimony (^{51}Sb), Bismuth (^{83}Bi), Ruthenium (^{44}Ru), Platinum (^{78}Pt) and so on.
- Things that are in mild amount are Zinc (^{30}Zn), Cadmium (^{48}Cd), Mercury (^{80}Hg) etc.

- Elements that are found in a plenty of amount are Tin (^{50}Sn), Lead(^{82}Pb), Carbon(^{6}C), Copper (^{29}Cu), Silicon (^{14}Si), Aluminum(^{13}Al) and last but not the least which is Iron (^{26}Fe)

5.5 Processing of E-waste and its environmental impact:

The wastes like metal boards, plastics and power supplies are normally taken and being dismantled or shredded via manual labor and the repairable components like Bipolar Junction Transistors, Metal-Oxide Semiconductor Field-Effect Transistors, capacitors and many other materials are being used to make a totally usable “Frankenstein”-ish product and then sold to the end users and the process brings the investors as well as the brokers a huge amount of fortune at a feasible cost. It is told to us that apart from Bangladesh many developing countries and countries like China deal with throwaways in a feasible but harmful way which has undoubtedly a bad impact on the workers involved with the electronic waste shredding, sorting and sampling jobs. Workers in those places are mainly ordered to filter the metals via burning the circuit boards and melt the plastic parts hence during the process different types of neurotoxins are being released which put a negative impact on the longevity of the people around that place.

5.6 Electronic waste to energy conversion via Microbial Fuel cells (MFCs):

5.6.1 What are microbial Fuel cells and how do they work?

In the recent days studies and speculations about MFC are getting mainstream as the process is capable enough to produce significant amount of energy. Basically metabolic operation performed by the bacteria is the formula that is at the core of microbial fuel cells' mechanism. This not a single unit rather its components include electrodes, proton exchange membrane, anode and cathode chambers. A conductor with a particular amount of impedance completes the circuit as a whole and proton exchange membrane, known as PEM is also there to distinguish cathode chamber from anode chamber [61]. Bacteria like pseudomonas produce both H^+ and e^- and hence the chemical energy is converted to electrical energy and microbes store the energy. During the reaction e^- flows from anode to cathode through the wire that completes the circuit. Via PEM H^+ ions flow, reach the cathode chamber and in the end creates H_2O. The reaction looks like-

$$4H^+ + 2O_2 + 4e^- \Rightarrow 2H_2O$$

Bacteria that cannot transfer e^- are called redox mediators [61]. Bacteria grow in anode and release e^- in cathodes, as written in Logan5 [62].

5.6.2 Dimension analysis of the components of the MFCs:

MFCs have been improved in terms of efficiency and performance over time but based on the cost of making one is the challenge to be taken care of quite seriously. Based on the materials that complete an electrode resistance of it varies. More resistance mean less power and electrodes purely made of ^{78}Pt can be too expensive. So considering overall reasonable cost and optimum efficiency carbon cloth could be used. Single chamber MFC would be the type for the experiment which would be $4x10^{-2}$ m lengthwise and $3x10^{-2}$ in terms of diameter [63]. Hence the area-volume ratio would be-

$$\frac{\pi\left(\frac{3/100}{2}\right)^2}{\left(\frac{3/100}{2}\right)^2 4/100} = 25\text{m}^2/\text{m}^3$$

Where area= $\pi\left(\frac{3/100}{2}\right)^2$ m^2 volume= $\pi\left(\frac{3/100}{2}\right)^2 4/100$ m^3

In this case if .02kgm^{-2} Pt is present in the 25m^2/m^3 carbon cathode [63]. According to the scrappers of Dholai Khal, sixty mechanical hard drives come to their junkyard on a monthly basis and each of the drives carry around 1-5 hard disk drive platters. So let's say each mechanical drives carry 3 platters on average. It has been confirmed that each platters a 3.5 inches in terms of diameter and has 30nm of Co-Cr-Pt alloy and the amount of Pt is 40%-50% which ultimately results in $2.2x10^{-6}$ kg of platinum [64]. Hence we get total $3.96x10^2$ mg of platinum for total 60 mechanical hard drives carrying 3 platters each.

Moreover, we would require Polycarbonate sheet, hollow rod and the dimensions of those materials would be .229m^3, .381m^3 respectively.

5.6.3 Quantity of the cells used, overall cost (estimated) and final result analysis:

Using unitary method it has been found that if 0.02 kgm^{-2} Pt is present in the *25*m^2/m^3 carbon cathode then $3.96x10^2$ $mgcm^{-2}$ will cover 4950m^2/m^3 carbon cathode.

Hence the total number of cells would be= 4950/25

=198 cells

Finally the power density of these 198 cells would be 9108 Wm^{-3}

Considering the quantity, materials and manual labor required the cost would result in BDT 16,029.48 where Over 90% of the cost is involved with the platinum extraction and around 5% of the cost is all about the carbon clothes due to the manner of their physical form.

5.6.4 Comparison of the power densities between lithium-ion batteries and MFCs backed up by a month of E-waste:

In this analysis the power density of the cells has been roughly estimated and now if its power density can be put against the best of the best in the market, which is the lithium cobalt oxide ($LiCoO_2$) many interesting things will appear that have never been talked about before.

Lithium ion batteries, known as Li-on batteries are the best option technology can offer today. By considering their specific power density, which can go from 250Wkg^{-1} to 340Wkg^{-1}[65] and hence the sweet spot can be considered 295Wkg^{-1}, which can be translated into $5.83x10^6$ Wm^{-3} and undoubtedly massive compared to the power density obtained using 198 MFCs, which is almost 640 times of what we have gotten for MFCs. In this case it seems like MFCs are not the things to be talked about but there is still chance for this technology as more power density only denotes that the battery would be able to store the energy quickly compared to MFCs but that does not mean that li-on battery is also able to hold the energy for a significant amount of time and this problem has been observed in many cases and it makes the li-on batteries quite unstable and unreliable sometimes. In terms of storing energy, energy density is the term to look forward to as the more energy density of a battery or cell denotes

that the battery or cell is more capable of keeping the energy within itself. So clearly it can be said that a battery with high amount of power density does not necessarily have high amount of energy density and in other words it can also be said that the battery with low power density does not necessarily have low energy density, so the hope is still there and in order to find the energy density of MFCs more and more researches and experiments need to be done.

	MFC	Li-On($LiCoO_2$)
Specific Power Density(Wkg^{-1})	0.46086	295
Power density(Wm^{-3})	9108	$5.83x10^6$
Energy density(Jm^{-3})	----	471.5

Table 9: Comparison Between MFC and Li-On($LiCoO_2$) battery

Chapter 6

Conclusion and Recommendation

Before talking about waste to energy conversion, the theme of waste to energy better be kept in mind as it will create the opportunity of improving the idea of waste to energy conversion which will be used for the betterment of the community right after. Managing wastes put a significant impact on the environment, usable lands as well as our health so it is a must to observe waste management as frequently as possible. There has been a crying need for the sanitary landfills in Bangladesh despite the boost in technological as well as economical fields for many years. Developing countries tend to dispose solid wastes in outside dumping fields and such fields need to handle gas present in the landfill hence environment pollution occurs with respect to the greenhouse gases which has been formed. It is estimated that the quantity of waste that will be produced will increase by .2 times on a yearly basis. Dhaka, the capital of Bangladesh alone produces around 7 kilo tons of solid waste, 4 kilo tons of construction and demolition waste on a daily basis. [sohel rana] Such wastes need to be processed via taking to the dumping fields in this case both of the city corporations of Dhaka

have acquired many ways to improve the situation of waste management for the betterment of the mass as the managed wastes will be used to generate power later on.

Speaking of waste to energy generation, thermal plasma gasification can be proven superior to landfilling in a technological manner as it is undoubtedly way better considering energy production and as this process requires short area of land, less amount of greenhouse gases can emit. So there are possibilities for this process, just a bit more commercialization and investment of the enthusiasts are necessary.

The motto that the report is based on is to mark the plus points of waste to energy conversion in Bangladesh's aspect and with the increasing rate of gross domestic product of the country the waste is being generated in a neck to neck rate and so the government has come forward to fund the processes like anaerobic digestion and combustion as well despite many environmental threats. Considering that the processes are being made more and more environment friendly and this report has a firm contribution in that case for sure. Previously which used to end up in landfills are now being processed and used as source of energy, thanks to the invention and restless development of processes like combustion, anaerobic digestion and plasma arc gasification. Moreover, by selling electricity and by forming greenhouse reduction mechanism waste to energy has been a medium that has no competitors other than the solar solution in the power generation sector.

Waste to energy conversion processes need to be introduced in the competitive power generation field in a commercial manner by the advertisement of the practical success they are capable of bringing to the mass. Frequent research works are a must to figure out the unknown capabilities and possibilities that the processes can achieve. Statistics like waste sources that pollute the environment, price of the remains that can be recycled and quantity of waste that are being produced on both industrial and surface level consumerisms' bases need to be pointed out in order to draw the attention of the enthusiasts and well-wishers who are willing to fund. People who are unaware of such technologies need to be drawn attention so that more and more enthusiasts along with environmentalists can come forward and embrace the ideas to build a better future. Starting up open conversations among the researchers and the people who are keen to know the possible potentials of waste to energy conversion processes can surely reduce the gap of ignorance and increase the awareness in a natural manner, which will be proven helpful in terms of flourishing a legitimate clean development

mechanism and it can be a helpful way to promote incineration mechanism as incineration is quite viable process for the investors to invest in.

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