BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING

Waste to Energy: The Modern Solution of Waste and Energy in Bangladesh

Submitted By

Yousuf Ali

Student ID: 172-33-484

&

Abdul Aziz Raian

Student ID: 172-33-526

Supervised by

Sumon Chowdhury

Lecturer

Department of EEE

Daffodil International University

Dhaka, Bangladesh

Certification

This is to certify that this industrial attachment and thesis and titled “Waste to Energy: the modern solution of waste and energy in Bangladesh” is done by the following students under my direct supervision and this work is an on desk research about the overall waste problem in Bangladesh specially Gazipur city Corporation as partial fulfillment of the requirements for the degree of Bachelor of Science in electrical and electronics engineering.

Signature of the candidates

_____

Name: Yousuf Ali
ID #: 172-33-484
Department of Electrical & Electronic Engineering

_____

Name: Abdul Aziz Raian
ID #: 172-33-526
Department of Electrical & Electronic Engineering

Countersigned

_____

Sumon Chowdhury
Lecturer
Department of Electrical & Electronic Engineering
Daffodil International University

The Thesis entitled “Waste to Energy: The Modern Solution of Waste and Energy in Bangladesh” submitted by Yousuf Ali (ID: 172-33-484) and Abdul Aziz Raian (ID: 172-33-526) session: Summer 2017 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Bachelor of science in Electrical and Electronic Engineering on January 2021.

Board of Examiners

Md. Ashraful Haque — Coordinator
Assistant Professor, EEE
Daffodil international University

Dr. Md. Alam Hossain Mondal — Internal Member
Associate Professor, EEE
Daffodil international University

Dr. M. Abdur Razzak — External Member
Professor, EEE
(IUB)

Date 31st January 2021

Declaration

We hereby state that this thesis is based on entirely on the final result observed through ourselves the working materials discovered through different researchers are expressed with the help of references. This thesis is submitted to daffodil international university for the partial success of the B.Sc. in electrical and electronic engineering. This thesis is neither complete nor in component was previously submitted for any degree.

<table>
<tr><th>Supervised By</th><th>Submitted By</th></tr>
<tr><td rowspan="2">Sumon Chowdhury
Lecturer
Department of Electrical & Electronic Engineering
Daffodil International University</td><td>Name: Yousuf Ali
Id: 172-33-484</td></tr>
<tr><td>Name: Abdul Aziz Raian
Id: 172-33-526</td></tr>
</table>

Abstract

In present days the economic development with rapid urbanization comes with large volume of MSW and energy demand. In the developing cities like Gazipur the problem is more severe. Hence, the proper management system of these wastes and innovating renewable energy can solve the problems. The proper municipal solid waste management (MSWM) system can get us out of the problems. In the city like Gazipur and Narayanganj, the present MSWM system is not enough to waste collection and disposal. The city corporation is collecting those wastes and landfilling in an area which is affecting environment and public health for a long time.

In our research we aimed to investigate present condition of MSWM system and its possible impact in Bangladesh. Further, we directed to analyze the changes needed on current MSWM system to be improved and to use the waste as resources to produce energy by available waste to energy technologies. Although we named the title of our thesis is modern solution of waste and energy in Bangladesh we have selected the Gazipur city corporation area as our study area. Our study's assessment and analysis we have collected from several literatures from different sources.

Table of Contents

List of tables

List of figure

Acronyms

3R	Recovery Recycle Reuse
MSW	Municipal Solid Waste
MSWM	Municipal solid Waste Management
GCC	Gazipur City Corporation
WtE	West to Energy
UNICEF	United Nations International Children's Emergency Fund
JICA	Japan International Cooperation Agency
GACC	Gazipur Aware Citizens Committee
RAJUK	Rajdhani Unnayan Kartripakkha
NGO	Non-Government Organization
CBO	Chief Brand Officer
SWM	Solid Waste Management
UNDP	United Nations Development Program
GoB	Government of Bangladesh
DCC	Dhaka City Corporation
LGRD	Local Government Rural Development
ADB	Asian Development Bank
EU	European Union
EPR	Extended producer responsibility
WMH	Waste management hierarchy
GHG	Greenhouse gas
AD	Anaerobic Digestion
DEFRA	Department for Environment, Food and Rural Affairs
MWh	Mega Watt hour
HHs	Health and Human service

Acknowledgement

We would like to thank Daffodil international university for giving us an opportunity to do our bachelors degree, in its wonderful educational environment. Our sincere gratitude to our supervisor Sumon chowdhury sir, for his continuous guidance and instruction on building idea and writing this thesis report. His positive and clear feedback always motivated us to focus on the subject matter that helped us to complete this report on given time.

Furthermore, We would like to express our sincere appreciation to the course coordinator Mr. Mahbub ud jaman for the continuous support and kindness during our study period. Likewise, our gratitude goes to Mr. Ashraful alam for his help and study advise and Mr. Mahbub ud jaman for giving valuable advises regarding study. Similarly, our special gratitude to the head of the department, Professor Dr. Mohammad Shahid ullah and other professors and lecturers involved in this Bachelors' program.

We would like to extend our special gratitude to our family for their unconditional love, continuous support and guidance which are the key motivation and strength in our journey.

Finally we would like to thank our friends who helped us during our study time.

Yousuf ali & Abdul Aziz Raian

Dedicated to Our Parents

Chapter 1

In this chapter We explained the overall background information of the existing scenario of municipal solid waste (MSW) and its management system in Bangladesh with particular focus in Gazipur City Corporation (GCC) Waste to energy (WtE) technology as solution for the waste management is also briefly explained. Furthermore, it includes problem statement, research objectives, research questions, brief overview of methods used and finally the chapter ends with outline of the thesis report.

1.1 Background information

In the developing country like Bangladesh the volume of MSW has been increasing due to rapid population growth and urbanization. The management for this MSW is appeared as key environmental issue to be concerned. The rising economic development and fast growing urban population are the major reasons for the generation of enormous amount of MSW and Gazipur is one of the city suffering from this problem.

Though the effects of municipal solid waste are huge, the management of these wastes is a highly neglected area of the overall environmental management system in Bangladesh. Waste management system in metropolitan areas must deal with many difficulties, in clouding low technical experience and low financial resources for safe final disposal, these factors are further exacerbated by inadequate financial resources and inadequate Financial Management and technical skills within municipalities and government authorities. In municipal Solid waste management of city corporations five typical problem areas identified: i) inadequate service coverage ii) operational inefficiencies of services iii) limited utilization of recycling activities iv) inadequate management of non industrial hazardous waste, and v) inadequate landfill disposal.

Municipal solid waste management in most urban countries draws on a significant proportion of the municipal budget, yet current practices pose a serious threat to the environment and to public health and well being. This may result in such consequences as pollution, reduction of aesthetic values and economic losses due to failures in recycling and composting valuable components of waste. Furthermore, poor management of solid waste may result in serious urban, sanitary and environmental problems such as an unpleasant odor and the risk of explosion in landfill areas, as well as ground water contamination. Municipal waste includes domestic as well as commercial and industrial refuge, street sweeping and construction and debris. Irrespective to different socio economic status, domestic wastes generally account for between 58% and 83% of total municipal solid waste. In high income countries, municipal solid waste can be around 1,100 kg per capita per year, whereas, in low income countries it is around only 128 kg per capital per year. In some South Asian cities, for example, in Karachi, yearly average per capita solid waste is around 266 kg and in Dhaka and Chattagram city corporations it is around 153 kg per capita per year. The major constituents of solid waste originating in the cities of our country are biodegradable.

Several studies found that the major constituents of waste in Dhaka and Chattagram cities are organic and compostable materials.

Current waste generation in Bangladesh is around 22.4 million tons per year or 150 kg per capita per year. There is an increasing rate of waste generation in Bangladesh and it is projected to reach 47, 064 tons per day by 2025 (**Wikipedia).** The Waste Generation Rate (kg/cap/day) is expected to increase to 0.6 in 2025. A significant percentage of the population has zero access to proper waste disposal services, which will in effect lead to the problem of waste mismanagement.

The total waste collection rate in major cities of Bangladesh such as Dhaka is only 37%. When waste is not properly collected, it will be illegally disposed of and this will pose serious environmental and health hazards to the Bangladeshis.

Solid waste disposal poses a greater problem because it leads to land pollution if openly dumped, water pollution if dumped in low lands and air pollution if burnt. Dhaka city is facing serious environmental degradation and public-health risk due to uncollected disposal of waste on streets and other public areas, clogged drainage system by indiscriminately dumped wastes and by contamination of water resources near uncontrolled dumping sites.

Bangladesh has minimal waste collection coverage which forces majority of the waste to be dumped in open lands. These wastes are not disposed of properly, where general wastes are often mixed with hazardous waste such as hospital waste. In a report on solid waste management in Asia, the data showed that, in Dhaka, only about 42% of generated waste is collected and dumped at landfill sites, and the rest are left uncollected. As much as 400 tons are dumped on the roadside and in open space. As such, these improperly disposed wastes poses serious health implications to the people where it may have the potential of transmitting diseases.

Due to the lack of funding, there are also insufficient subsidies put in place for the issue of waste management in Bangladesh. Hence, there are essentially no proper disposal facilities to cater to the rapid creation of waste.

Normally residents bring their refuse to nearby communal bins/container located in the street, whilst in some specific areas communities have arranged house-to-house collection of garbage by their own initiatives and efforts. Household, commercial, institutional and medical wastes are deposited in the same waste collection bins located beside the streets. Street sweeping is done manually and debris is loaded from the side into handcarts and delivered to the street storage facilities. In the down town areas, where the roads and lanes are narrow, the wastes are transported by two types of trucks i.e. either flat-bedded open vehicles or trucks with closed bodies (with shutters that slide vertically on both sides). In the new part of the City, a container system where containers are lifted hydraulically is working. Every vehicle has its own designated areas and routes for collecting wastes. The wastes, which remain uncollected, are dumped in open spaces, street and drains, clogging the drainage system, which create serious environmental degradation and health risks. The collected waste is presently being disposed of mainly in a low-lying area about 3 kilometers from the corporation area. There are few number of minor sites also which, are operated in an uncontrolled manner without any proper earth cover or compaction. In Dhaka, wastes, which have market value, are being reclaimed or salvaged for recycling. Recycling contributes to resource conservation as well as environmental protection. Recycling of paper, plastic, glass, metal etc. plays a very important role in the economic sphere and a large number of poor people are dependent on it for their livelihood. The major component of municipal waste i.e. organic food waste-is totally ignored even though it has potential value and can be converted into organic fertilizer.

Due to some reasons solid waste management system is not satisfactory in our country. Some reasons are Technical Constraints, Financial Constraints, Institutional Constraints, Economic Constraints, Social Constraints, and Social Constraints.

There have been recent developments in Bangladesh to improve waste management, especially in urban cities. In Dhaka, Dhaka City Corporation with support from the Japan International Corporation Agency (JICA) has a master plan underway to better handle the solid waste management in Dhaka. For instance, Social Business Enterprise Waste Concern has sprung up

to tackle the municipal waste accumulation problem through working with the households. UNICEF has also initiated recycling programs and waste control with the city corporations and municipalities. However, currently, there are still insufficient incentives to improve the standard of waste management across all relevant sectors, especially for industrial waste and medical waste.

Gazipur City Corporation is the largest city corporation of Bangladesh. It is considered as one of the most important industrial zone of our country. Because of rapid population growth and increase of industrialization the amount of waste generation in this area is increasing at an alarming rate. As the city corporation is formed newly, corporation authority is struggling to cope with the existing situation. Inadequate management practices and unrolled waste dumping are creating numerous environment problems. This study revealed that the existing waste management practices in Gazipur city is behind the satisfactory level due to poor infrastructural facilities in waste management ,lack of trained workers, lack of technologies and lack of proper planning‘s and monitoring activities.

1.2 Current situation of waste in GCC

Mainly the waste of GCC comes from two different places (i) Commercial (ii) Household the waste of both house and commercial is collecting by GCC authority. The waste collection method runs by

a. Community bin system

b. Collection drum truck

c. house to house collection

a. community bin system runs the city corporation authorities. The city corporation set up some bins at the selected point to drop the wastes of household and commercial at that selected point then they set some laborers to collect those wastes from bins.

b. The waste that the laborers collect with the help of the vans they drop that waste at the dump the city corporation sated.

c. house to house collection is very important the house owners make a bin at front of their house for dropping their waste at that bins.

Then the city corporation drops the wastes at the landfilling area where the “Tokai”s collects different recyclable items of low market value from the waste landfilling area.

1.3 Problem statement

As mentioned above that MSWM is a major problem in gazipur city Corporation as it is in many cities of developing countries. The rapid utilization of urban cities is producing waste. Every home is producing waste when you buy an item from market you use it and what left is waste you throw it and it goes to nature it can be harmful for environment did you ever thought that where it goes? The city corporation needs to be stricter.

1.4 Research objectives

The research objective of the thesis is to develop knowledge on how gazipur could reduce the environmental impact from its current MSWM practice by adopting waste management technology based on WtE.

Specific objectives are:

1. To design WtE model for efficient MSWM system in GCC
2. To identify the composition of MSW and its total volume through secondary literature.
3. To analyze the current municipal solid waste management in gazipur city corporation.
4. To identify what to change in current municipal solid waste management system.
5. To access and analyze the impact from current MSWM

1.5 Research question

The main research question:

What changes are needed to use waste as a resource for energy produce in gazipur City Corporation?

Sub questions:

1. How the current MSWM system in GCC is organized and with what results?
2. How could my concept of MSWM system for WtE can help GCC to reduce waste and gain energy?
3. What changes need to perform GCC to transform current MSWM system to a WtE system

Chapter 2

This chapter covers the basic overview of the main concept required by this research which are based on the prior research, scientific journals, reports, data and information from different sources. For this, the chapter begins with description of the study site, current MSWM system and institutional arrangement for the MSWM. In addition, the existing SWM legislation and policy are described at the end of this chapter.

2.1 description of the study area

Gazipur City Corporation is a local government body located in Gazipur district in central Bangladesh. It is a municipal administration and autonomous institution of Bangladesh. Among the city corporations of Bangladesh, Gazipur City Corporation is the youngest in terms of establishment and the largest in terms of size. Gazipur City Corporation has an area of 329.90 sq km. Mirzapur Union of Gazipur Sadar Upazila to the north, Yarpur Union of Dhaka North City Corporation and Savar Upazila to the south, Baria Union of Gazipur Sadar Upazila to the east, Nagri Union of Kaliganj Upazila and Prahlbadpur Union of Sreepur Upazila and Mouchiak Owla of Shamapur and Uniqim of Kaliakair Upazila Damsona Union is located. Gazipur City Corporation has a population of about 65 lakhs. Gazipur City Corporation consists of 57 wards. About 75% of the country's garment industry is located in this region.

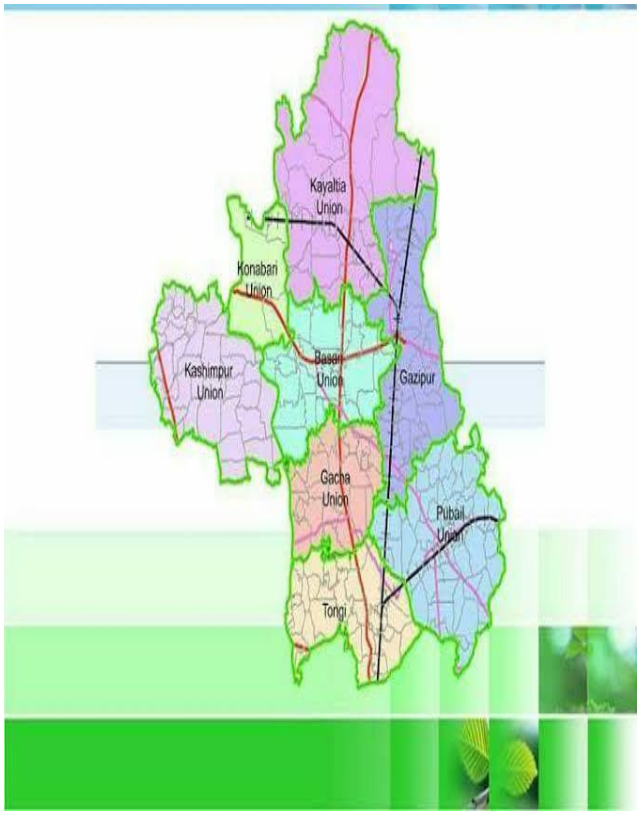


Figure 1: Road map of Gazipur city Corporation

Figure 2: 5 zone of Gazipur city Corporation

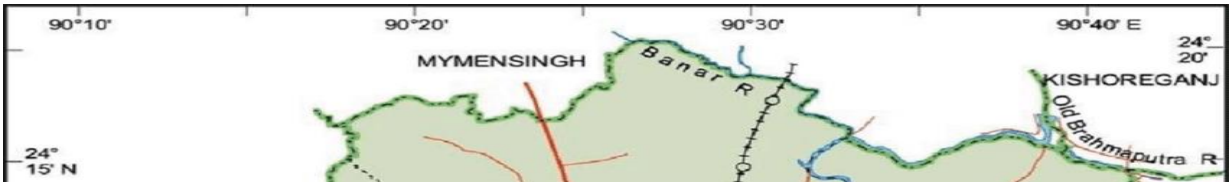


Figure 3: Map of Gazipur district

2.2 Municipal solid waste situation in Bangladesh

In order to include the portion of waste generated from non-domestic sources in the estimates, the total domestic urban waste generation amount is multiplied by an element to supply an estimate for the quantity of total urban waste generation; 20,900.98 tons per day during the season , or 29,261.37 tons per day during the wet season.

The study recognizes that waste generation rates during wet season are estimated to be approximately 40% higher than during the dry months of a year. Accordingly, to estimate the total daily urban average waste generation rate, the wet season is assumed to last for 120 days, while the dry period is assumed to last for 240 days.

Thus the total daily urban waste generation average is estimated to be 23,687.78 tons per day, or 0.56kg per capita per day.

The composition of municipal waste are generally organic, plastics, paper and paper products, glass, metals textiles, rubbles and leather et al. . The organic waste shares the highest volume in comparison to other waste in Bangladesh.

However, the volume and composition of MSW is governed by living standard and economic status of the community and households. The following figure 3 shows the MSW composition in 271 urban localities in Bangladesh of which 10 are cities/city corporations, 106 are Category A pourashavas, 96 are Category B pourashavas, 56 are Category C pourashavas, and three are defined as a special category.

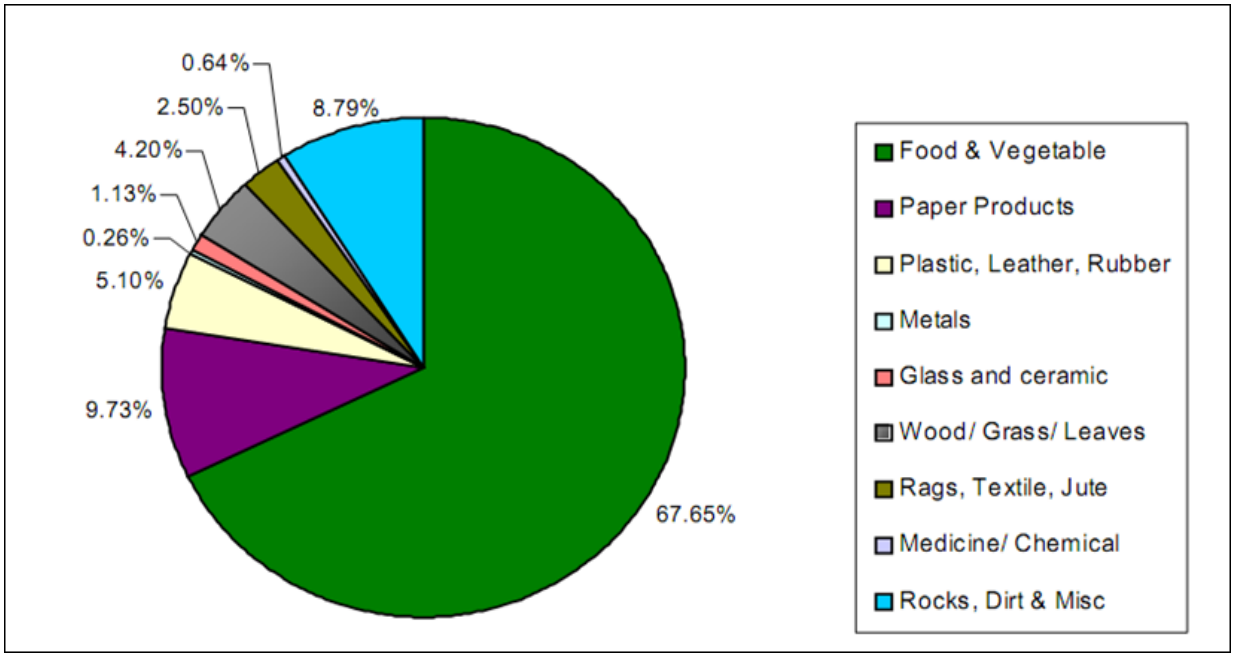


Figure 4: Average physical composition of urban solid waste in Bangladesh

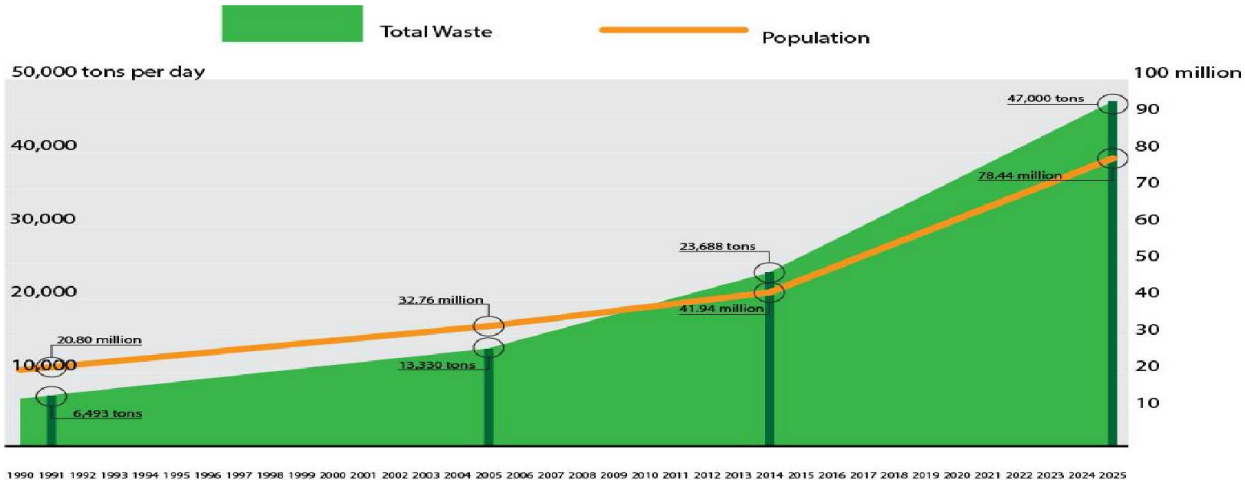


Figure 5: Total Waste Generation vs. Urban Population

2.3 Municipal solid waste situation in Gazipur

Gazipur is the largest city corporation in the country in terms of size. But civic amenities are very few. This city corporation has an area of about 330 square kilometers and a population of 3 million. There are 1,006 factories. But with so many people, so many factories without waste and sewerage system. Garbage all over the city.

Local residents and people's representatives acknowledge this fact and say that Gazipur is like a garbage city. In a little rain, Gazipur is captured in its original form. Many roads are submerged in dirty water on rainy days. They said that the problem of water and waste in Gazipur has gone so far that these two problems have become as big as the size of the city corporation.

Professor Mukul Kumar Mallick, a member of the Gazipur Aware Citizens Committee (SNAC), told that, 'Gazipur will be a beautiful city, that is what everyone expected. But our expectations were not met. City waste has become unbearable. But before the election, all the candidates promised to build a beautiful city.

Gazipur City Corporation was formed in January 2013. This city corporation consists of six unions including Old Tongi and Gazipur Municipality. Seven years have already passed since the city elections in July 2013. But there is no master plan for the city corporation yet. As a result, factories, roads and houses are being built unplannedly in Gazipur, one of the most industrialized areas of the country.

Asked about this, city expert Professor Nazrul Islam told that the infrastructure of Gazipur City Corporation is very weak and incomplete. Large rural areas are included. It was not built as a city of housing and industrialization. The planning was the responsibility of RAJUK. They could not pay attention due to limitations. When they looked again, they came across obstacles in Tongi and Gazipur municipalities.

Madan Chandra Das, conservancy inspector of Gazipur City Corporation, told that the problem would not be solved unless a permanent dumping ground was set up. Looking for a new place. At present, about four thousand metric tons of garbage is being removed from Gazipur City every day. Of this, 2,500 metric tons of garbage is collected by the city corporation every day. Garbage in the 6th and 7th zones of the city is collected by the local community through their transport. There are 22 secondary substations in Gazipur. Of these, 2 are pucca, the remaining 20 are in open space. Garbage is being collected from these open spaces in Kadda area. There is a height of 17-18 feet when garbage is dumped there. At present they have 360 employees and 45 vehicles. Due to the presence of electric wire on the dirt, the electric wire has ruptured several times while working with Veku.

Table 1: Average waste generation rate of boardbazar

Family No	Number of family members	Dry season 2016		Wet season 2016	
		Amount of waste (kg/day)	Generation rate (kg/capita/day)	Amount of waste (kg/day)	Generation rate (kg/capita/day
1	7	2.8	0.4	2.9	0.41
2	5	1.01	0.202	1.1	0.22
3	6	2.6	0.433	2.5	0.42
4	4	1.03	0.26	1.04	0.26
5	8	3.09	0.39	3.08	0.385
6	7	2.01	0.29	2.00	0.28
7	5	1.03	0.206	1.02	0.204
8	7	1.05	0.15	1.06	0.15
9	3	1.01	0.34	1.2	0.4
10	5	2.67	0.534	3.765	0.753
Total	**57**	**18.297**	**Average generation rate= 0.321**	**19.665**	**Average generation rate= 0.345**
		At 2015	0.316	At 2015	0.426

Table 2: Average waste generation of kaliakoir

Family No	Number of family members	Dry season 2016		Wet season 2016	
		Amount of waste (kg/day)	Generation rate (kg/capita/day)	Amount of waste (kg/day)	Generation rate (kg/capita/day
1	5	2.04	0.408	2.59	0.518
2	12	2.58	0.215	3.16	0.26
3	10	1.35	0.135	2.39	0.239
4	7	4.87	0.695	5.62	0.8
5	6	1.40	0.23	4.52	0.75
6	6	1.5	0.25	3.2	0.53
7	7	2.97	0.42	4.56	0.65
8	9	3.02	0.33	4.58	0.50
9	8	2.1	0.2625	4.28	0.535
10	7	2.04	0.291	3.6	0.514
Total	**77**	**23.87**	**Average waste generation rate=0.31**	**38.5**	**Average generation rate=0.50**
		At 2015	0.31	At 2015	0.37

Table 3:Average waste generation of kaligonj

Family No	Number of family members	Dry season 2016		Wet season 2016	
		Amount of waste (kg/day)	Generation rate (kg/capita/day)	Amount of waste (kg/day)	Generation rate (kg/capita/day
1	8	2.8	0.35	2.5	0.31
2	7	1.2	0.17	5.74	0.82
3	8	2.5	0.31	1	0.125
4	6	1.02	0.17	1	0.17
5	4	3.08	0.77	1.05	0.375
6	12	2	0.17	3.08	0.32
7	3	1.04	0.35	2.6	0.87
8	9	1.04	0.116	1.02	0.113
9	7	1.02	0.15	1.56	0.22
10	8	3.02	0.385	2.05	0.26
Total	**72**	**18.72**	**Average generation rate=0.26**	**21.6**	**Average generation rate=0.30**
		At 2015	0.27	At 2015	0.36

Table 4: Average waste generation of kapasia

Family No	Number of family members	Dry season 2016		Wet season 2016	
		Amount of waste (kg/day)	Generation rate (kg/capita/day)	Amount of waste (kg/day)	Generation rate (kg/capita/day
1	4	0.85	0.2125	1.58	0.395
2	7	3	0.4285	2.3	0.33
3	8	1	0.125	2.9	0.36
4	5	1.02	0.204	1.4	0.28
5	6	1.03	0.172	1.8	0.3
6	4	0.78	0.195	1.3	0.325

7	9	1.04	0.116	2.59	0.29
8	12	4	0.33	4.29	0.36
9	12	1.39	0.116	4.64	0.39
10	8	0.89	0.111	0.45	0.056
Total	**75**	**15**	**Average generation rate=0.20**	**23.25**	**Average generation rate=0.31**
		At 2015	0.2026	At 2015	0.36

Table 5: Average waste generation of sreepur

Family No	Number of family members	Dry season 2016		Wet season 2016	
		Amount of waste (kg/day)	Generation rate (kg/capita/day)	Amount of waste (kg/day)	Generation rate (kg/capita/day
1	6	2.01	0.335	2.5	0.42
2	6	1.00	0.17	1.5	0.25
3	5	1	0.2	1.02	0.204
4	4	1	0.25	1.03	0.2575
5	7	2.06	0.29	2.3	0.33
6	6	1.05	0.175	1.4	0.23
7	4	1.5	0.375	1.8	0.45
8	5	1.6	0.32	2.3	0.46
9	3	1.01	0.337	1	0.33
10	8	3.97	0.49	2.97	0.37
Total	**54**	**16.2**	**Average generation rate=0.3**	**17.82**	**Average generation rate=0.33**
		At 2015	0.289	At 2015	0.377

Table 6: **Comparison between waste compositions**

Type	**Primary station (%)**	**Secondary station (%)**	**Final Dumping site (%)**	**Difference between primary and secondary station**	**National waste composition (%)**
Food	64.85	57.87	58.46	-6.98	67.65
Paper	13.04	5.57	5.01	-7.47	9.73
Plastic	5.82	5.59	4.08	-1.04	5.10
Garden trimming	2.22	4.34	3.58	+2.12	4.20
Rubber	1.57	1.05	1.15	-0.05	N/A
Leather	0.37	0.99	1.00	+0.62	N/A
Wood	0.57	4.34	4.57	+3.77	4.2
Bone	2.32	2.5	1.06	+0.18	N/A

2.3.1 Current solid waste situation in Gazipur City Corporation

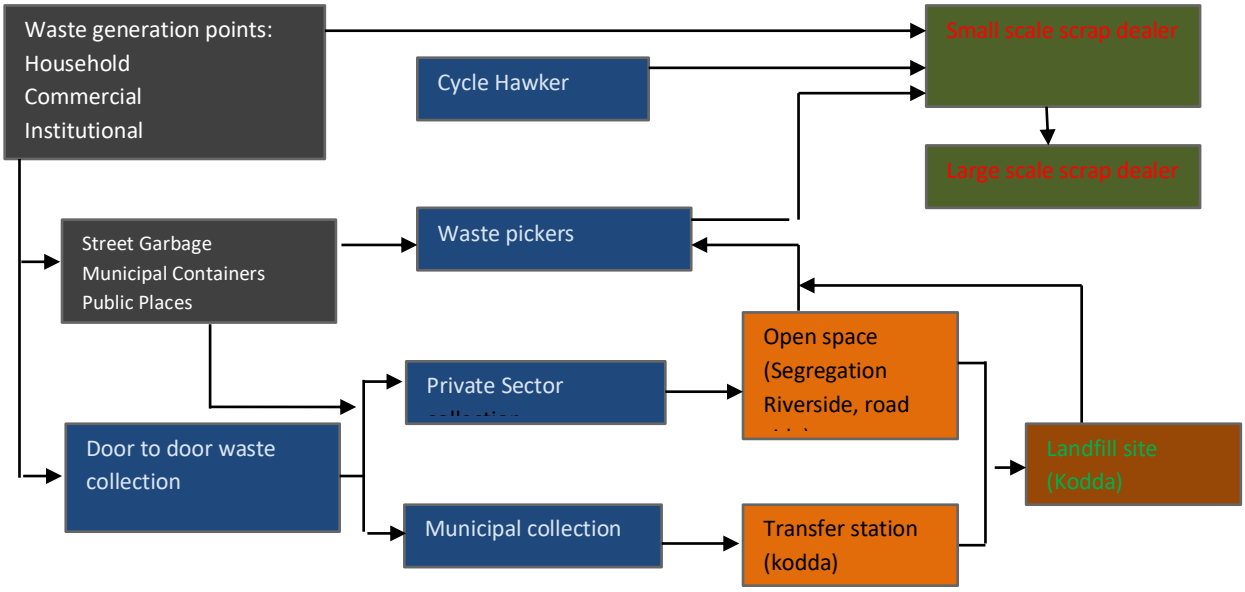


Figure 6: Current MSWM system in Gazipur city Corporation.

Gazipur, the country's largest city corporation by size, has yet to develop a waste management system. There is no specific dumping station. The whole city is unclean.

The Gazipur City Corporation area started as soon as you crossed Abdullahpur to go from Dhaka. Garbage can be seen on both sides of the 12 km road up to Chandna Chowrasta in Gazipur. From Dhaka to Mymensingh Road, in the corner of Ahsan Ullah Master Stadium in Tongi, in front of the fish seed production farm in Boardbazar area, a little further in the area of Malek's house, across Chandna crossroads, in front of Ulka Cinema Hall. These are open spaces, in the way of human movement. In the area from Bordbazar to the crossroads, separate drains have been made on both sides of the road outside the sewers. Open drain water is black and dirty, crammed in polythene bags. The stench spreads all the time. To enter most of the shops, you have to climb the wooden or bamboo stairs from the road.

Figure 7: Garbage from residential areas and industries dumped beside a road in Gazipur city

Source: The Independent, Dhaka.

Mahfuzur Rahman, a security guard at a private company, said the canal had been cut for almost a couple of years. He has to stand by the drain and perform his duties. He used to cover his nose with a handkerchief most of the time. Now a lot has been tolerated.

Joydebpur, the main center of the city corporation, is on the right hand side of the road from Chandna crossroads. Gazipur city in the language of the locals. Even if you go there, you will see mountains of dirt in at least two important places. To enter the city, garbage is dumped at the corner of Sardi Road and at the corner of Shivbari. Apart from these two places, a few kilometers long road before the rail crossing is littered with rubbish. The office of the Department of Environment is just inside the corner where the waste is dumped at the corner of Sardi Road. The environment department has written to the city corporation not to dump garbage in the area. But the city corporation says they are helpless for now.

Figure 8: Waste Garbage beside Dhaka tangail highway

This is not the end. On the Tongi-Ghorashal road also, it is seen that household waste is being dumped in the open. Garbage is piled on the side of the main road at Ahsan Ullah Master flyover, Shimultali Bridge area, Morkun, Amtali area. Ordinary people are throwing garbage in these places, that is not the case. The city corporation dumps garbage in these open spaces.

SM Sohrab Hossain, chief waste manager of Gazipur City Corporation, told Prothom Alo that the problem of waste management is not being solved due to lack of space of the city corporation for dumping, required manpower, vehicles and other crises. They have 6 cleaners. Household waste is collected from old Tongi and Gazipur municipality areas. Apart from this, waste is collected from other areas on a weekly or regular basis. They are stored in 10-15 places. Later they were initially dumped at a place on roads and highways in Kadda.

Figure 9: landfilling area in Baimail Gazipur city Corporation.

Source : getty images

Figure 10: waste Mountain in Kodda, Gazipur city Corportion in beside of Dhaka Tangail highway.

Source: News 24, 2020.

Locals say the condition of the main town is somewhat better but not very clean. Across the Joydebpur junction, garbage is dumped at many places in the residential areas of Chhayabithi, Tankir Par and Jor Pukur. The city corporation has not taken any initiative to keep the roads and sidewalks clean. Roads are not regularly swept.

One of the slogans of the current mayor's election campaign was 'Green City, Clean City'. Acknowledging the mismanagement of the city's garbage, Gazipur City Corporation Mayor Jahangir Alam told Prothom Alo, "I have visited many countries in the world. Honestly, our Gazipur City Corporation is in the rubbish. Gazipur is the longest dustbin and garbage city in the world, that's for sure. 'He said the reason for this was the lack of dumping stations. In 56 wards, 60 places are required for dumping and 4 more places for crashing. About 200 bighas of land is required for household waste. That place does not belong to the City Corporation. They have written to the government. Hopefully, the place will be given soon.

2.3.2 MSW transfer and final disposal at landfill (kodda)

Around 400 workers and 25 vehicles are employed to scrub garbage from the town areas. Among these vehicles, 12 were purchased about 20 years ago when the city corporation was still a municipality. A letter has been sent to the Department of Local Government, seeking permission to purchase new vehicles and employ more manpower .
GCC chief executive officer KM Rahatul Islam said, "We're trying our best to manage the situation. But we will not find land to line up a dumping station."
He also cited funds crunch and lack of manpower for the town corporation's failure to resolve things . He, however, said that the GCC has purchased garbage trucks and payloaders from its own resources to remove additional garbage.
"Besides, we've recently received seven vehicles from the government ministry for removal of garbage. It also assured us to provide more vehicles for this purpose. We hope to achieve success if our plans fall in place," he added.
The acting mayor of GCC, Asadur Rahman Kiron, said, "It's our main challenge. We've allocated a large amount of money in the budget for garbage management. We want to line up dumping stations at every ward."

2.3.3 Resource recovery

Resource recovery in MSWM involves with the processing of recovering energy or different product from MSWM for another use. This strategies primarily aims to reduce environmental, economic and social burden for the municipality from the MSW to be landfilled7. The resource recovery in waste management hierarchy stand as reduce, reuse and recycle which ultimately helps to reduce MSW and generate energy.

In the case of MSWM in GCC, resource recovery is not performed formally and adequately although the SMW Act 2011 has emphasized on 3 R principle of waste management, reduce, reuse and recycle. However, some resident of GCC has been practicing 3R waste management at household level such as composting from organic waste.

Recycling
Recycling of MSW in GCC is basically carried out by non-government body such as NGOs, CBOs, private sector, informal group including waste picker and scavengers. The recyclable waste from HHs, commercial and institutes are collected by private sector and sell to scrap dealer.
The following figure 12 represents informal sector involvement in the informal recycling system in the developing countries. And this informal recycling system consists of at least four main categories depending on the place of waste recovery which is resembled to the current scenario of MSWM in GCC. The first is itinerant waste buyers buy specific recyclable waste

from door to door. Second is street waste picker who collects waste from mixed waste thrown on the road and public places. Third is municipal waste collection crew where secondary raw materials are recovered from container or truck that transport waste to landfill. Fourth is waste picking from dumping area where scavengers segregate recyclable waste from final disposing waste (Wilson et al., 2006). These actors play an important role in collection of reusable and recyclable waste in GCC.

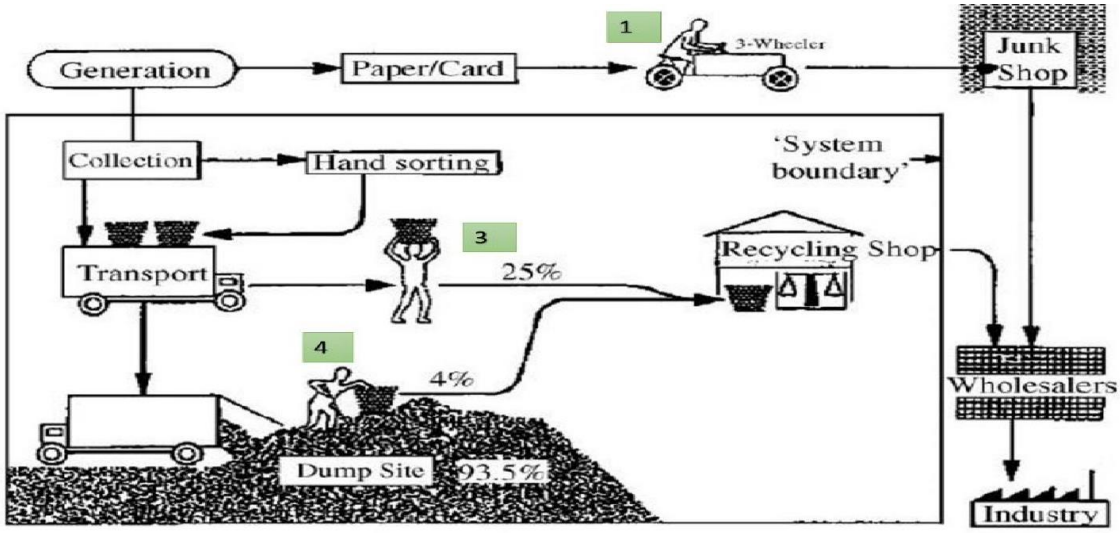


Figure 11: formal sector engagement in recycling of MSW in GCC.

Composting and Energy recovery (WtE)
The composting of biodegradable waste is another resource recovering process. The MSW composition is highly organic with great potential for composting as well. However, this has been practiced in household level for kitchen garden and some private company in small scale. WtE is the process of recovering energy from waste is a new concept in Bangladesh.

2.3.4 Public awareness
Most of waste are generated from households in GCC. Hence, the public participation and consultation is essential for the establishment of efficient and robust SWM system. One of the key challenges of SWM is lack of public consciousness and knowledge on SWM that is also observed in case of MSWM in GCC . Waste segregation as organic and inorganic is most important at source and this should be recognized by public. For this, environment department of GCC had formed a community mobilization unit which is working closely with different groups of community for raising awareness and providing them with training and necessary support and also promotion of 3R principle for the efficient SWM in GCC (Water Aid, 2008). Although providing and delivering all mentioned awareness program and effort delivered by GCC, many people and even staff of municipality are still unaware of proper SWM. OAG 2015 stated that various organization are actively involved in awareness program for sustainable SWM and cleaning up activities implemented in school level as well. However, the waste separation at source and haphazard disposing of waste is still in practice in GCC.
2.3.5 Special waste management

Special waste refers to the waste generated from construction and industries, waste from medical centers, lab and dead animals. These waste need a careful and systematic approach to be managed separately from MSW and to ensure that it is not mixed with MSW. In case of GCC, though most of the hospital use incinerator to burn these special waste, however, there is no proper slaughterhouse seen and dead animal are mostly thrown in a river, open public space or dumped in landfill.

2.4 Institutional arrangement for the MSWM

Table 7: Institutional arrangement for the MSWM system

SL no.	Major Initiatives	Inception Year	Funding Organization (s)
1	Recycling Training Centre	2006	Government of Bangladesh (GoB) and United Nations Development Program (UNDP)
2	Strengthening of Solid Waste Management in Dhaka City	2007	Japan International Cooperation Agency (JICA), Dhaka City Corporation (DCC) and Local Government, Rural Development and Co-operatives (LGRD&C)
3	Improvement of Solid Waste Management in Dhaka toward the low carbon society	2008	JICA partnership with DCC and LGRD&C
4	Preparation of Solid Waste Management Plan for 19 towns of Bangladesh	2009	United Nations International Children's Emergency Fund (UNICEF), GoB and Waste Concern
5	Urban Public and Environmental Health Development Project	2010	GoB, Asian Development Bank (ADB)
6	Bangladesh towards zero waste	2013	European Union (EU)
7	Value for waste (First Phase)	2013	Waste Concern, Swisscontact

The table shows that which institutes are taking what actions for controlling waste in Bangladesh .

2.5 MSWM planning in GCC

From 2014 GCC had prepared an Action Plan on Solid Waste Management. However due to inefficient operational activity led to current disorganized waste management system. The action plan need further updates which should include concrete plan, vision, mission and aim for the GCC's effective MSWM. Similarly, recently elected local government representative has to give equal priority to environmental issue such as MSWM as other developmental issues of the municipality.

2.6 Actors involvement in MSWM system in GCC

Different stakeholders such as government body, private sectors, INGOs, NGOs, CBOs and public participate in MSWM activities in GCC. The 57 wards of GCC has a semi-formal

MSWM practice that is involvement of private sector in collaboration with GCC. Most of the private organization are informal and are not legally registered to government agency. However, there is also involvement of formal private organization who has an agreement with GCC and NGOs contributed in waste management activities and there is also willingness of community for the waste separation at source . In addition, some NGOs and civil society group are undertaking public awareness campaign such as Bagmati river cleanup campaign where public participate to clean river. Likewise, in recent year, some private recycling companies collect waste (paper, plastic, glass bottle, metal and electronic waste) from door to door and with free of charge, even allowing public to sell their recyclable waste. Though they are limited to particular area, has contributed in MSWM in GCC.

2.7 Policies, Guidelines and Regulations with EPR Implications (There is no specific policies related to EPR)

Although economists have emphasized the need of internalizing the environmental costs (ECs) for long, a new impetus in this direction, particularly for waste management, has come from the introduction of extended producer responsibility (EPR), which is a strategy designed to promote the integration of ECs associated with goods throughout their life-cycles into the market price of products. Assigning such responsibility bears potential to (i) prevent waste at source, (ii) promote environmentally sound product design and (iii) support recycling by public. EPR can thus serve as policy for industry to drive recovery and recycling rates.

One attractive feature of EPR policies is that they can shift the waste management cost or physical collection of used goods partially or fully from local governments to producers.
Although there are no specific legislations or policies related to Extended Producer Responsibility (EPR) in Bangladesh yet, national government sectoral, urban and environmental policies do have provisions or implications of EPR nature. This section lists general policies, regulations and guidelines related to environmentally-sound waste management and the 3Rsin Table 8, Table 9, Table 10 and Table 11.
The tabular presentations below show that the already existing national regulatory framework does have bearing for EPR to serve as a tool or strategy for ensuring 3R practices at product manufacturing stage. However, because of potential disincentive to the business and industrial activities or because of limited power of the policy implementing agencies such as DoE to serve as an effective EPA, EPR strategy has yet to become an effective tool for ensuring 3R practices at product manufacturing stage or to financially and technologically support the municipalities to promote 3R practices effective at consumer or citizen level.

Table 8: National government policy having provisions on and implications for extended producer responsibility (EPR)

Policy	Provisions
1999 National Agriculture Policy	- Promotes use of compost and organic fertilizer by farmers to improve soil productivity and food security
2006 National Urban Sector Policy	- Proposes public utilities adopt user pays principle to extend services and reduce burden on municipal budgets - Government support for recycling by imposing user fees for waste disposal, encouraging composting and formalizing the function of waste pickers/ informal sector
1998 Urban Management Policy Statement	- Supports private sector participation in SWM and recycling services
1998 National Policy for Water Supply and Sanitation	- Sanitation includes Solid Waste Management - States measures should be taken for recycling of waste as much as possible.
1992 National Environment Policy	- Restrict use of chemical fertilizers and pesticides that pollute water or damage ecosystem - Encourage the use of organic fertilizers and promotes organic farming
2005 National Industrial Policy	- This policy is recommended use of EMS and Cleaner Production practices amongst the industries
2008 National Renewable Energy Policy	- This policy is promoting production of biogas and other green energy from waste and also providing incentive such CDM to promote green energy projects.

Table 9: Acts and rules with provisions on Extended Producer Responsibility (EPR)

Acts	Provisions
2009 Local Government (City Corporations) Act 2009 Local Government (Municipality) Act	- The occupiers of all other buildings and land within the City Corporation/ municipality shall be responsible for the removal of refuse from such buildings and lands subject to the general control and supervision of the city corporation/municipalities.
2006 Fertilizer Act	- Makes provisions for the development of a compost standard, which was circulated in 2008.
1995 Bangladesh Environmental Conservation Act	- Identifies need to control discharge, disposal and dumping of solid and other types of waste which may cause harm to the environment; - Enacts 'polluter pays' principle whereby originator of the pollution must pay for mitigation; - Allows for formulation of environmental guidelines and rules for control and mitigation of environmental pollution, conservation and improvement of the environment.

2010 National Solid Waste Management Handling Rules	- Identifies the following objectives for SWM in Bangladesh: Encouraging recycling, resource conservation and recovery; Encouraging private sector participation and citizen participation in SWM/ - Identifies responsibilities of residents, municipal authorities and Department. - Sources Segregation: Encourages reduction of waste at the source, and highlights segregation of biodegradable, non-biodegradables and hazardous waste at source to assist in recycling.
Fertilizer Management Rules 2007	- Emphasizes fertilizer quality management and standardization

Table 10: National strategies with provision on extended producer responsibility (EPR)

Strategies	**Provisions**
National 3R (Reduce, Reuse and Recycle) Strategy for Waste Management 2010	Guiding principles include: - Source separation of waste - Selection of appropriate, affordable and emission reducing technology - Industrial symbiosis and by product exchange - Polluters Pay Principle and take back provisions - Linking service provision with payment (user pays)
Poverty Reductions Strategy paper (PRSP) 2005 and the Sixth Five-year plan (FY2011-2015)	- Emphasis on source segregation and 3R approach
National Sanitation Strategy 2005	- Resources recovery and recycling as alternative to disposal identified as key to improve urban sanitation

Table 11: National environmental plans with provisions on extended producer responsibility (EPR)

Plans	**Provisions**
National Environmental Management Action Plan 1995	- Promotion of waste reduction and recycling of waste
Environment Management Plan 2005	- Waste reduction and recycling identified as a priority

2.8 Conclusion

It is observed that the urbanization and increasing population has accelerated the MSW volume in which the organic waste is dominating in total MSW composition. This organic waste is

landfilled in Kodda which is critically out of its carrying capacity. Further, it can be analyzed that GCC has poorly managed MSW which is creating environmental and public consequences. Hence, there is an urgent need to manage this MSW problem. For this, following key approaches need to be highlighted for improving SWM in GCC.

i. While the enactment of the new SWM Act in National 3R 2010 was a major step toward improving SWM practices in Bangladesh, it has not been effectively translated into actions and results on the ground. A national SWM policy and strategy that specifies key policy objectives, guiding principles, and an implementation strategy with a timeline and a clear monitoring and evaluation mechanism needs to be developed to provide clear strategic direction to local bodies.

ii. For the effective MSWM, the waste management hierarchy (WMH) can be effective tool. It includes 5 different components which are prevention, reuse, recycling, recovery and disposal (Ec.europa.eu, 2019). The WMH will be helpful to prioritize waste prevention and management.

iii. Promotion of new concept like Waste to Energy approach should be initiated for energy recovery from waste. In recent years, WtE has been considered as a solution to solve the increasing MSW in many emerging cities and fast growing energy demands (GIZ, 2017).

The following figure 12, demonstrate the waste management hierarchy for effective MSWM.

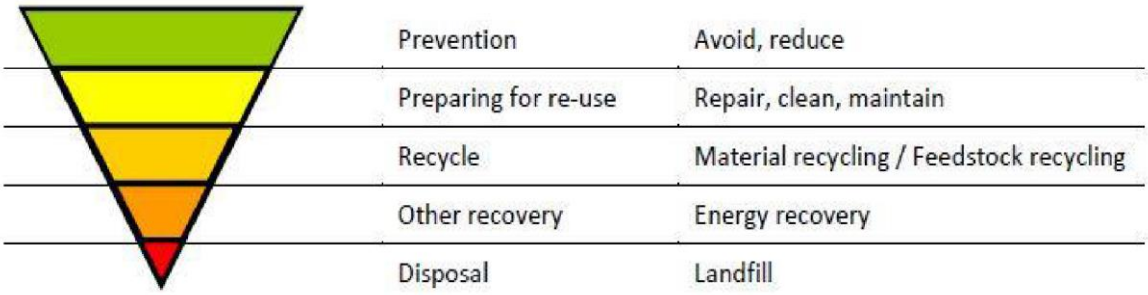


Figure 12: WMH based on the EU directive 2008/98/EC and European commission 2016

Chapter 3

In current world the electricity is most needed energy. That is why in our research we have tried to create a system that can make electricity from the waste in this chapter we will show that how can we build an WtE plant and what benefit we will have from it. The waste is a problem in our daily life so we have tried to use it as a source of energy. In this chapter we will calculate the energy that can be generated from different MSW and its analysis. The chapter ends with the description of new proposed MSWM model for GCC.

3.1 Energy recovery

In term of environment protection the energy recovery or renewable energy is one among the important components of WMH with is performed by either combustion or anaerobic digestion of MSW. The combustion or digestion of MSW not only support to scale back waste but also recover energy. The energy generated from the process are renewable and it contributes to replace fossil fuel which ultimately reduce GHGs and also minimize the methane generation in landfill site.
The heavily increasing MSW in many developing cities of low income nations such as Gazipur has been a part of concerned issue in term of possible impacts toward environment and public health.

3.2 Waste to energy Concept

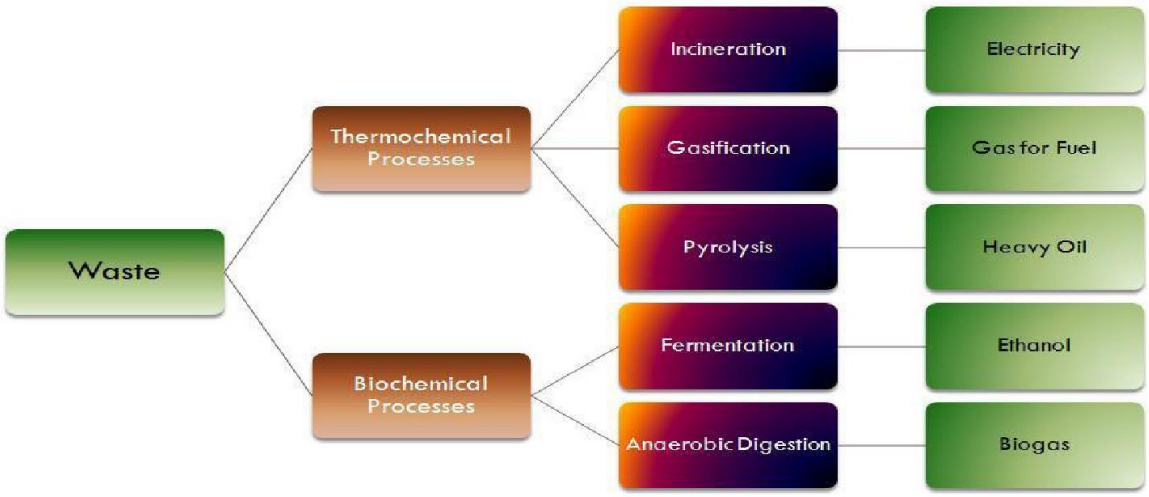


Figure 13: Waste to energy concept.

Pereira and Lee, 2015 stated that there is more challenges than opportunity to manage MSW and get materials from it as recycling products, biogas, heat or energy. MSW composition differs from country to country since its production depend on economic development, climatic condition and cultural and traditional value. The composition of MSW of developing countries is mostly organic while in developed countries the MSW consist high volume of inorganic waste (Trang and Wilson, 2017). The MSW is increasing day by day as the population is increasing, there is an urgent requirement to develop the strategies to manage and treat these

growing volume of MSW in the world.
WtE approach and its technologies are favorable for low income countries for converting MSW into useable sort of energy (Moya et al., 2017) to affect the environmental problem and energy crisis. Waste to energy technologies are used as a serious tool within the integrated SWM to mitigate the impact of worldwide warming and global climate change in most of the developed nations.
WtE is the technological approach that contribute to recover energy into heat, electricity or other substitute fuels such as biogas (GIZ, 2017) from MSW. The scope of the concept WtE is a broad term which includes a wide range of technologies at various scales and intricacies. This technology comprises thermal treatment of waste in incineration plant, co-processing of refuse derived fuel in cement plant or gasification (GIZ, 2017), pyrolysis, collection of methane gas from landfill sites and cooking gas production in household digesters from organic waste (Gumisiriza et al., 2017). These technologies possess different functions and characteristics and can be applied to various categories of waste that include semi-solid (such as thickened sludge from effluent treatment plants) to liquid (such as domestic sewage) and gaseous (such as refinery gases) waste (GIZ, 2017). However, Eurostat 2013, stated that, at least within the European Union, treating MSW is the most common practice.

3.3 Waste to energy technology options

WtE technology was started as the incineration technology which was built in Denmark in 1903 for the first time in history (Dbdh.dk, 2019). MSW can be transformed into energy from various WtE conversion processes and most commonly used techniques are thermal treatment technology (thermochemical conversion) and biological treatment technology (biochemical conversion) for converting MSW into energy (Shrestha et al., 2017 and Zafar, 2019). According to Zafar, 2019, thermochemical conversion is applicable for the low moisture content waste whereas biochemical conversion is best option for high moisture content waste such as organic waste. The following flow chart (figure) show the varied waste converting technologies.

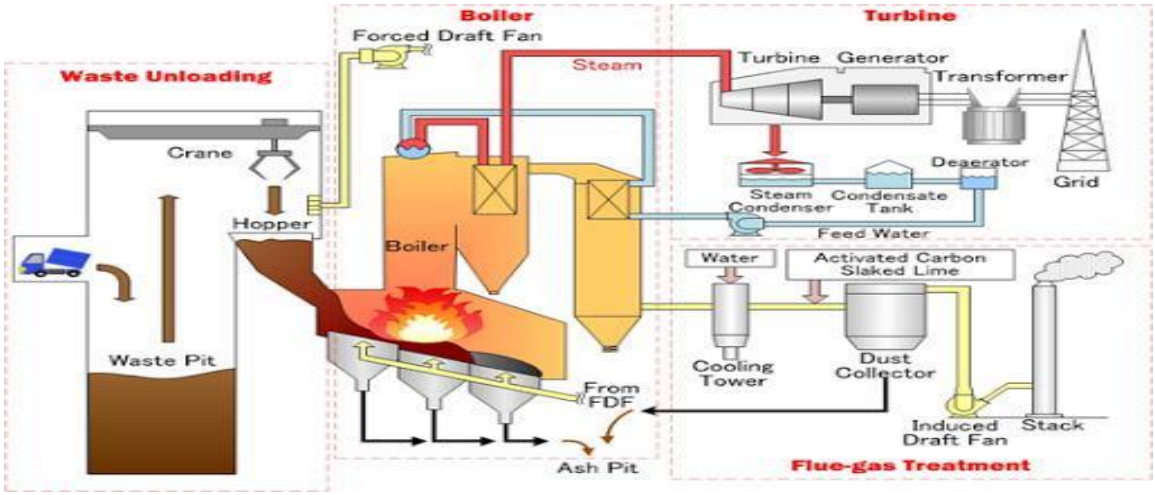


Figure 14: Waste to energy technologies.

Source: Zafar, 2019

3.3.1 Thermochemical conversion

The thermochemical conversion are often classified into incineration (combustion in excess air), gasification and pyrolysis. Incineration is that the process of combustion of municipal waste within the raw form to get energy within the sort of electricity or heat. The process of combustion takes oxygen to fully oxidize the waste and converted it into carbon dioxide and water producing 850 degree Celsius combustion temperature (DEFRA, 2019). Energy recovery through incineration process is a well-known technique and high quality treatment of municipal waste in big cities which helps to reduce the quantity of the waste to be landfilled. This technology seems feasible for urban setting which may be a practical solution to manage huge volume of municipal waste also as recover energy from it. However, this technology requires high investment since environmental measures should be considered to regulate emission. Therefore, before implementing incineration technology, waste volume, combustion heat of the waste, location, maintained facilities, operation and maintenance cost and investment has to be deliberated. Furthermore, these environmental consideration and huge investment cost is not preferred alternative in most of the developing countries to implement incineration technology for waste management.

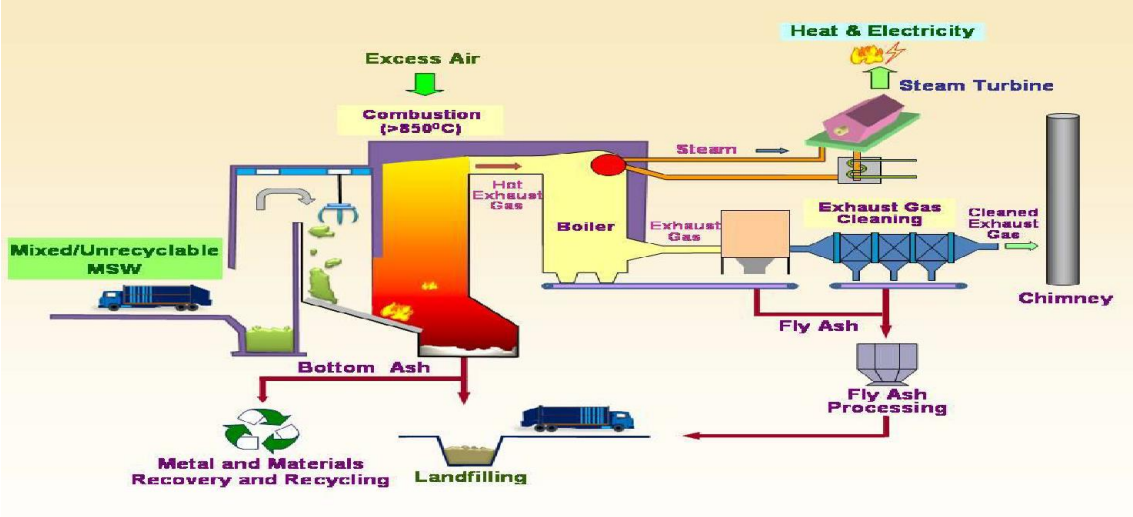


Figure 15: Incineration flow chart which shows the thermal treatment technology

Source : "Frank Knotts on September 3, 2017

Pyrolysis and gasification technique are used as the alternative to incineration which are thermal treatment process. These process reduce volume of the waste by converting solid waste into gas or oil followed by the combustion. These process are regulated in USA and European Union countries as waste incinerators and these process consist of thermal treatment of solid waste and combustion of resulted gases from process both in site or distributed fuel (Tangri and Wilson, 2017). Particularly, gasification process include decomposition of solid waste requiring high heat which is above 600 degree Centigrade during a starved oxygen level (Moustakas and Loizidou, 2010). Likewise, pyrolysis is analogous to gasification which also convert waste into oils and gas also as solid waste outputs within the presence of warmth without oxygen supply. These technologies has been testing over 30 years by various companies (Tangri and Wilson, 2017).

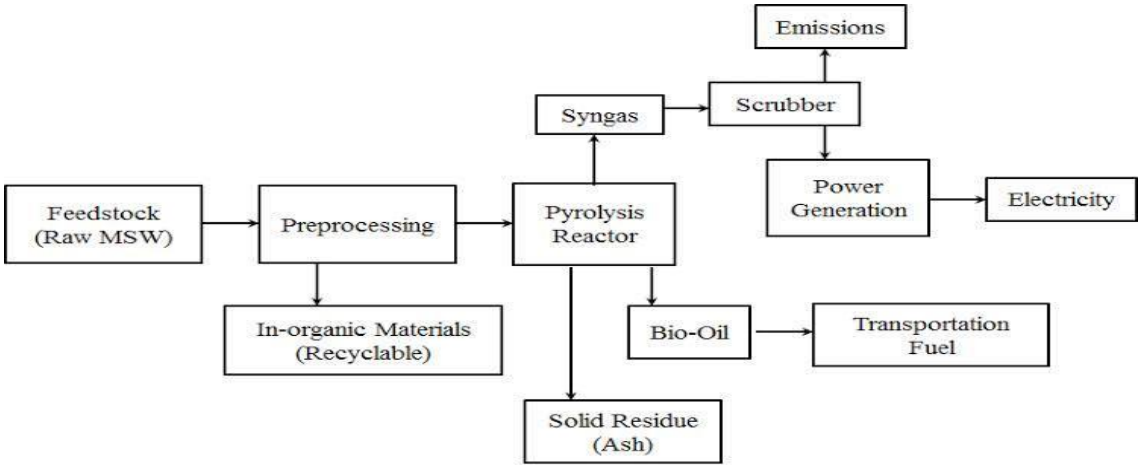


Figure 16: Pyrolysis process frow diagram for municipal solid waste treatment in urban environment

Source: Urso Campos, 2015

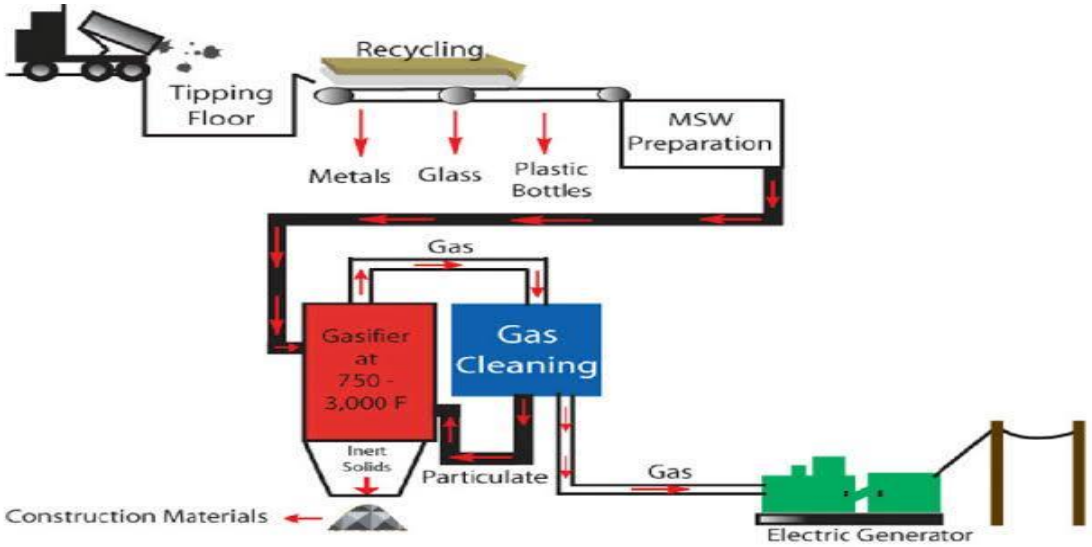


Figure 17: Schematic of MSW gasification and power generation plant

Source: Salman Zafar, 2009

3.3.2 Biochemical treatment

Likewise, biochemical treatment process are done by fermentation (in aerobic condition for composting) and anaerobic digestion (AD) process. AD may be a natural organic process of converting organic waste into combustible gas which may be a mixture of methane and CO2 without presence of oxygen (Moya, et al, 2017) is also described as WtE approach but is apposite of thermal process. And this treatment process needs limited amount of energy in comparison to aerobic process. AD are often an efficient technology for treating organic waste (Zafar, 2019) since biodegradable municipal waste has huge potential of energy production. Hence, this treatment technology is meant and engineered for the organic MSW to be treated by natural organic process (DEFRA, 2019). AD technology is practical option for managing organic waste in most of developing countries that produce larger volume of organic waste.

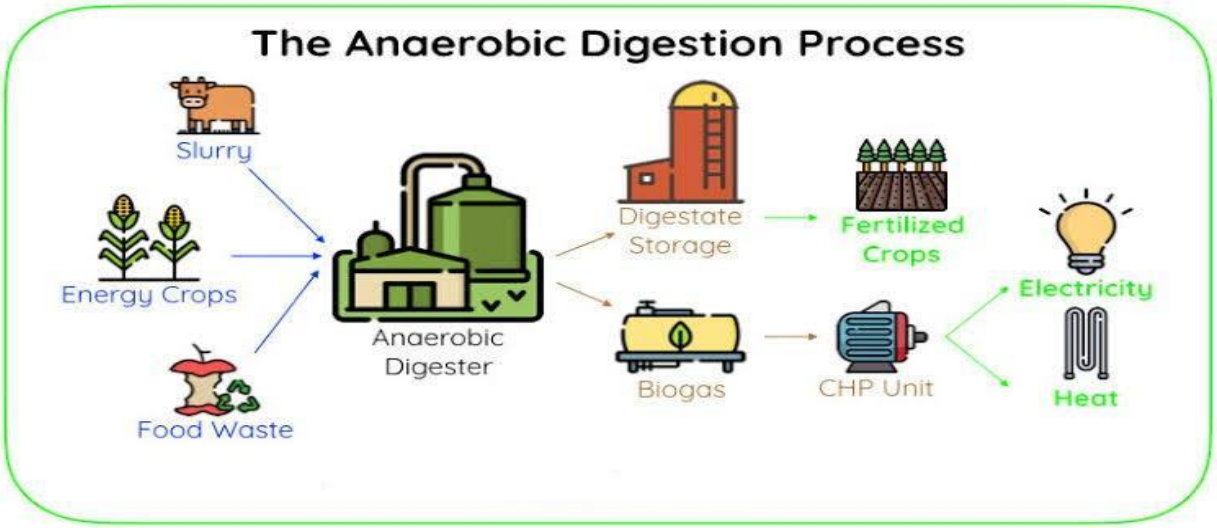


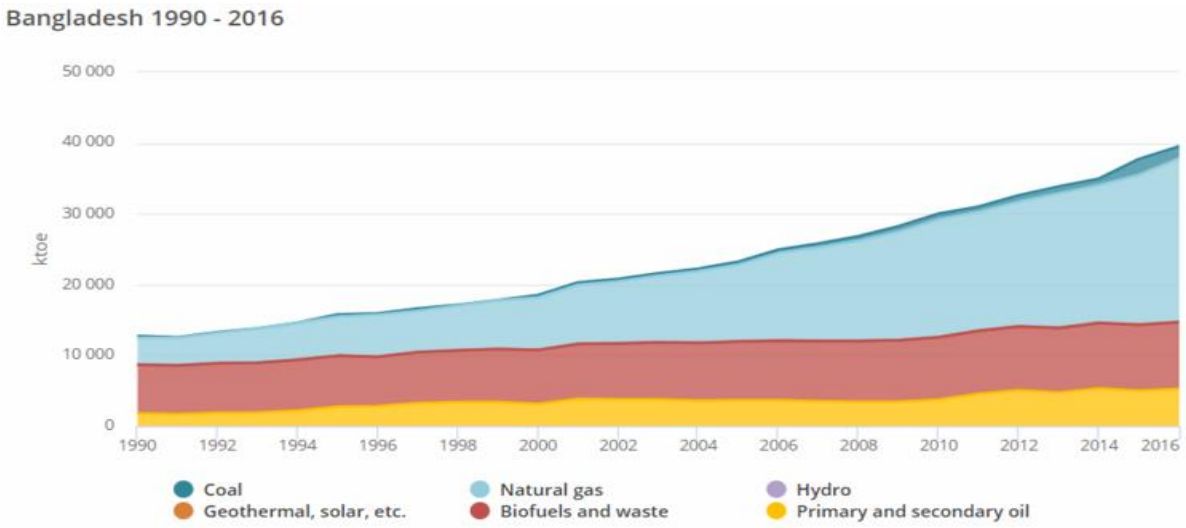
Figure 18: Anaerobic digestion of organic waste
Source: Clean Coast Resources, Inc. 2020

3.4 Waste to energy: an opportunity for GCC to save Natural gas

The power sector in Bangladesh is very hooked in to fossil fuels, as gas and coal are the dominating sources for power generation within the country. About 62.9% of Bangladeshi generated electricity comes from gas , while 10% is from diesel, 5% comes from coal, 3% of heavy oil, and 3.3% is of renewable sources.

Despite the very fact that the Bangladeshi energy sector uses and covers varied products; electricity, petroleum products, gas , coal, biomass and solar, yet the policy and decision makers are mostly pre-occupied with electricity, because it is that the commonest used sort of energy within the country. Thus, because there's endless and rapidly widening gap between electricity supply and demand, therefore it's a serious challenge for the energy sector in Bangladesh.

In 2016, the entire number of consumers connected to the grid is 21.8 million. Out of the 21.8 million, 16 million are domestic connections (households), which would represent roughly 50% of all Bangladeshi households (30-40 million). Another 15% of the households have access to off-grid electricity.



As you can see from the chart the main source of energy in Bangladesh is Natural gas so the natural gas can be finished and if it happens then what we need to think about it right now. The coal using in Bangladesh is increasing rapidly it very harmful for natural environment and public health.

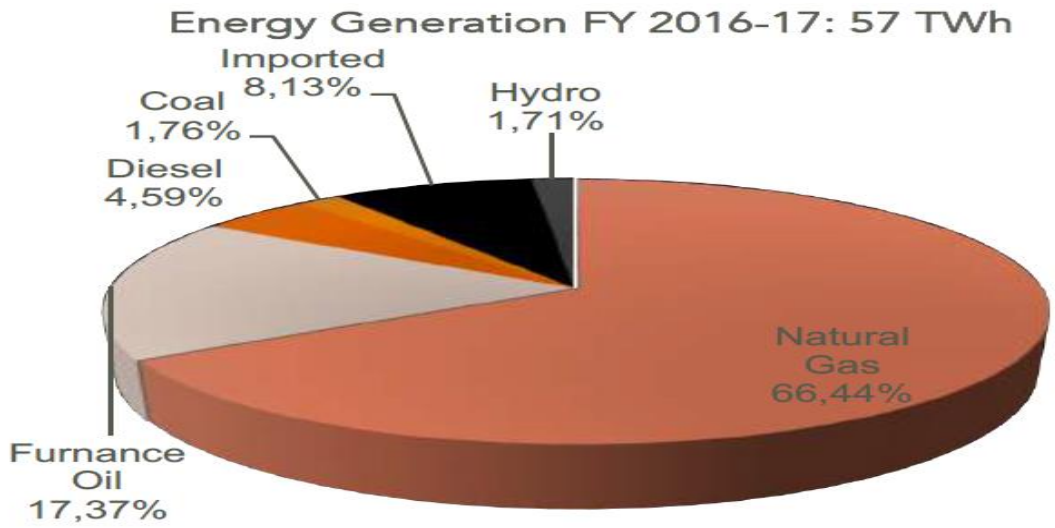


Figure 20: Bangladesh's total energy generation by sources 2016-2017
Source: Suntrace, 2018

As shown in the previous figure, Bangladesh's energy production, from both different oil products and biofuels, is almost steady along the past two decades, while natural gas is gaining more dependency and accelerating since the early 2000s.

The following figure shows an example of the country's energy production from different sources during the few past fiscal years; in particular the fiscal year 16/17, and as shown, natural gas is highly dominant.

The approaches and its key advantages of WtE are still not sufficiently noticed for the immediate respond to act mostly in developing countries like Bangladesh. MSW can be the important resource for generating energy by using WtE technologies even; 3R and preventing waste from generation are most preferred options in waste hierarchy in MSWM system (Shrestha et al., 2014). However, as stated by Idris et al., 2004, it is crucial to assess waste characteristic and its volume before selecting suitable WtE technology both thermal and biological, also it is equally important to analyze energy content of the each waste composition. In addition, as MSW consist of heterogeneous waste materials, investigating energy potential of each waste material is not a simple task to explore.

3.5 Energy content of MSW in GCC

The heat content of each MSW of GCC is calculated theoretically by using given formula on the basis of MSW data released by ADB in 2013. The calculated total heat content of each type of MSW of GCC is present in table below.

*Total Heat Content (E) =∑fi *HVi*

Note:

E= theoretical heat content (million Btu/ton)
Fi= Fraction of waste component in total MSW composition
HVi= Heat value of waste component (million btu/ton)
Table 12:

S.N	Type of MSW	% of MSW composition	Fraction content of MSW	Heat Value (million Btu/ton)	Heat content in MSW (million Btu/ton	Energy content in MSW (MWh)
1	Organic	43.32	0.43	7.6	3.292320	0.960
2	Plastic	21.6	0.22	22.6	4.881600	1.430
3	Paper	25.41	0.25	6.7	1.702470	0.500
4	Glass	2.66	0.03	0.1	0.002660	0.001
5	Metals	1.86	0.02	0.7	0.013020	0.004
6	Textiles	2.77	0.03	13.8	0.382260	0.112
7	Rubber and Leather	0.75	0.01	20.65	0.154875	0.045
	Total value				10.43	3.052

Note: 1 million Btu/ton = 2.9307*10^-7 MWh

Source for average heat value of different MSW: Shrestha et al., 2014

From the calculation, it's observed that each ton of MSW of GCC has potential to get 10.43 million Btu of warmth that's 3.052 MWh/day of energy are often produced theoretically. Likewise, if organic waste is employed to get energy where other components of MSW are often recycled and reused, nearly 3.3 million Btu of warmth that's 0.96 MWh/day of electricity can be generated.
Furthermore, the most essential factor- moisture content of solid waste is very significant to understand the total energy content in the MSW for selecting and implementing appropriate WtE technology (Shrestha et al., 2014 and Sodari & Nakarmi, 2018). The research carried out by Sodari and Nakarmi found that 70% moisture content in organic waste of MSW of GCC where 20% in paper and 5% moisture content in plastic. It is perceived that GCC's MSW composition is dominated by organic, paper and plastic which has high moisture content, however, these wastes also has high energy content which is shown in the table. This indicates that the MSW of GCC has comparatively good potential to supply energy by using WtE technology particularly AD for organic waste and incineration for plastic and paper waste.

3.5.1 Electricity generation potential from plastic and paper waste in GCC from incineration

Plastic and paper combined is the second dominant source of MSW in GCC which shares one fourth of total waste. Currently, recyclable plastic and paper waste are exported to India for further processing and remaining from these waste are considered as non-recyclable are landfilled in bulk. Knowing this facts, incineration technology can be adopted to incinerate plastic and paper waste to produce electricity since plastic waste has high heat content.
Therefore, the data from ADB 2014 report is used to calculate energy potential of plastic and paper from incineration technology. The current plastic waste has potential of 1430 kWh of

electricity generation capacity while paper waste has 490 kWh theoretically which is shown in table 13 . Since the electricity amount is not high but it can contribute during energy deficit period. However, Solid Waste Management Act 2010 of Bangladesh emphasized on 3 R waste management rather than energy recovery from waste through incineration. Nevertheless, WtE technology as incineration is good option for managing increasing trend of plastic and paper waste in future although current production is not huge as organic waste in GCC. However, burning of plastic waste can produce harmful gases such as dioxin and furans (Verma et al., 2016). Hence the incineration should have pollution control measures to reduce air pollution.

Table 13: Fractional content, heat value, electricity generation of plastic and paper waste in million Btu/ton and MWh.

Type of MSW	% of MSW composition	Fraction content of MSW	Heat Value (million Btu/ton)	Heat content in MSW (Million Btu/ton)	Energy content in MSW (MWh)/day	Energy content in MSW (kWh)
Plastic	21.6	0.22	22.6	4.8816	1.43	1430
Paper	25.41	0.25	6.7	1.70247	0.49	490

3.6 Potentiality of bio-gas generation from organic waste in GCC

It is found that organic fraction of municipal waste is relatively higher than other inorganic waste in GCC where households is the major source and produce 77.78% of organic waste. Analysing this situation, the organic fraction of MSW of GCC can be a great resource for generating renewable energy. Thus, AD as WtE technology is suitable option for converting this organic MSW into biogas (methane) and this can also generate electricity which subsequently reduce the volume of MSW to be landfilled.

AD process is also called as biomethanisation which is the biochemical decomposing of the complex organic material by different microorganisms in the absence of air (Vogeli et al., 2014) to produce biogas. Biogas is an inflammable gas, stable and non-toxic with relatively odorless and colorless character which has heat value of 4500-5000 kcal/m3 when it has methane contain range from 60-70% (Igoni et al., 2008). There are several important parameters which are necessary for the good yield of biogas from organic waste. These parameters are temperature, pH value, feedstock characteristics, carbon to nitrogen ratio (C: N), hydraulic retention time, design of digester and operation situation. Two different temperature is considered as best for the performance of anaerobic bacteria where 30-40 degree Celsius is good for mesophilic bacteria with average is 27 degree Celsius and another is 45-60 degree Celsius for thermophilic bacteria with optimum is 55 degree Celsius (Vogeli et al., 2014). Likewise, ideal range of pH is 6.5-7.5 for the high amount of biogas production (Khalid et al., 2011). Another important parameter for AD process is C: N ratio which influence the biogas production (which will be lower) if its concentration is high in solid waste where best value range is from 16-25 (Vogeli et al., 2014). Likewise hydraulic retention time is the duration of material stays in reactor is another parameter which affects biogas yield and the time ranges from 10 to 40 days (Vogeli et al., 2014). The lesser retention time is rather for higher temperature in the thermophillic range because the process is faster. It also depends on reactor volume that is large volume of reactor needs more retention time to digest organic material and it produces large amount of biogas (Vogeli et al., 2014).

Implementation of AD technology for managing organic waste of GCC requires to considering all these different aspects mentioned as a part of technical factors.

According to Alterative Energy Promotion Center (AEPC, 2014), biogas yield from organic MSW of GCC can be calculated from the following formula.

$$\text{Biogas yield } (m^3/\text{kg of VS}) = \text{Biogas yield } (m^3/\text{kg of VS}) * \text{TS (\%)} * \text{VS (\%)}$$

Where, M^3= Cubic metre
TS= Total organic waste
VS= Volatile solid

AEPC 2014 stated that biogas production of 0.35 m^3/kg of VS which comprise of 75% of methane gas and is used for the electricity generation. Further, AEPC suggests in "biogas calculation tool user´s guide" that municipal organic waste contain 20% of total solid (TS) and 80% of volatile solid (VS). That means, it assumes that municipal organic has 80% moisture content in average in Bangladesh. The biogas and methane gas yield is calculated and presented in table from this data and formula mentioned above.

Table 14: Estimation of biogas and methane production from organic waste of GCC

Amount of organic waste collected for AD (ton/day)	% Total solid (TS)	% of Volatile Solid (VS)	Biogas yield (m^3/kg of VS)	Biogas yield (m^3/kg of waste)	Total biogas yield from organic waste (m^3/year)	Methane gas potential (m^3/year)	Methane gas potential (m^3/day)
16024	3204	12819	0.35	0.056	4,128,880	3,096,660	8,484

The table 6 shows that organic waste of GCC has a potential of generating approximate $4x10^6$ m^3 of biogas which contain approximately $3x10^6$ m^3 of methane (CH_4) per year. That is approximate $11x10^3$, m^3 of biogas and $8x10^3$ m^3 of methane gas can be generated every day from the organic waste of GCC. Likewise, the produced methane can be used to power the electricity generator. This noticeably indicates that organic waste can play vital role in energy demand, reduce landfill waste and produce nutrient rich organic fertilizer as digested material which can improve the quality of soil for the good crop production (US, EPA, 2018).

3.6.1 Biogas to electricity

Biogas is converted to energy through an indoor combustion engine. The energy rotates an electrical generator which produces the electricity.

Biogas engine - uses the biogas to get energy . Biogas is carefully mixed with the right proportion of air and drawn into the biogas engine by the force of the engine pistons moving downwards, creating a vacuum. The air and biogas mixture is then compressed because the piston moves up. Biogas may be a slow burning fuel, and a better compression ratio engine is important for efficient combustion. A high energy sparking plug ignites the compressed gas and biogas mixture. The burning biogas air mixture heats rapidly, expanding then forces the piston right down to create torque to rotate the engine. The biogas engine valve opens, releasing the spent air and fuel mixture into a device to extract remaining combustion energy. Inoplex has carefully optimized this conventional four-stroke internal-combustion engine operation to suit a variety of biogas, which burns very differently to petrol, gasoline or diesel. Inoplex biogas

engines include High compression ratios, high energy ignition sparks, swirling of air-fuel mixture and low exhaust temperatures. Generator - the generator produces the electrical output from the engine-generated energy . This energy rotates an iron core wrapped in copper wire inside a strong magnet to make an electrical current. The Inoplex Permanent Magnet Generator allows considerable benefits. Physical benefits with reductions in weight and length, including electronic benefits, ensure a superior technology devised to maximize the efficiency of the entire power grid .

Commonly combustion engines are wont to convert the biogas to electricity. This has another bonus of easy to seek out new and replacement engines, spare parts, also as simple local repairs making it a viable solution for regional or even remote use.

Diesel engines are often utilized in dual-fuel mode, where a little amount of diesel is employed to assist the ignition of the biogas. Gas motors can operate solely on biogas sometimes employing a bit of LPG to start out the engine if the biogas is especially weak, or low in methane.

Energy from methane

Biogases are often utilized in many of an equivalent ways gas or LPG are often used like cooking, heating, and lighting also on produce electricity.

Methane is that the usable a part of the biogas which supplies the energy. The remaining components of the biogas include CO2, water vapor, and other trace elements like nitrogen, oxygen, ammonia and hydrogen sulfide.

Biogas is lower in methane than gas - biogas 50-75% to gas 90 - 98 %.

The energy value of the biogas is contingent a variety of things including the sort of feedstock (raw material) wont to generate the gas, temperature in fermentation, length of fermentation, and the specific plant design.

Crops like maize silage create biogas with a way higher energy value than alternatives like manure , around eight times the maximum amount actually .

Biogas power generation using manure remains a viable Endeavour, however, 8 times more gas are going to be needed to get an equivalent amount of electricity. Factors like this may be considered during the engineering and style phase of the bioenergy plant found out.

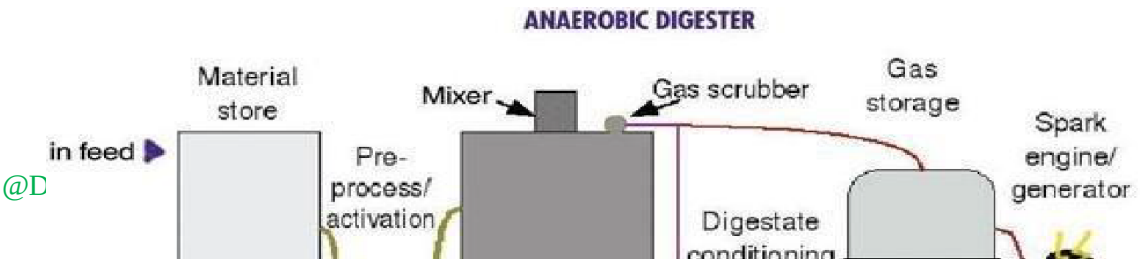


Figure 21: Anaerobic digestion process and electricity generation from biogas

Calculation of electricity generation from biogas

The average calorific value of biogas is 21-23.5 MJ/m^3 which has an electricity generation potential 6kWh/m^3 when using gas motor as combustion engine (Agency of Renewable Resources, 2005, AQPER, 2019). Biogas contain 75% of methane gas produce from organic MSW (AEPC, 2014).

Formula for calculating electricity from Methane gas

Electricity generation (MW/day) = (methane yield/day*energy generation/m^3)/ (75*1000*24)

Source: (Adhikari, Khanal & Miyan, 2015)

Table 15: Estimation of electricity generation from methane from the biodegradation of organic waste

Estimated methane (m^3/day)	Energy generation per m^3 (kwh)	% of average methane in biogas	Electricity generation(MWh)/day
8,484	6	75	2.83

The electricity generation from AD process is illustrated in table 14. About 2.8 MWh/day of electricity can be generated from the methane gas produce from the anaerobic digestion of organic waste of each day of GCC. Hence AD can be the promising technology for managing organic waste of GCC and help for recovering energy crisis and help to reduce dependency on import of external fuel for cooking.

In addition, the dumping of huge amount of organic waste in landfill can be reduced significantly and minimize the release of several gases such as methane, carbon dioxide in the environment which ultimately contribute to global warming lead to climate change and discharge of leachate causing water contamination from the landfill waste.

3.7 WtE technology integration in MSWM framework for GCC

The following framework presented in figure 22 developed by the researcher after the in-depth analysis of current MSWM which is proposed for the sustainable MSWM system in GCC. This framework is prepared with considering various factors with particular focus on GCC. This framework consists of different elements of MSW system which is more systematic and more sustainable way of managing MSW with considering environment and public health which

follows the waste hierarchy concept and sustainable integrated MSWM. In addition, WtE approach is particularly focused as it is the efficient way to reduce the volume of waste sent to landfill and it generates useful energy. Hence, WtE approach can address the energy demand issue and contribute in sustainable MSWM as well.

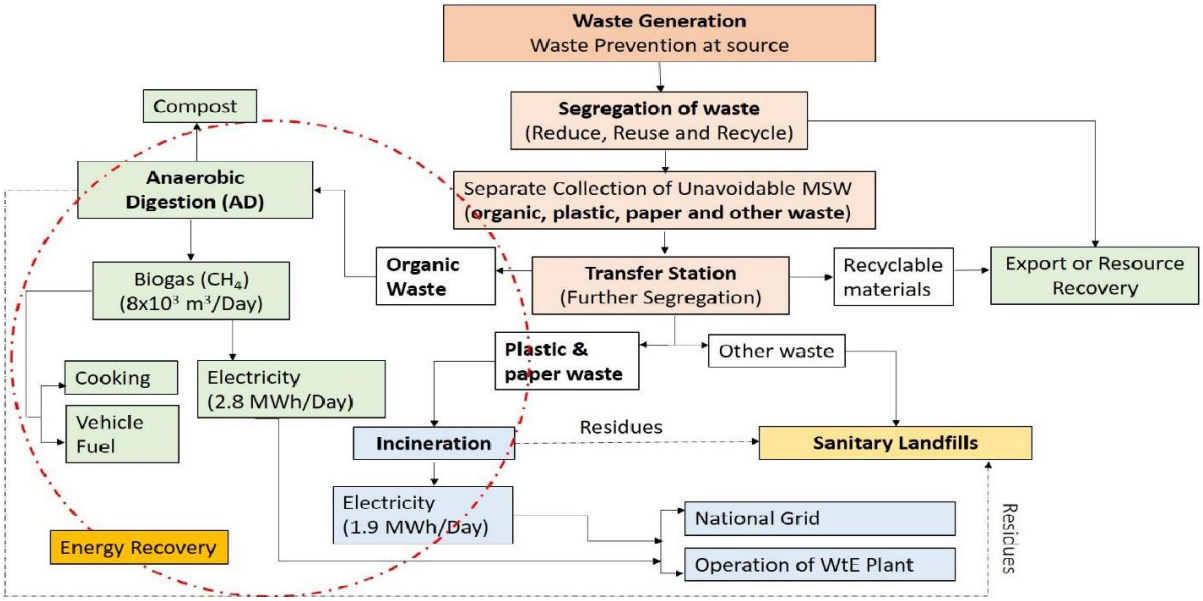


Figure 22: The proposed MSWM framework for Gazipur city Corporation

3.8 Conclusion

The presented issue of current unsystematic MSWM of GCC cannot be overlooked. For this, the proposed MSWM framework for GCC can be the solution to address the MSWM problem. The proposed framework is systematic, efficient and more sustainable MSWM than the current system in term of its long term benefits and is more environment friendly system. This framework is focused on energy recovery using WtE technology as one the efficient way for managing waste and generating energy. However, different aspects such as proper policy, public awareness and organizational arrangement, financial and technical factor are inevitable to be considered for transforming current MSWM system to more sustainable MSWM for GCC. Following are the factors which can influence the establishment and integration of WtE technology in MSWM for GCC:

 It is observed that GCC's MSWM system lacks organized policies and legal framework. Hence, an appropriate legal framework need to be established and its execution has to be in process of development before implementation and operation of any WtE plant in MSWM system.

 Public awareness is major requirement because, the proposed framework demands the waste segregation at source as an important element.

 The most important aspect, an institutional arrangement should be adequately effective and strong for implementing sustainable MSW.

 Likewise, technical human resource is also required for establishing WtE system.

Chapter 4

This chapter covers the comparative analysis of existing MSWM system and newly designed MSWM framework in chapter 3. Hence, this chapter presents analysis of the different aspects

need to be changed for implementing the proposed framework for the systematic MSWM in GCC.

4.1 Requirements for integrating WtE system in MSWM of GCC

Some basic conditions has to be met before implementing appropriate WtE technology in MSWM system in GCC. Likewise, various aspects got to be adjusted and altered for the implementation of proposed framework which are discussed below.

4.1.1 Management aspect

The following figure 23 shows the differences between the current MSWM system which is traditional waste management hierarchy and the proposed framework for sustainable MSWM as new waste management paradigm. The proposed framework is more focused on waste reduction and energy recovery. GIZ states that WtE technology should be viewed as a part of sustainable MSWM system where waste prevention, reduction and recycling options has high preference (GIZ, 2017).

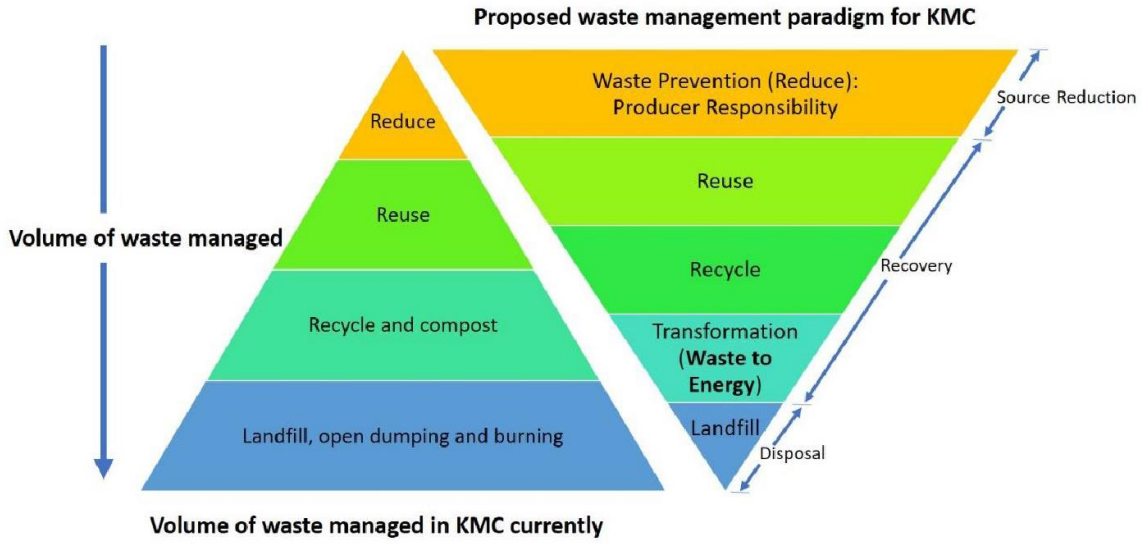


Figure 23: Comparison between current MSWM and proposed framework for sustainable MSWM based on waste management hierarchy in GCC

Improvements toward sustainable SWM

Current ineffective practices need to be stopped first. For example, collecting waste in open piles on the roadside, which is done by GCC, is not only inefficient but highly unhygienic, creating a public nuisance and health risks. The present scenario of MSWM involve waste generation-collection-disposal in very irregular manner. It does not have any strategic directive for systematic operation of day to day activities of MSWM. In addition, waste are collected in bulk without any segregation since municipality has not announced any system or methods for segregation of waste at source which could have motivate citizen to participate in sustainable MSWM. In the present scenario, GCC is accountable for every activities regarding MSWM from waste collection to final disposal without guiding concrete framework. As a result, GCC

is facing challenge of chaotic MSWM system. The Office of Auditor General analysed in the study suggested that GCC does not have sufficient human, technical and financial resources and unable to coordinate with different sectors for performing successful MSWM system. Therefore, for improving this situation, technical and financial aspect are another essential elements that should be carefully assessed.

4.1.2 Approach for implementing proposed framework of MSWM system in GCC

The present MSWM system basically focused on MSW collection and disposal. The existing policy regarding the SWM system lacks the proper and specific guidelines required for the sustainable MSWM. Likewise the policies are rarely implemented which resulted the present mismanagement of MSW in GCC. Therefore, the changes and amendment in current policy and its implementation are required for sustainable MSWM in GCC which are further discussed below.

i. MSW generation

Sustainable MSWM always associated with 3R approaches (reduce, recycle and reuse) in waste management which is also emphasized in SWM act in Bangladesh. However, it is not in practice at present. Hence, this proposed framework recommend less waste generation at source which means it contributes in waste minimization at source. The generated waste disposal in roadside, riverside and open space should be stopped and different waste bin should be provided to each neighborhood for discarding different waste and collection of this waste should be carried out regularly.

ii. Segregation of organic, plastic and paper waste at source

Segregation is one of the key elements of MSWM in term of waste recovery and processing that is to give second life to waste in a circular manner. Hence, this framework suggests the segregation of waste into organic, plastic, paper and other waste at source. Therefore, the policy should incorporate this issue through public awareness program and school level curriculum. In addition, GCC should provide incentives to encourage public to involve in sustainable MSWM such as by providing different bins for different waste.

iii. Collection of different segregated waste

The collection is another important element which involves not only the collection of waste (organic, plastic and paper) from different sources but also the transportation of these waste to the specific transfer station. For effective collection, the collection of different waste should be done on different day. For example, biodegradable, non-biodegradable (plastic and paper) waste and other waste can be collected in different day that ensure the efficiency and importance of segregation. The policy should address this issue and properly indicate that there should be provision of penalty for those who does not follow the rule.

iv. Transfer station and transport

The allocation of proper transfer station for storing of waste collected from GCC is essential because the waste need to be sort out further before transferring to processing plant and landfill site. The transfer station either located near to processing plant area or particular planned area.

After sorting of all waste transfer to processing plant to convert waste into energy and remaining refuse waste to sanitary landfill.

v. Energy/resource recovery and processing

The existing policy mentioned modern technology for managing and recovering waste to be implemented, however, it does not provide specific directive for its implementation. Hence, the policy needs to be adjusted and it should incorporate the innovative technology like WtE.

The larger share of organic waste generated in GCC can be managed by converting waste into biogas through WtE technology (anaerobic digestion process). Likewise, plastic is the second highest amount in MSW composition of GCC and has high energy content. Hence, plastic waste can be managed by incineration which also produce energy. About 90% MSW can be recovered from WtE system in GCC. 67% of organic waste can generate 4x106 m3/year of methane gas and 2033 MWh/year of electricity theoretically. Likewise, incineration of about 22% plastic and 25% paper waste can produce 1200 MWh/year electricity in GCC. This can play important role as alternative energy source in meeting energy demand.

vi. Final disposal

The least prefer option in waste management hierarchy is landfilling of waste. In case of MSW of GCC after implementation of proposed MSWM framework, only about 10% of remaining waste consisting glass, metal, rubber and leather that can be further segregated for recycling excluding nearly about 2% inert waste (non-recyclable, non-reusable and non-recoverable) and residues coming from bio digestion process and incineration process can be landfilled. If 90% of waste recovered through the proper implementation of WtE technology as discussed above, about 1419 tons of waste can be reduced and about 147 tons waste has to be landfilled as final disposal.

4.1.3 Financial aspects in term of establishing WtE plants in MSWM system

Implementing WtE plants require considerably high investments as compared to landfill . The investment cost includes not only treatment procedure but also include operation and maintenance cost alongside cost allocation for operational risks like accident or fires. Thus, securing funding for implementing sustainable MSWM is quite challenging for the municipality, thus it is suggested that PPP approach can contribute in this regard where private company can invest for establishing and operating WtE facilities in collaboration with government. National subsidies provision can contribute in initial phase of implementation. In addition, fund are often managed by collecting waste management charge from public and revenues from selling of recovered energy (biogas and electricity) and compost. Further, access to revenue from international carbon fund such as green climate fund and tax refund for promoting clean energy can be another source of fund for the regular operation of the facility.

4.1.4 Public participation and consultation

Municipality solely cannot perform and meet all the activities related to MSWM and its issues of maintaining hygiene and sanitation of municipality. Community are the foremost in case of MSWM since they are generating waste. Thus, their participation in MSWM is important. The new framework encourage community participation as an important stakeholder for MSWM.

The new working procedure should focus on the current environmentally harmful practice and should not repeat again. Such as waste accumulation in open public spaces. For this, private partner should promote source separation at source and keep different waste in different waste bin in public places as well as at household level and more emphasis should be given to 3R waste management practice. This awareness should begin from very basic, for instance 'no littering' in public places. Likewise, there should be rules for collecting different waste in different day, for example, collection of organic waste in one day and inorganic waste in another day. And this rule should be strong with some penalty provision such as household who do not follow rule would get fine or waste won't be collected.

4.1.5 Public private partnership (PPP)

It has been realized that municipality office only cannot handle all the activities related to MSWM. The efficient MSWM can be undertaken through the private public partnership approach. Traditionally, it is understood that municipalities are distinctly accountable for overall MSWM in Bangladesh. Hence, formal involvement of private sector is rarely seen and has not possessed impressive results at the present situation in GCC. However, the PPP approach is evolving in many developing countries for the efficient MSWM. Thus, the PPP approach has a great potential for improving the overall operation and management in collection, transportation, processing and final disposal of MSW with very cost-effective manner.

The suggested framework for MSWM requires PPP approach since the current context of MSWM system is incapable of efficient operation of whole MSWM supply chain. However, the municipality should be able to select qualified and experienced partners with complete strategic operation plan. Hence, municipality should enhance its capacity to formulate strong policy under sustainable MSWM based upon PPP approach. In addition, it is required to strengthen the municipality capacity in term of conducting competitive bidding and develop the robust system for monitoring and evaluation of overall MSWM activities through private partner. The private partner is suggested to take overall responsibility for managing entire supply chain of MSW under the government norm and regulations.

4.1.6 Data management, updating, and dissemination

Data on municipal waste is very essential for developing strategy and plan to design efficient MSWM in any municipality. However, there is no adequate data collection system and is seldom updated in GCC in current situation. There is lack of study on MSWM due to lack of information and data on MSW generation, its composition. As a result, it is difficult to develop plan for designing proper MSWM system.

Therefore, it is suggested that the data related to MSW activities should be regularly tracked, updated and disseminated to related stakeholders. This will help the stakeholder including public to understand the overall MSWM status and enable to compare the situation over the time which ensure to make plan for further improvement. And the tracked data can be used by research scientists and academicians for further research to innovate new prospective in MSWM.

4.2 Conclusion

The prepared sustainable MSWM framework based on present circumstances requires PPP approach with commitment in cooperation with citizen since they are primary source of waste. This system encourage to prevent and reduce waste at the source and is basically grounded on waste hierarchy. In addition, the existing policy need to be amended as discussed above for the smooth implementation. All these aspects will contribute to establish the recommended framework for MSWM in GCC which is the dream of citizen of Gazipur. Most importantly, the implementation of this framework for MSWM can generate various benefits which are previously discussed.

Chapter 5

This chapter will make the conclusion of this research which mainly answers the main and sub questions of this research. The chapter ends with recommendation and overall reflection of this study.

5.1 Conclusion

The current MSWM system of GCC is completely unsystematic and traditionally practiced. GCC is accountable for carrying out MSWM in which the department of environment is responsible for every activities related to MSWM. However, informal sector are very active

in collecting, abstracting some material for recycling and transporting waste to dump in landfill site. Surprisingly, most of these organizations are not registered legally and it is hard to track all the information and data related to MSW. Likewise, the important stakeholders directly and indirectly involved in MSWM of GCC are Government of Nepal, municipality office, SWMTSC and other line ministries.

The 3 R concept to manage waste at source has not been practiced and source segregation is negligible. Households, commercial, institutions and industries are the main source of MSW generation in GCC where organic waste share large fraction of total MSW and is followed by paper and plastic. The inorganic waste can be either recycled or reused. The generated waste are collected from door to door, limited public container, roadside and other public places by GCC and informal PSOs. GCC is collecting from 32 wards and informal sector collecting waste from 25 wards of GCC. The collected waste are completely mixed. Hence, bulk amount of unsegregated waste are transferred to landfill and informal workers such as waste pickers and scavengers separate recyclable and reusable waste by hand. These recyclable and reusable wastes are sold in local scrap dealers and export to local recycling industries. The remaining waste including all organic waste which is about 60% of total MSW are landfilled in Kodda. This is only the landfill for disposing waste of whole Gazipur and already reaching out of its carrying capacity. The concept of resource recovery from waste is totally absent in current MSWM system to reduce the volume of MSW and generate energy. In addition, the present MSWM system doesn't meet the environment standard which is causing severe impact in environment and human health.

5.2 Recommendation

This section provides the recommendation for the best MSWM system in GCC which is very specific and based on this study finding. After the assessment and analysis of current MSWM practice, its impact in environment and public health, the potential solution and changes needed on present system to deal with these issues are discussed in prior sections. Based on this, the following recommendations are made.

A new framework for MSWM in GCC

Systematic MSWM framework is developed which is centered on sustainability and waste management hierarchy after the investigation of current inefficiency in entire MSWM supply chain. This framework requires PPP approach for implementation for improving the effectiveness in management since the current system is implemented by GCC but very poorly operated. For involving PPP approach, the existing SMW policy need to be revised and GCC should also formulate a specific policy including the details about the collaboration with different stakeholders.

The proposed model for MSWM starts with 3 R principle of waste management hierarchy that is waste being reduced at source and it prefers reuse, recycle and recover in the whole waste management chain which are the essential components to reduce waste and only less waste has to be landfilled ultimately avoid extra cost for final disposal and minimize the environment risk.

Then the waste separation at source is also a high priority in the framework that will subsequently contribute in smooth MSWM as it saves time and cost for further segregation. The separated waste then transported to waste recovery facilities (WtE) plants which can be established near to landfill (the new landfill site 'Naujure kodda' allocated by government). As

GCC is generating large fraction of organic waste, AD as a WtE technology is mentioned in the framework to generate energy. Though, the concept WtE is yet noble and unexplored in Bangladesh but this can be the practical solution for minimizing waste and generate energy in the same time can support energy demand. The generated energy can be used as vehicle fuel, cooking gas and to generate electricity.

Further research

Further research are urgently needed to investigate the other issues such as medical waste management, construction of new landfill site in Naujure Kodda related to MSWM. The lack of availability of data and information regarding MSWM in GCC is the limitation of this study. . Hence, it is strongly recommended to GCC office and academic institution to conduct research, collect data on timely manner and update them. The available data are mostly unreliable and insufficient. This might hinder for developing proper plan and strategies regarding MSWM.

5.3 Overall reflection of this study

Municipal waste management has appeared as one of the major challenges in GCC for many years since the Baimail landfill has been out of its capacity to accommodate increasing waste of Gazipur. In addition, waste dumping in open public spaces has been creating not only nuisance in the environment but also impacting public health by spreading diseases by various vermin and insects. The current MSWM system lacks proper framework that should help in addressing every aspects regarding MSWM. The current MSWM system lacks proper framework that should help in addressing every aspects regarding MSWM. Although government has formulated policy in different time period aiming for the proper MSWM however, it is found that enforcement provision for strict implementation does not exist until now. The different activities related to proper MSWM such as waste segregation at source and energy recovery which are mentioned as most important aspects to be executed, however, these are limited only in policy documents.

Similarly, it is observed that GCC lacks motivated and proper technical staff to handle the overall MSWM system. In addition, the attitude of citizen towards MSWM need to change. It is also noticed that waste is taken as nuisance and citizen perceive that managing municipal waste is only the responsibility of municipality. The people's perception towards MSWM require to change and they should recognize this issue and participate and cooperate municipality in MSWM, for instance, in waste segregation at source.
After assessing and investigating the current MSWM and different aspect related to MSWM in GCC, it is distinctly noticed that disorganized MSWM system is currently in practice and waste are discarded in landfill without resource recovery which urgently needs to change for the proper MSWM.
Therefore, this research emphasized on integration of WtE technology in MSWM system for recovering and reduce waste that goes to landfill. For this, planned and strategic framework is required which is developed as proposed MSWM model for GCC. This framework highlights mainly to recover energy from waste that helps to reduce waste and contribute towards environmental protection. The implementation of this framework requires to update major aspects such as policy and legal framework, managerial aspect, financial aspect, technical aspect and adoption of PPP approach. The proposed model can be an example for the MSWM in many other municipalities of Bangladesh as many municipalities are emerging as big cities and are facing MSWM challenge.

Most of the municipality rarely have proper plan and strategies for proper MSWM system. Hence, the developed framework and knowledge (different theories and approach used such as waste management hierarchy and WtE approach) in this study can contribute in developing plan for MSWM.

References

Zafar, S. (2009). Gasification of municipal solid wastes. *Researchgate*. Retrieved from https://www.researchgate.net/publication/285295261

Worldbank.org. (2012). WHAT A WASTE A Global Review of Solid Waste Management. https://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf

Wilson, D., Velis, C., & Cheeseman, C. (2006). Role of informal sector recycling in waste management in developing countries. *Habitat International*, *30*(4), 797-808. doi: http://10.1016/j.habitatint.2005.09.005

Waste-management-world.com. (2019). Landfill: A Victim of Dutch Success? https://waste-management-world.com/a/landfill-a-victim-of-dutch-success

Verschuren, P. and Doorewaard, H. (2010). *Designing a Research Project* (2nd ed.). *Eleven International Publishing*. The Hague

Vogeli Y., Lohri C. R., Gallardo A., Diener S., Zurbrugg C. (2014). Anaerobic Digestion of Biowaste in Developing Countries: Practical Information and Case Studies. Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dubendorf, Switzerland

Abbasi, T., Tauseef, S.M., & Abbasi, S. A. (2002). Chapter 2: A Brief History of Anaerobic Digestion and 'Biogas'. *Biogas Energy*, 1-169. https://doi.org/10.1007/078-1-4614-1040-0

Abd El-Salam, M., & I. Abu-Zuid, G. (2015). Impact of landfill leachate on the groundwater quality: A case study in Egypt. *Journal of Advanced Research*, *6*(4), 579-586. doi: http://doi.org/10.1016/j.jare.2014.02.003

Abualqumboz, M. (2016). ENVIRONMENTAL IMPACTS OF SOLID WASTE OPEN DUMPS-JOHR AL DEEK DUMP SITE AS A CASE STUDY. In *ISWA-SWIS Winter School* (pp. 45-54). Arlington: Solid Waste Institute for Sustainability (SWIS). Retrieved from http://www.uta.edu/swis/Publications/WS_Proceeding_2016.pdf

Adhikari, B., Khanal, S., & Miyan, R. (2015). Quantitative Study of Biogas Generation Potential from Different Landfill Sites of Nepal. *Waste Technology*, *3*(1). Retrieved from https://www.academia.edu/16355303/

AEPC. (2019). Household Biogas. Retrieved from https://www.aepc.gov.np/household-biogas

Beemaraj, R.K. &Prasath, K. A. (2013). Utilization of natural energy. International Journal of Industrial Engineering & Technology. 3 (2), 67-72. Retrieved from https://www.researchgate.net/publication/322852613_

Campos, U., Zamenian, H., Koo, D., & Goodman, D. (2015). Waste-to-Energy (WTE) Technology Applications for Municipal Solid Waste (MSW) Treatment in the Urban Environment. *International Journal of Emerging Technology and Advanced Engineering*, *5*(2), 504-508. Retrieved from https://www.researchgate.net/publication/273379114

Central Bureau of Statistic. (2012). National Population and Housing Census 2011. National report. Vol.1. Government of Nepal. Retrieved from https://unstats.un.org/unsd/demographic-social/census/documents/Nepal/Nepal-Census-2011-Vol1.pdf

Central Bureau of Statistic. (2014). Population Monograph of Nepal. Volume I (Population Dynamics). Government of Nepal. Retrieved from https://nepal.unfpa.org/sites/default/files/pub-pdf/PopulationMonograph2014Volume1.pdf

Central Bureau of Statistics. (2011). *National Population and Housing Census*. National report. Retrieved from https://web.archive.org/web/20130418041642/http://cbs.gov.np/wp/content/uploads/2012/11/National%20Report.pdf

Central Bureau of Statistics. (2014). *Population Monograph of Nepal*. Volume III. Economy Demography. Retrieved from https://lac.unfpa.org/sites/default/files/pub-pdf/Population%20Monograph%20V03.pdf

DEFRA. (2019). Energy from waste: A guide to the debate. Revised edition. Department of Environment Food and Rural Aaffairs. Retrieved from

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/284612/pb14130-energy-waste-201402.pdf

DEFRA. (2019). Incineration of Municipal Solid Waste. Department for Environment, Food and Rural Affairs. Retrieved from http://www.wtert.co.uk/content/Defra%20report.pdf

DISASTER WASTE MANAGEMENT POLICY, STRATEGY & ACTION PLAN. (2015). Retrieved from https://leadnepal.org.np/wp-content/uploads/2018/07/4.-Nepal-Disaster-Waste-Strategy-report-Dec2015.pdf

Ec.europa.eu. (2019) ISWA Key Issue Paper on Waste Prevention, Waste Minimization and Resource Management. Retrieved from http://ec.europa.eu/environment/resource_efficiency/pdf/ISWA%20International%20Solid%20Waste%20Association.pdf

EPA. (2019). Energy Recovery from the Combustion of Municipal Solid Waste (MSW). Retrieved from https://www.epa.gov/smm/energy-recovery-combustion-municipal-solid-waste-msw

European Commission. (2016). Optimal use of biogas from waste streams. *An assessment of the potential of biogas from digestion in the EU beyond 2020.* Retrieved from https://ec.europa.eu/energy/sites/ener/files/documents/ce_delft_3g84_biogas_beyond_2020_final_report.pdf

GIZ. (2017). Waste-to-Energy Options in Municipal Solid Waste Management. A guide for Decision Maker in Developing and Emerging Countries. Retrieved from https://www.giz.de/en/downloads/GIZ_WasteToEnergy_Guidelines_2017.pdf

Igoni, A. H., Abowei M. F. N., Ayotamuno J. M., and Eze, C. L. (2007). Effect of total solids concentration of municipal solid waste in anaerobic batch digestion on the biogas produced. *Journal of Food, Agriculture & Environment*, *5* (2): 333 – 337. Retrieved from https://www.researchgate.net/publication/274006623

Korai, M., Mahar, R., & Uqaili, M. (2017). The feasibility of municipal solid waste for energy generation and its existing management practices in Pakistan. *Renewable and Sustainable Energy Reviews*, *72*, 338-353. doi: http://10.1016/j.rser.2017.01.051

Lee, M., Hidaka, T., Hagiwara, W., & Tsuno, H. (2009). Comparative performance and microbial diversity of hyperthermophilic and thermophilic co-digestion of kitchen garbage and excess sludge. Bioresource Technology, 100(2), 78-85. Retrieved from https://www.researchgate.net/publication/23219552

http://gcc.gov.bd/site/page/0f4394e7-0406-422e-9e43-f2ec6455ecb9/-

http://gcc.gov.bd/sites/default/files/files/gcc.portal.gov.bd/miscellaneous_info/31449c94_cb55_4b3a_8c09_4fb9ba7f78b6/(%E0%A7%A8%E0%A7%A6%E0%A7%A7%E0%A7%AD-%E0%A7%A8%E0%A7%A6%E0%A7%A7%E0%A7%AE).pdf

https://gcc.portal.gov.bd/site/view/officer_list_category/%E0%A6%AC%E0%A6%B0%E0%A7%8D%E0%A6%9C%E0%A7%8D%E0%A6%AF%20%E0%A6%AC%E0%A7%8D%E0%A6%AF%E0%A6%AC%E0%A6%B8%E0%A7%8D%E0%A6%A5%E0%A6%BE%E0%A6%AA%E0%A6%A8%E0%A6%BE%20%E0%A6%AC%E0%A6%BF%E0%A6%AD%E0%A6%BE%E0%A6%97/-

Nixon, J., Dey, P., & Ghosh, S. (2017). Energy recovery from waste in India: An evidence-based analysis. *Sustainable Energy Technologies and Assessments*, *21*, 23-32. doi: https://doi.org/10.1016/j.seta.2017.04.003

Paudyal, R. (2019). Sustainable energy future: Energy mix is the key. *The Himalayan Times*. Retrieved from https://thehimalayantimes.com/opinion/sustainable-energy-future-energy-mix-is-the-key/

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjI_5yglb_uAhVbzzgGHUR-A_4QFjACegQIBBAC&url=https%3A%2F%2Fwww.researchgate.net%2Fpublication%2F280935703_Waste_generation_and_management_in_Bangladesh_An_overview&usg=AOvVaw0BZqE94ogYaDY1wFHnku8A

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjI_5yglb_uAhVbzzgGHUR-A_4QFjAMegQIDxAC&url=https%3A%2F%2Fwww.sciencedirect.com%2Fscience%2Farticle%2Fpii%2FS0197397597000398&usg=AOvVaw2vtSceY5hiQQBMU-hIJJGV

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjI_5yglb_uAhVbzzgGHUR-A_4QFjAPegQIGxAC&url=https%3A%2F%2Fwww.banglajol.info%2Findex.php%2FJESNR%2Farticle%2Fdownload%2F11601%2F8492&usg=AOvVaw3GoPrwPQaS3kZSDx9wcTQb

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjI_5yglb_uAhVbzzgGHUR-A_4QFjATegQIEBAC&url=http%3A%2F%2Fwww.isca.in%2FIJSS%2FArchive%2Fv5%2Fi10%2F7.ISCA-IRJSS-2016-113.pdf&usg=AOvVaw01XfWlc4_bUPwd9_JSLMeB

Research questions	Data and information to answer the research questions	Sources of data	Accessing data

Main question	Main question: How is the waste management system in Gazipur city Corporation currently organized and managed and which changes are needed to use the waste as resource for energy production?	Demography and socioeconomic situation of Gazipur city Corporation History of the solid waste management in the city Corporation and observation Policy on solid waste management Type of current waste management practice in the metropolitan city Impact of current waste management practice (environmental and social)	Secondary Data and different literatures, reports, journal, central bureau of statistic, policy documents	Content analysis Search method for different literature
Sub questions	How is the current waste management system in Gazipur city Corporation organized with what results?	Waste collection, transport, treatment and dumping processes Type, composition and volume of waste generated in the city Corporation Organization /stakeholder working on waste management Any private sector's involvement in the solid waste management	Primary and secondary data Primary information from interview for qualitative analysis Secondary data and different literatures, reports, journal	Content analysis Face to face interview to access information from officials
	How could a waste management system according to concept of waste to energy look like for GCC?	Available policy documents Type of technology (converting waste to energy) and its feasibility in context of type of waste generated in Gazipur city Different literature analysis (from other country who has practiced waste to energy approaches)	Primary and secondary data and different literatures, reports, journal Primary information from interview for qualitative analysis Reports and documents	Content analysis and search method for different literature Face to face interview to access information from officials
	What changes in the current waste management system of Gazipur city Corporation are needed for transforming it into a waste to energy system?	Municipality's plan for applying waste to energy concept to manage solid waste Type technologies that municipality are willing to implement Policy gap for effective waste management plan Different literature analysis (from other country who has practiced waste to energy approaches)	Primary and secondary data and different literatures, reports, journal Informant: from municipality and AEPC for secondary source validation Available planning documents and related stakeholders	Content analysis and search method for different literature Content analysis and interview with official from municipality and AEPC

Appendix 1

Appendix 2: Opportunity and benefits from new proposed MSWM system in GCC

The existing solid waste management approach is based on obsolete system in GCC and operates inefficient. So, it neither creating any opportunity to use the waste nor protecting

environment. The proposed framework is based on sustainable MSWM system which suggests involvement of public private partner (PPP) approach for the implementation. It is believed that the successful implementation of this framework will be able to address the following issues.

i. Reduction in impacts on human health and environment and aesthetic value of the city

Haphazard disposing and open burning of solid waste is common practice in GCC creating environmental pollution and impact on public health since current MSWM do not meet the proper environmental standards. This current landfill site was designed for disposing waste of Gazipur city for 4 years and started from 2016 as a part of temporary solution. Since then, waste generated is dumped still now in 2021. Residents live to the vicinity of this landfill are suffering from the smell from garbage and diseases spread from the open decomposition of the organic waste. In addition, the study reported that the decomposition of organic wastes in Kodda landfills is generating greenhouse gases and untreated leach ate is polluting surrounding soil and water resources (OAG, 2015). Likewise, many rivers inside the cities are littered by full of trash and garbage which can damage the ecosystem of river as well as aesthetic value of water resources. However, the proposed framework is structured to address all these issues.

ii. Minimize high dependency of fossil fuel

Although Bangladesh depends on natural gas in future the gas will finished and then what so we have to think and reduce the use of gases and make change in dependency. This research can save so much of it