Estimation of Power Generation from Yangon Regional's Waste to Eastern and Southern Dagon Industrial Zone

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Abstract: The conventional fuels required for production of electricity is decreasing day by day and it is very important to find out alternative sources which can be used as the fuel for the production of electricity especially for developing countries like Myanmar. With the growing demand for electric power supply, there is a need to look into all possible means of electricity generation especially renewable ones. Yangon Regional Government have 29 industrial zones and there are also large amount of pollutants through the various industrial activities from the industrial zones. At the moment, the adverse effect of pollution is not serious but it is evident that careful attention may be needed for the near future and the required action programmes must be provided. The electricity production from Munisipal Solid Waste (MSW) could be an alternative way in order not only to solve the problem of insufficient electric power but also to management the waste dumping problem.

Key Words: Municipal solid waste, Waste management, Alternative source of electricity, Waste to Energy technologies , Processes of renewable energy.

1. INTRODUCTION:

In many parts of the world, solid waste is used to produce electric power via incineration or gasification of the fuel, or through landfill methane capture, and much research has focused on waste to energy solutions. The people of today's world is solely dependent on the electrical energy [1]. Researchers in this field say that the reserved gas will be finished soon, and usage of gas is increasing day by day. In developing countries, there is not enough generation of electrical energy to keep up with the demand, and there is a scarcity of raw materials for producing the energy. Alternative sources are now explored to prepare for the future dearth of traditional energy sources. The waste materials can be a good source of energy as the amount of waste is increasing every day, and can help in meeting the electrical energy. Yangon is the former capital city of Myanmar, for now the center of commerce and trade, is growing with increasing population, reinforced by continuous migration of rural people to the city and new satellite towns. Nearly 6.2million and the area of 716 sq. km, and has the density about 90,000 persons per sq. km. The city is located at a strategic spot in the country's communication network. Motor roads, railroads, waterways and airways connect with the whole country and the major seaport; a gateway to foreign vessels and the international airport of the country is located in Yangon. In fact the city is the biggest urban center in the country with the highest population, financial, economic and educational facilities.

2. OBJECTIVE OF THE STUDY:

- To generate electricity to provide to the consumers at the load shedding periods using municipal waste through anaerobic process;
- To find an environment friendly alternative way to generate electricity
- To identify how much waste is produced per capita per day and determining how suitable it is for energy production.
- To determine the amount of energy produced by the incineration process.

3. SCOPE OF THE STUDY:

It has been found by many surveys and analysis that the quality, quantity and nature of solid waste changing over time and with development. Populated cities of developed countries have more consume of waste and their quality, i.e. calorific value is much higher. In this situation 'waste to energy' generating process will help to get rid of the problem of electricity scarcity and waste management.

4. DEFINING AND CLASSIFYING SOLID WASTE:

Solid wastes are the wastes arising from human and animal activities that are normally solid and discarded as useless or unwanted. The term solid waste is all inclusive, encompassing the heterogeneous mass of throwaways from the urban community as well as more homogenous accumulation of agricultural, industrial, and mineral wastes. Two main types of solid waste can be classified: municipal solid waste and hazardous wastes.

` Waste composition is influenced by factors such as culture, economic development, climate, and energy sources; composition impacts how often waste is collected and how it is disposed. Low-income countries have the highest proportion of organic waste. Paper, plastics, and other inorganic materials make up the highest proportion of MSW in high income Countries. Although waste composition is usually provided by weight, as a country's affluence increases, waste volumes tend to be more important, especially with regard to collection: organics and inerts generally decrease in relative terms, while increasing paper and plastic increases overall waste volumes.

A. WASTE-TO-ENERGY (WTE) TECHNOLOGIES

The most widely used and proven WTE is the process of producing energy in the form of heat and/or electricity from waste sources combustion [2-5]. There are a number of developed and emerging technologies that are able to produce energy from waste without direct combustion. These Technologies produce combustible fuels. Typical combustible fuel includes methanol, ethanol, synthetic fuels, and methane [4].

Many of these technologies have potential to produce more electric power from the same amount of fuel than would be possible by direct combustion if the cost processing is not considered [3, 6,7]. This is mainly due to the separation of corrosive components (ash) from the converted fuel, thereby, allowing higher combustion temperatures in boilers, gas turbines, internal combustion engines, fuel cells [8].

WTE technologies can be classified as thermal and non thermal. Thermal technology includes incineration, gasification, thermal de-polymerization, pyrolysis, and plasma arc gasification [8]. Incineration recovers energy in the form of electricity, district heating, steam, district cooling or any combination.

Gasification produces combustible gas, hydrogen, synthetic fuels. Thermal de-polymerization generate synthetic crude oil, which can be further refined. Pyrolysis produces combustible tar/bio-oil and chars. Plasma arc gasification or plasma gasification process produces rich syngas including hydrogen and carbon monoxide usable for fuel cells or generating electricity to drive the plasma arcs.

Non-thermal technology includes anaerobic digestion and fermentation process. Anaerobic digestion produces biogas rich in methane. Fermentation process generates products such as ethanol, lactic acid, and hydrogen[3,4]. The primary and most widely used WTE technology in the world are incineration and gasification. Over 600 WTE facilities are in place worldwide which combust about 130 million tonnes of MSW, producing electricity and stream for district heating and recovered metals for recycling [4, 9]. The incineration technology is very well developed, regulated, and widely implemented both in developed and developing countries.

B.WASTE-TO-ENERGY (WTE) PROCESSES

There are four main processes which are used in WTE plants, three are thermal (combustion, gasification and pyrolysis) and one is biological (anaerobic digestion). For reasons which are not at all obvious, as all four processes have been in widespread use for many decades, the Government has decided that 'gasification', 'pyrolysis' and 'digestion' are Advanced Conversion Technologies (ACTs), while 'combustion' is not.

Combustion: Wastes that can be used in combustion processes includes MSW, RDF (refuse derived fuel), bulky waste, product specific industrial waste, packaging waste, hazardous waste, sewage sludge, clinical waste, waste cooking oil, waste lubrication oil, straw, and combustible fraction from fragmentation of metal scrap SLF(shredder light fraction) [13, 1 4,15,16].

The boiler and the flue gas cleaning system are important parts of the waste combustion plant. In the boiler the waste is combusted and heat recovered by boiling water. The steam can then be used for power production in a steam turbine or for heat production. Heat can also be recovered from the steam leaving the steam turbine.

Grate furnace, fluidised bed and rotary kiln are techniques for combustion of waste, where grate furnace seems to be the most commonly used technique at least for MSW [13, 17, 18 , 19]. In fluidised beds the fuel particle size cannot be too large. For straw, grate furnaces are recommended since it has a low ash melting point and it can cause the bed particles in a fluidised bed to stick together. Development to optimise the conditions in fluidised beds to use this technique also for straw is going on [15, 21].

The flue gas from waste combustion can have high concentrations of corrosive substances, as for example chlorides, which influence the boiler design and steam data used, due to avoiding corrosion problems. Modest steam temperature and pressures around 40 bar and 400 °C are usually used with some higher temperatures, up to 540 °C, possibly for straw combustion. [13, 15, 17, 18, 19]

A solution to reduce corrosion problems for wastes with high content of metals and chlorine, as for example SLF, can be to co-combust the waste with other fuels [16].

Energy efficiency improvements of the waste combustion process can for example be done by flue gas condensation, extracting heat from flue gases from combustion of wastes with high water contents, or integrating the process with other energy conversion processes as for example a gas turbine in a hybrid dual-fuel cycle, where the steam produced in the boiler can be superheated with the flue gases from the gas turbine.

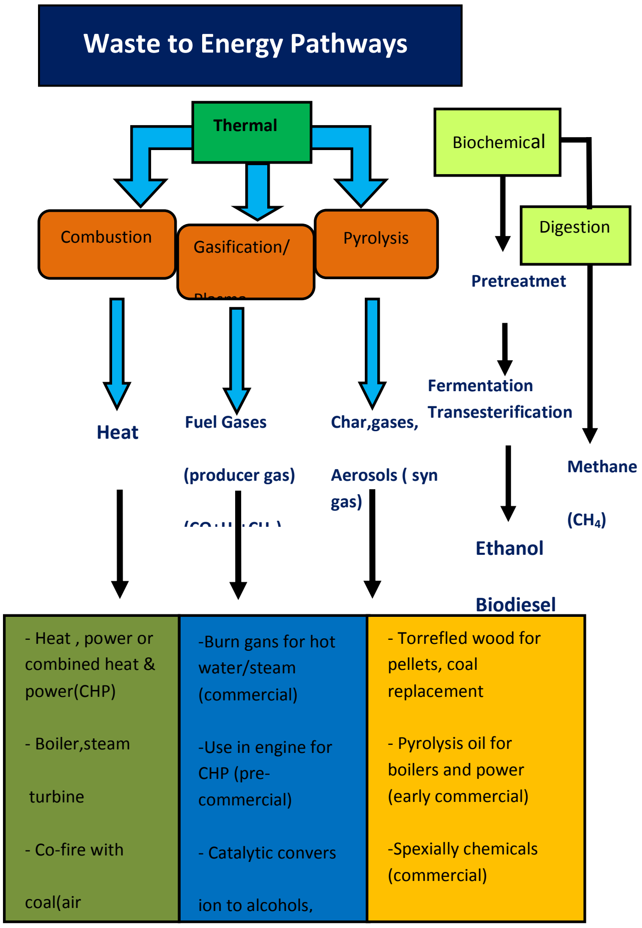

Fig.1 Pathways of Waste to Energy Technologies

Gasification: This is defined as a thermal reaction with insufficient oxygen present for reaction of all hydrocarbons (compounds of carbon, hydrogen and oxygen molecules) to carbon dioxide (CO_2) and water (H_2O). Gasification is where oxygen in the form of air, steam or pure oxygen is reacted at high temperature with the available carbon in the waste to produce a gas (e.g. methane, CH_4), ash or slag and a tar product. Although the gasification method is very recent in its application to biomass and waste materials, the underlying technology, the gasification of coal, is now extremely well proven. The major benefit of gasification of bio-wastes is that the product gas can be used directly, after significant cleaning, to fuel a gas turbine generator which itself will form part of a CHP or Combined-Cycle Gas Turbine system, thus theoretically improving the overall thermal efficiency of the plant. The main disadvantage is that there are many more items of large equipment and the capital investment is correspondingly higher, so the pay-back period will have to be carefully defined.

Pyrolysis: This is also a thermal process and involves the thermal degradation of organic waste in the absence of free oxygen to produce a carbonaceous char, oils and combustible gases.Although pyrolysis is an age-old technology, its application to biomass and waste materials is a relatively recent development. An alternative term for pyrolysis is thermolysis, which is technically more accurate for biomass energy processes because these systems are usually starved-air rather than the total absence of oxygen. Although all the products of pyrolysis may be useful, the main fuel for power generation is the pyrolysis oil. Depending on the process, this oil may be used as liquid fuel for burning in a boiler or as a substitute for diesel fuel in reciprocating engines, although this normally requires further processing.

Anaerobic Digestion (AD)**:** This is a biological process which is a method most commonly used with liquid and semi-liquid slurries such as animal waste. It is also used for obtaining gas from human sewage, but is now being applied to a limited degree to certain other wastes and biomass streams. AD utilises the same biological processes that occur in a landfill site, but under controlled conditions in a digester system. The four-stage process of hydrolysis, acidification, acetogenesis and methanogenesis takes place in the digester tank, which is a warmed, sealed, airless container where bacteria ferment organic material in oxygen-free conditions to produce biogas. The amount of biogas produced is limited by the size of the digester tank, so is largely used as a fuel which may be burned in a conventional gas boiler to heat nearby buildings or in a reciprocating engine which is used to generate electricity.

The main advantage of AD is that it deals well with ‘wet’ waste, which is a real problem for all other forms. It is also ideal for small-scale operations, such as farms, where enough energy (electricity and heat) can be produced to run the farm (including fuelling some of the vehicles) from what is produced on the farm. Its drawbacks are that it takes up a relatively large amount of space and it is often difficult to avoid odours, both of which make it less suitable for urban installations. Furthermore, it is relatively inefficient (i.e. amount of useful energy recovered) when compared on a like-for-like basis with other forms of WTE, because not all of the organic matter is converted. Furthermore, most AD systems tend to be ‘batch’ rather than ‘continuous’ processes, which means that parallel systems are required if a continuous output is needed.

5. CURRENT SITUATION OF SOLID WASTE MANAGEMENT IN YANGON CITY:

Yangon City is now faced with significant urban problems. Most of the infrastructures related to water supply, sewerage, drainage and waste disposal are rather old and not adequately fitted to cope with the present demand.

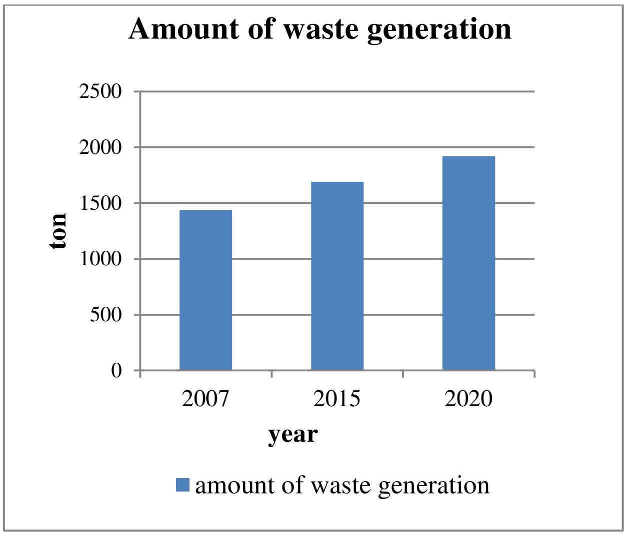

Fig 2. Yangon Regional Waste Generation

Pollution Control and Cleansing Department (PCCD) is the responsible agency for Solid waste Management (SWM) in Yangon City. Solid waste generation in the city in 2007 was estimated at about 1400 tons per day. PCCD possesses collection vehicles and uses daily. It is reported that the waste collection ratio in Yangon City is only 67% as of 2007.

In other word, the features of SWM in Yangon City are basically labour intensive and uncontrolled. During the period of Municipal (1988), Cleansing department took responsibility for the city clean and green and the cleansing staffs worked for sewage at night and for waste sweeping and collection in day light. At that time, Cleansing department took responsibility for the activities of cleansing and collection of sewage, drainage, back lanes, sidewalk grass, roads and streets waste, garden waste, cemetery, laundry factories and public toilets.

6. WASTE GENERATION AND COLLECTION RATE:

As for the data of waste generation rate of Yangon City at the year of 2007, it is estimated as 0.395 kg/day for one person. Table I summarizes the waste generation and collection by four districts. Waste generated about 1435 tons per day and used daily collection system across the 33 townships. Waste generation amount about 0.4 kilograms per capita per day from survey of Pollution Control and Cleansing department. During this year 2015,the amount of waste generated is 1690 tons per day and YCDC forecasts that the amount of waste generated in 2020 in Yangon City will increase up to 1920 tons per day.

TABLE I
WASTE GENERATION & COLLECTION IN

YANGON CITY BY DISTRICTS IN 2007

Dist-rict	Popu-lation	Kind of Waste					Total Amount
		HO		MA	ST	Oth-ers	
East	1065228	265	384	51	15	24	384
West	511480	152	345	73	32	24	345
South	898665	220	341	37	17	24	341
North	1217069	258	365	38	18	22	365
Total	3692442	895	1435	199	82	94	1435

Note: HO (Household Waste). CO (Commercial Waste), MA (Market Waste), ST (Street Waste) [Source: YCDC (2007 a)]

7. CASE STUDY:

The waste to energy TPD (Ton Per Day) Incineration Plant at Htawe Chaung, North Dagon, is with the Incineration capacity of 600t/day (300t/day×2sets) as the amount of generated waste at the Htawe Chaung Final Disposal Site is 612 tons per day.

Electricity Energy Recovery; MSW (municipal solid wastes) has a heating value ranging from 9300 to 12800kJ/kg. It is possible to recover this energy by using MSW to fire boilers in order to produce steam that can be used to drive a steam turbine. The turbine then turns a generator producing electricity. Before electricity is produced, these are efficiencies and losses that must be accounted for. Heat losses include heat losses due to the sensible heat content of the ash and the unburned carbon remaining in the ash, heat losses due to radiation, and water losses. Since the actual furnace combustion suspends all the combustion water in gaseous form, energy of vaporization is needed for this suspension. This wasted energy is the water loss. Water losses include loss due to the moisture content, loss due to combined water and loss due to the net hydrogen water. The latent heat of vaporization of water is equal to 2420 kJ/kg.

For the sensible heat of the ash, the specific heat is normally taken as 1047 J/kg-•C. The heating value of carbon is 32851kJ/kg. Radiation losses range from 0.003 to 0.005 kJ/kg of fuel. After all these losses are counted for, these are subtracted from the higher heating value of MSW to obtain the sensible heat content of the stack gases. These gases are then passed through boiler tubes. As the gases travel through the tubes, the sensible heat contents are given up heating the water in the boiler to steam. It is this steam introduced to the steam turbine that drives the generator to produce electricity. For steam turbine generator systems of less than 12.5 MW capacities, thermal efficiency range from 24 to 40%, with a typical value of 29%, excluding the boiler, for systems over 12.5 MW capacities, thermal efficiencies range from 28 to 32%, with a typical value of 31.6%, also excluding the boiler. MSW boilers have thermal efficiencies of about 70%. The power plant itself uses electricity. Approximately 6% of gross plant electrical output is allotted for this service. In addition, an unaccounted for plant loss of 5% is also provided. The empirical formula of MSW is **$C_{562}H_{900}O_{414}N_{6.6}S$.** MSW is used to fire an MSW energy recovery plant.

Assumptions; The MSW contains 20% moisture and 20% inert. The ash contains 5% carbon and higher heating value of the MSW is 1200kJ/kg. Also, the fuel enters at 25•C and that the ash is at 420•C. The MSW contains 20% moisture and 20% inert. The ash contains 5% carbon and higher heating value of the MSW is 1200kJ/kg. Also, the fuel enters at 25•C and that the ash is at 420•C.

Calculation of Electricity Export

Total heat input = 600ton/day×10^3kg/1ton× 12000kJ/kg

$= 7.2 \times 10^9$ kJ/day

For heat loss in ash,

Inert = 0.2 × 600 ton/day ×10^3kg/1 ton

= 120000 kg/day

Let x = mass of C

$x/(18600+x) = 0.05$

$x = 6315.79$ kg/day

Ash = 120000 + 6315.79

= 126315.79 kg/day

According to theory;

For the sensible heat of the ash, the specific heat = 1047 J/kg-•C

Heating value of carbon = 32851 kJ/kg

Heat of vaporization of water = 2420 kJ/day

Heat loss in ash= loss due to sensible heat +loss due to heat of combustion of C

$= [126315.79 \times 1.047 \times (420-25)] + (6315.79 \times 32851)$

$= 25.97 \times 10^7$kg/day

where the temperature for sensible heat calculation is 25•C and for the ash is 420•C.

For water losses

$C_{562}H_{900}O_{414}N_{6.6}S = 0.6 \times 600 \times 10^3 = 360000$ kg/day

$C_{562}H_{900}O_{414}N_{6.6}S$ = (562 × 12) + (900 × 1.008) + (414 × 16) + (6.6 × 14) +32

= 14399.6

$$\text{Combined water} = \frac{(414\times16)}{14399.6}\times360000\times\frac{18}{16}$$

$$= 165604.6 \times\frac{18}{16}$$

= 186305.18 kg/day

Net hydrogen water = [{(900 × 1.008)/14399.6 × (360000)} – {(2.016 ×165604.6)/16}] × (18/2.016)

= 16200.45 kg/day

Total water = moisture + combined water + net hydrogen water

= 120000 + 186305.18 + 16200.45

= 322505.63 kg/day

Water losses = total water × heat of vaporization of water

= 322505.63 × 2420

= 7.8×10^8 kg/day

Assume radiation losses = 0.004 kJ/kg MSW

Radiation losses = $0.004 \times 600 \times 10^3$

= 2400 kg/day

Total losses = $(25.97 \times 10^7) + (7.8 \times 10^8) + 2400$

= 10.397×10^8 kJ/day

Sensible heat in stack gas = $(7.2\times10^9) - (10.397 \times10^8)$

= 6.16×10^9 kJ/day

(based on 25°C)

(For simplicity of calculation, flue gas has been assumed to cool down to the base temperature of 25°C)

Boiler efficiency = 70%

Steam energy efficiency = $0.7 \times 6.16 \times 10^9$

= 4.31×10^9 kJ/day

Thermal efficiency for steam turbine = 31.6%

Plant service allowance = 6%

Unaccounted for losses = 5%

Net electrical export = $0.316\times 4.31\times10^9 \times [1-(0.06+0.05)]$

= 12.13×10^8 kJ/day

= $(12.13 \times 10^8)/(3600\times 24)$

= 14036.64 kJ/sec

= 14036.64 KW (kJ/sec = KW)

= 14.04 MW

Overall efficiency = $(12.13 \times 10^8) / (7.2 \times10^9) \times 100\%$

= 16.8%

TABLE II

Hourly Consumption of Eastern and Southern Dagon Industrial Zone

Hour	Demand from Eastern Dagon industrial zone (MW)	Demand from Southern Dagon industrial zone (MW)	Total demand from Eastern and Southern Dagon industrial zone (MW)	Supply from WTE plant (MW)
1:00	2.4	4.86	7.26	14.04
2:00	2.4	4.66	7.06	14.04
3:00	2.58	4.48	7.06	14.04
4:00	2.75	4.66	7.41	14.04
5:00	2.75	4.56	7.31	14.04
6:00	3.08	4.94	8.02	14.04
7:00	4.75	7.15	11.9	14.04
8:00	6.58	8.96	15.54	14.04
9:00	7.91	11.35	19.26	14.04
10:00	8.66	17.01	25.67	14.04
11:00	8.08	17.54	25.62	14.04
12:00	7.5	14.59	22.09	14.04
13:00	7.25	13.94	21.19	14.04
14:00	7.25	14.79	22.04	14.04
15:00	7.5	16.8	24.3	14.04
16:00	8.25	17.41	25.66	14.04
17:00	7.8	15.68	23.48	14.04
18:00	5.75	11.16	16.91	14.04
19:00	4.41	9.65	14.06	14.04
20:00	4.08	8.8	12.88	14.04
21:00	3.08	7.43	10.51	14.04
22:00	2.75	6.86	9.61	14.04
23:00	2.41	6.66	9.07	14.04
24:00	2.25	6.12	8.37	14.04

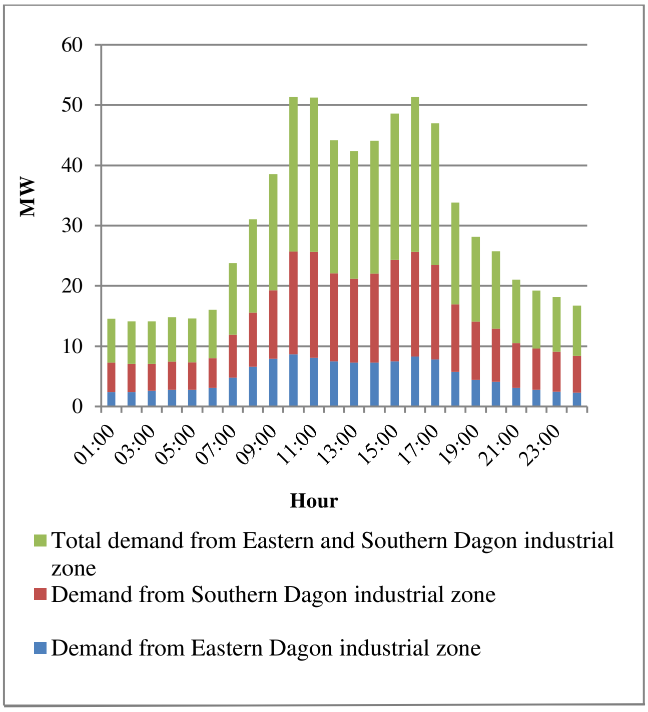

Fig. 3 Demand from Eastern and Southern Dagon Industrial Zone

The output of the WTE plant is 14.04 MW for the input of 600 ton per day and the overall efficiency of this plant is 16.08%.Table II shows the hourly consumption of Eastern and Southern Dagon Industrial Zone and WTE plant's supply. The minimum total consumption of Eastern and Southern Dagon industrial Zone is 7.06 MW and maximum total consumption is 25.67 MW. WTE plant can cover completely for the minimum total consumption of the two regions but 54.7% cover for the maximum total consumption of them.

8. CONCLUSION:

The current situation on solid waste management reforms is assessed to be proper technical, social, environmental, financial, and economic viewpoints. Therefore, YCDC improve and introduce the current system based on the strategies proposed. In this study, the improvement of the institutional system is given priority, followed by technical improvements in general and suitable integrated solid waste management system.

For the effective and economical implementation of the project, YCDC needs to have a development guidelines and suitable frame works in a form of a long-term, sustainable master plan, to build Yangon City as a clean, green, livable, bright and healthy international standardized city.

Pure Waste to energy plant (just only use the waste of 600ton/day) in this case cannot catch completely the demand of Eastern and Southern Dagon industrial zone hourly and it can cover only 54.7 % for the maximum total consumption but it can provide the reliable supply for the base load of the two industrial zones.Fig.4 shows how much WTE plant's supply can cover the total consumption of Eastern and Southern Dagon industrial zone. If we can hold other WTE plants to use all of Yangon regional waste (1435ton/day), we can supply completely to the demand of the Eastern and Southern Dagon industrial zone. Moreover, the overall efficiency of WTE plant in my case study is 16.8%.So, I am trying to analyse the proper technology like using plasma theory in order to get the proper supply and also proper overall efficiency.

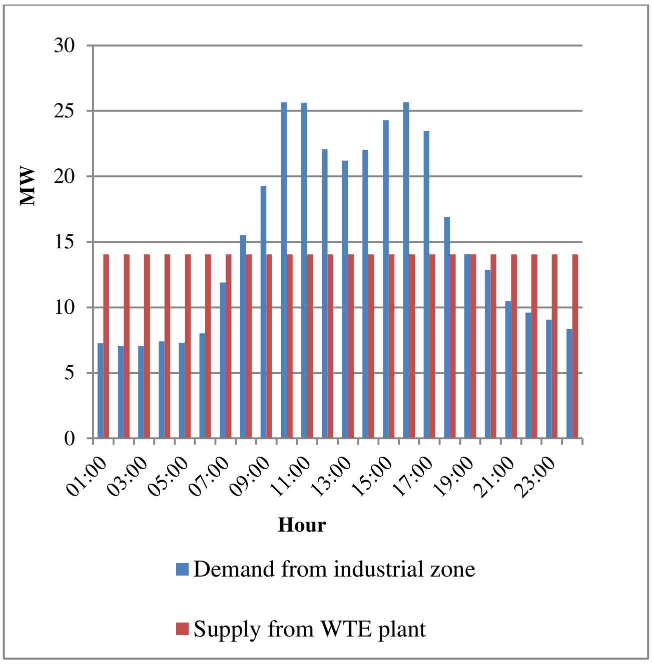

Fig. 4 Power supply from WTE to Industrial Zone

REFERENCES:

1. Alamgir, M. & Ahsan, A. Municipal solid waste and recovery potential: Bangladesh perspective. Iran. J.Environ. Health. Sci. Eng.,4 (2), 67-76. (2007).

2. Cheng, H. & Hu, Y. : Municipal solid waste (MSW) as a renewable source of energy: Current and future practices in China. Bioresource Technology, 101, 3816–3824. (2010).
3. EEA (European Environment Agency). :Case studies on waste minimisation practices in Europe.Copenhagen: EEA. (2002).
4. Enayetullah, I. & Hasmi, Q. S. I. : Community Based Solid Waste Management through Public-Private- Community Partnerships: Experience of Waste Concern in Bangladesh.3rd Asia Conference October 30 to November 1, Tokyo, Japan. (2006).
5. Energy Bangla. : Load Shedding Crosses 1000 MW with Peak Summer Still Far in Bangladesh. Retrieved April 21, 2011, from http://www.energybangla.com/index.php?mod=article&cat=PowerSector&article=2392.
6. GKNS Energy Pvt Ltd. : Executive project report: waste to energy. Andhra Pradesh: GKNS Energy Pvt Ltd. (2008).
7. Hasan, G. M. J. & Chowdhury, M. A. : Municipal waste management and environmental hazards in Bangladesh. Asian Journal of Water, Environment and Pollution, 1(3), 39-48. (2006).
8. Hossain, M. K., Halder, D., Mondal, M. N. I. & Haque, .M. N. : Direct and indirect effects of socioeconomic and demographic factors on age at death of infant and child of slum area in Rajshahi City, Bangladesh. International Journal of Current Research, 11, 100-106. (2010).
9. Klee, A. J. : Quantitative decision making, design and management for resource and recover series. (1980).
10. Energy consumption datas from Ministry Of Electric Power, (2015)
11. Kumar M, Gayen K. Developments in biobutanol production: New insights**,** Appl Energ 2011;88,6:1999-2012
12. European Commission. Integrated Pollution Prevention and Control, Reference Document on Best Available Techniques for the Waste Incineration, BREF (08.2006), 2006.
13. Singhabhandhu A, Tezuka T. Prospective framework for collection and exploitation of waste cooking oil as feedstock for energy conversion, Energy 2010;35:1839–1847
14. Hinge J. Elaboration of a Platform for Increasing Straw Combustion in Sweden, based on Danish Experiences, Värmeforsk project no. E06-641, 2009
15. Gyllenhammar M, Victorén A, Niemi J, Johansson A. Energiåtervinning av brännbar fraktion från fragmentering av metallhaltigt avfall (Energy recovery of combustible fraction from fragmentation of metal scrap), Project No. WR-08, Waste Refinery, 2009 [in Swedish]
16. Johansson A, Niklasson F, Johnsson A., Fredäng J, Wettergren H. Drift och underhåll av avfallsförbränningsanläggningar – en jämförelse av två tekniker och strategier, (Operation and maintenance of Waste Combustion plant – development of a method for economical comparison of different techniques and strategies), WR-09, Waste Refinery, 2009 [in Swedish]
17. Buchhorn B. Optimisation And Extension Of The WTE Plant Dordrecht, Netherlands, ISWA World Congress, 15-18 –November, 2010, Hamburg, Germany
18. Weiler C, Grotefeld V.. Licensation, Design and Erection of the RDF-CHP Plant in Bernburg and Enhancement of MWIP, ISWA World Congress, 15-18 November, 2010, Hamburg., Germany
19. Fendel A, Firege H. Competition of Different Methods for Recovering Energy from Waste Leading to Overcapacities, ISWA World Congress, 15-18 November, 2010, Hamburg, Germany
20. Chunjiang Y, Jianguang Q, Hu N, Mengxiang F, Zhongyang L. Experimental research on agglomeration in straw-fired fluidized beds, Appl Energy 2011;88 :4534–4543.