Zero-Waste City Implementation using Waste-To-Energy Technology in Myanmar

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ABSTRACT
Waste management is a complex topic that is handled in different ways around the world based on available local resources, technologies, and intensity of community initiatives. So, Waste-to-Energy (WTE) is a renewable energy technology that has seen a major rise in the last decade as Myanmar has been looking for methods for handling its population boom and related rapid increase in waste generation rates. 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. In this paper, feasibility study of waste to energy (WTE) power conversion plant is presented to fulfil the main aim of zero-waste city implementation, Mandalay, Myanmar. With the application of WTE plants, the electricity requirement can be fulfilled and also helpful for environmental condition. For case study, Mandalay Industrial Zone is selected since it has low reliability of power supply form national grid and is suitable for construction of a WTE power plant. The simulation for WTE power plant with a peak load of 30 MW is described using HOMER software. Average energy consumption of the industrial zone is estimated approximately 283 MWh/day and WTE has consumed almost 118,935 tonne per year of municipal solid waste (MSW). The proposed system is designed to provide approximately 100% of energy from the municipal solid waste for the proposed area.

KEYWORDS: WTE, Renewable energy, Municipal solid waste, HOMER software

INTRODUCTION

Waste-to-energy is now a clean, renewable, sustainable source of energy. The need to reduce waste production and to ensure their sustainable management has become a matter of citizenship. WTE is the process of producing energy in the form of heat and electricity from waste sources combustion. The technology of WTE incineration also solve the problem of landfills, causing pollution, with no recovery, as it could be used drawing the energy content that some of these wastes can offer. The estimation of the quantity municipal solid waste that can be generated in industrial zone (Mandalay Region of Myanmar) per day and estimation of the generation potentiality of energy through combustion and gasification of municipal solid waste is discussed in this paper. Myanmar has been facing considerable challenges with the management of waste as a result of increasing income and consumption levels, urban population growth and lack of effective waste treatment and disposal options. WTE systems as one of renewable energy sources (RES) has been rapidly spreading throughout the world due to its easy cleaning environmental impacts [1]. One of common issues on WTE systems as similar other kinds of RES are output stabilization with because of its high dependence on waste potential conditions such as MSW (non-gaseous waste and non-liquid waste). The power output fluctuation causes power imbalance. The irregular load profile can be smoothed using waste to energy source.

With the growing demand for electric power supply, there is a need to look into all possible means of electricity generation especially renewable. Myanmar has many renewable energy resources, and many regions that cannot be supplied to be fulfil demand with electricity from the main grid. The load profiles of the proposed area and the waste potential profiles are determined. The advantages of that system, in terms of uninterrupted, sustainable energy supplies and environmental effects are analysed through simulations using HOMER software. The penetration of distributed generation (DG) sources is constantly increasing, as a result of both technological advancements and institutional changes in the electric power industry. The applying of new technology for power plant is often hindered by a variety of factors, including technical considerations and requirements, usually resolved at the expense of the investor. As the interest for stalling new generation facilities escalates, the adoption of transparent and easily applicable technical evaluation procedures becomes imperative [2].

In Mandalay Region of Myanmar, the performance of WTE plant has been implemented on 30MW for industrial zone. The objective of this work is to provide electricity uninterrupted and sustainable power supply to fulfil the domestic as well as commercial and industrial needs with RES. This paper presents spatial technique to reduce

environmental impacts waste. It is intended to solve the waste problems and to present the distributed generation system. For the case study, Mandalay industrial zonen (IZ), Mandalay, Myanmar, is selected. The power demand of the distribution system and the available municipal solid waste are formerly observed. Then the available power from waste is calculated. Then the generated power from WTE plant using synchronous generator is supplied for proposed area.

WTE Technologies

Geothermal and WTE systems emit some air pollutants, though total air emissions are generally much lower than those of coal- and natural gas-fired power plants. WTE and geothermal power plants, like coal- and natural gas-fired power plants, may require water for cooling. Hydroelectric power plants can disrupt river ecosystems both upstream and downstream from the dam. However, renewable energy study, which included WTE system found that effects environmental pollution can be reduced and withdrawal would be increased significantly in a future with high using of renewable.

There are four main technologies 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 technologies 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. 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) [3]. The system block diagram shown three options of WTE generation is illustrated in Figure 1. In this paper, the stand alone WTE power plant using gas engine is presented for proposed area.
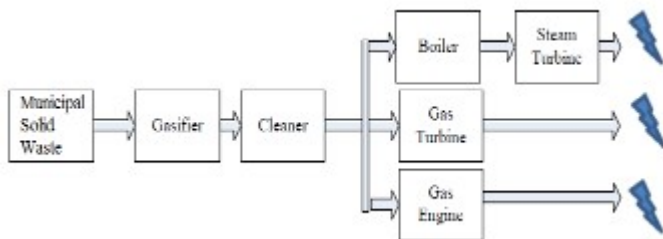

Fig.1 System Block Diagram for WTE Power Plant

Waste Management

In the waste to energy (WTE) electricity generation, the power can be obtained from dry solid waste directly or from wet solid waste via gasification.

A. Waste Generation Rates

In this paper presents about MSW which comprises dry solid waste (DSW) and wet solid waste (WSW). Both of them can generate electricity but their efficiencies differ depending on their components. The component percentage of DSW and WSW are 30% and 70% [4].

Myanmar's municipal solid waste is generated from household (60%), markets (15%), commercial (10%), hotel(2%), garden(5%), and others(8%) and is shown in Fig. 2.
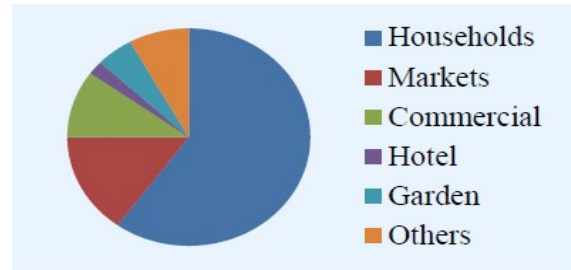

Fig. 2 Municipal Solid Waste in Mandalay

The major sources of MSW generation of IZ are Organic (77%), Plastic (13%), Paper (7%), and others (3%) of waste type. Based on survey data, the available waste from Mandalay is described in Table I. The southern part of Mandalay (Thaung Inn Myout Inn) generates, on an average, about 560 tons of MSW per day [5] and WTE plant use only the wastes from Thaung Inn Myout Inn.

Table1. Waste Generation Amount of Mandalay

District	Tons of waste per day
Northern part of Mandalay (Kyar Ni Kan)	400
Southern part of Mandalay (Thaung Inn Myout Inn)	560
Total	960

B. Waste Disposal Methods

Waste can be handled in many ways by a given community. In general, waste management experts and professionals adhere to a waste management hierarchy that presents best practices in the field of waste management. This hierarchy, shown in Fig. 3, prioritizes the reduction and reuse of waste where possible. Where waste is unavoidable, it should be recycled or composted to give the material new value. When recycling and composting are not viable solutions, responsible energy recovery methods, such as WTE, should be used. Lastly, the leftovers that have no better treatment solution are discarded into landfills.

Fig. 2 Waste Disposal Hierarchy

Design Management

In this paper, WTE stand alone system is presented to supply the proposed area.

A. Demand Side Management

The proposed area is the industrial zone which is located at 21.89 (N) latitude and 96.09 (E) longitudes in Mandalay region in Myanmar. From consumption of load profile for load component, the daily and monthly load profiles for industrial zone are shown in Fig. 3 and Fig. 4, respectively [6].
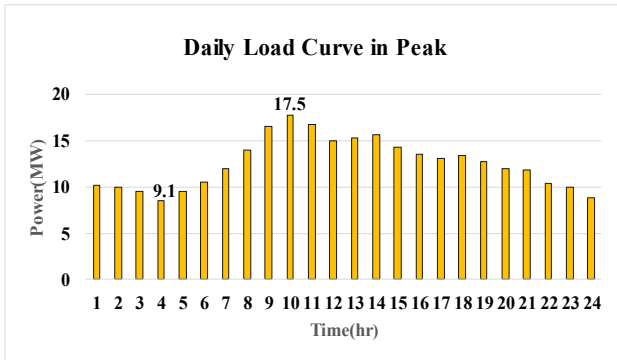
Fig. 3 Daily Load Profile for Industrial Zone

Figure 3 shows daily load profile for Industrial Zone. The maximum load is 17.5 MW at 10 am and the minimum load is 9.1 MW at 4 am. According to the calculation, the average power demand over a day is about 11.9 MW. Due to the presence of industries, the power demand is high between 7:00 a.m and 4:00 p.m.
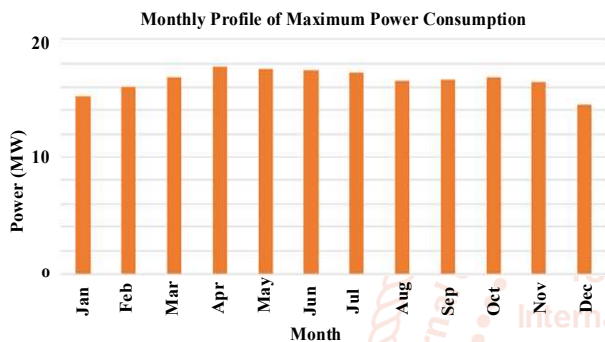

Fig. 4 Monthly Load Profile for Industrial Zone

Figure 4 shows the monthly load profile for industrial zone. These values are the average values over the corresponding month. As monthly average, the maximum demand is observed at April with 17.8 MW and minimum demand is observed at December with 14.3 MW. The demand is large during rainy season and summer. In winter (during November to February), the demand decreases as shown in Fig. 4.

B. Supply Side Management
For supply side management, WTE power plant using gasification technology is presented to fulfill the demand side requirements.

1. Waste Potential
Mandalay industrial zone has availability to use wast for power production throughout the year Southern part of Mandalay (Thaung Inn Myout Inn). The selected value of gasification ratio is 0.7 (kg gas/kg biomass). The LHV of biogas is 5.5 MJ/kg. The average price of waste incentive is $7/ton. The waste potential for proposed area is shown in Fig. 5.
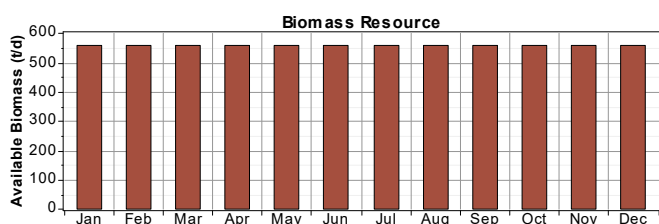

Fig. 5 Monthly Biomass Resource Profile for Proposed Area

2. WTE Gasifier and Synchronous Generator
A gasification plant includes the gasifier reactor as well as support equipment. The design of a gasification plant would involve design of individual units:
➢ Gasifier reactor
➢ Waste-handling system
➢ Waste-feeding system
➢ Gas-cleanup system
➢ Ash or solid residue-removal system

The movement of biomass down the gasifier is shown in Fig. 6, including a description of the temperature gradient during the gasification process.
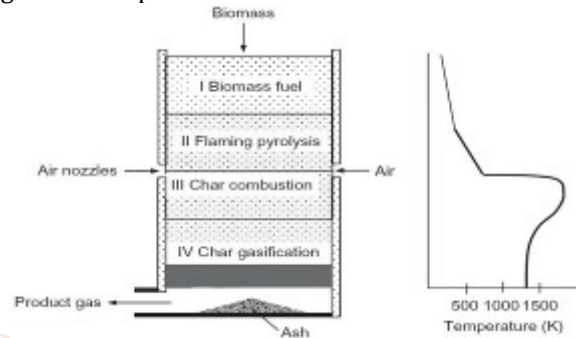

Fig. 6 Schematic of the Operation of a Throatless Downdraft Gasifier (left) and Temperature Gradient along the Height (right)

The technical and economical parameters of the biogas generator are listed in Table II.

TABLE 2 Technical and Economic Parameters of the Biogas Generator Set

Parameter	Value	Units
Size	30	MW
Capital cost Bio gasifier and generator set (incl. transport cost)	75×10^6	$
Replacement cost	60×10^6	$
Operation and maintenance cost	0.03	$/hr
Minimum load ratio	30	%
Lifetime (operating hours)	30000	hours
Rated volage	400/230	V
Rated Frequency	50/60	Hz
Rated speed	1500	rpm

THEROTICAL BACKGROUND FOR EVALUATION
The performance of the renewable system can be analyzed based on the goals of cost minimization, system reliability improvement, and reduction of greenhouse gas emissions [7]. The net present cost is calculated by discounting the annual, quarterly, and monthly financial flows [8]. The net present cost of a system is the present value of all costs minus all values over its lifetime, and it includes capital costs, replacement costs, operation and maintenance costs, and fuel costs. The levelized cost of energy is calculated by dividing the total life-cycle cost by the total energy output during the project lifetime [8]. The mathematical equations are formulated for the simulations using the HOMER, as follows [8], [9], [10].

$$C_{NPC} = \frac{C_{anntot}}{CRF(i,n)} \qquad (1)$$

$$i = \frac{i_{nom} - f}{1 + f} \qquad (2)$$

$$LCOE = \frac{TLCC}{\sum_{n=1}^{N} \frac{Q(n)}{(1+r)^n}} \qquad (3)$$

$$TLCC = \sum_{n=1}^{N} \frac{C(n)}{(1+r)^n} \qquad (4)$$

$$S = C_{rep} \cdot \frac{L_{rem}}{L_{comp}} \qquad (5)$$

$$f_{es} = \frac{E_{sc}}{E_{tot}} \qquad (6)$$

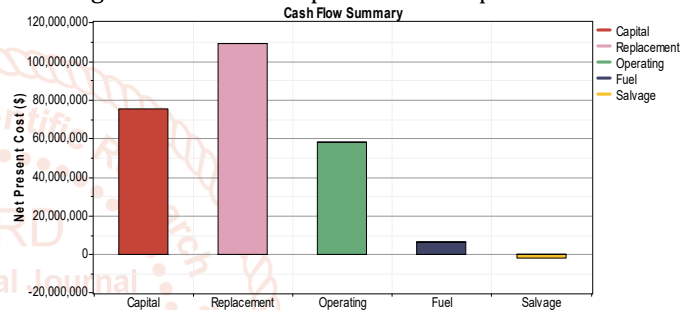$$CRF(i,n) = \frac{i(1+i)^n}{i(1+i)^n - 1} \qquad (7)$$

The parameters in (1)–(7) are defined as follows.

C_{NPC} : net present cost ($)

C_{anntot} : total annualized cost ($/yr)

$CRF(i,n)$: capital recovery factor

i : annual real interest rate (%)

i_{nom} : nominal interest rate (%)

f : annual inflation rate (%)

n : index for the year

N : project duration (yrs)

$LCOE$: levelized cost of energy ($/kWh)

$TLCC$: total life cycle cost ($)

$Q(n)$: energy output of power generation system in the specific year of n (kW)

$C(n)$: total cost in the specific year of n ($)

r : annual discount rate (%)

S : salvage value ($)

C_{rep} : replacement cost of the component ($)

L_{rem} : remaining life of the component (yrs)

L_{comp} : lifetime of the component (yrs)

f_{es} : capacity shortage fraction

E_{sc} : total capacity shortage (kWh/yr)

E_{tot} : total electric (kWh/yr)

SIMULATION RESULTS

In the simulations, the parameters presented in table 2 and the equations (1) to (7) presented in above section are used to show the simulation results.

A. Economic Results

For WTE system, 60 MW WTE gasifier-generator set is used for supplying the proposed area. The simulation results for the net present cost and nominal cash flow are shown in Figs. 7 and 8 respectively. The generations from the WTE is fulfilling the 100% of total power consumption.

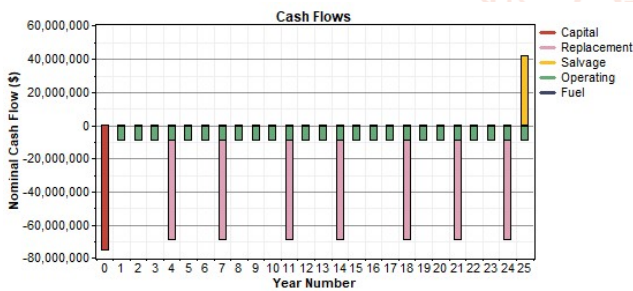| Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
WTE	75,000,000	109,246,320	57,776,408	6,102,537	-1,982,992	246,142,272
System	75,000,000	109,246,320	57,776,408	6,102,537	-1,982,992	246,142,272

Fig. 7 Net Present Cost

Fig.8 Nominal Cash Flow for Case Study I

B. Electrical Results

The monthly average generation for WTE is illustrated in Fig. 9 and the electrical results for WTE are described in table3.
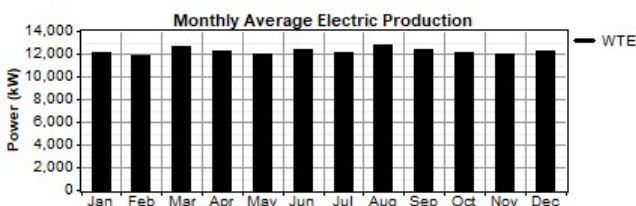
Component	Production (kWh/yr)	Fraction
WTE	107,303,752	100%
Total	107,303,752	100%

Fig. 9 Monthly Average Generation of WTE

TABLE 3 ELECTRICAL RESULTS FROM WTE

Quantity	Value	Units
Excess electricity	3.58	%
Cost of energy	0.325	$/kWh
Unmet load	0.01	%
Capacity shortage	0.02	%
Renewable fraction	1.000	
Hours of operation	8,758	hr/yr
Number of starts	2	starts/yr
Operational life	3.43	yr
Capacity factor	40.8	%
Electrical production	107,303,752	kWh/yr
Mean electrical output	12,252	kW
Min. electrical output	9,000	kW
Max. electrical output	29,790	kW
Bio. Feedstock consump.	118,935	t/yr
Specific fuel consumption	0.776	kg/kWh
Fuel energy input	127,194,264	kWh/yr
Mean electrical efficiency	84.4	%

C. Environmental Results

The simulation results for environmental impacts in term of the emissions of CO_2, CO and NO are shown in table 4.

TABLE 4 ENVIRONMENTAL RESULTS

Pollutant	Emissions (kg/yr)
Carbon dioxide	20,574
Carbon monoxide	773
Unburned hydocarbons	85.6
Particulate matter	58.3
Sulfur dioxide	0
Nitrogen oxides	6,898

CONCLUSION

Distributed generation model of WTE system has been proposed in this paper. To simulate the proposed model, the simulation has been done for the WTE system using real resource data and load demand. Myanmar, being a country that has many renewable energy sources and non-electrified rural villages, was found to be suitable for the implementation of renewable systems. Thus, in this paper, the industrial zone in Myanmar is selected and supplied from the stand alone system with economic feasibility, considering the specific local conditions and resource availability for that area. The evaluation results in this paper suggest that government and private sector organizations in Myanmar should consider the WTE system as a highly suitable alternative, when implementation of zero-waste city for Mandalay.

ACKNOWLEDGMENT

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