Comparison of the Various Waste to Energy Technologies and Selection of the Technology Best Suited for the State of Sikkim

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Abstract—The urbanization and growth of the state of Sikkim poses a grave environmental hazard to the state in the way of Municipal Solid Waste (MSW). The waste generated in the state of Sikkim today stands at 106 Tonnes per day which although is quite small compared to other states, but for the tiny state which has about 70% of land as protected or covered under forest or uninhabitable, finding lands for creating land fills is a big problem. This paper tries to find a solution to the problem by finding a suitable method for converting of the waste generated into energy by studying and comparing the various Waste to Energy (WTE) technologies.

Keywords-*Municipal Solid Waste (MSW); Techno-Economic feasibility; Waste-to-Energy (WTE): Refuse – derived fuel (RDF)*

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I. INTRODUCTION

Sikkim is a small state with approximate area of 7096 sqm. Out of which 70% of the land is either under protected area, forest or uninhabitable. And with the government policy of clean and green Sikkim, it is but imperative that a solution be found for the MSW apart form land fills.

The MSW in the state, as per the report presented by Urban Development & Housing Department of the state (http://www.sikkimudhd.org/Part%204_SKFinal%20Report%20101008%20[Compatibility%20Mode].pdf)in the year 2015 stood at 106MT/day which is to grow to 142MT/day.

WTE technology gives an excellent solution to the problem and this paper tries to find the best suited technology for the tiny clean state of Sikkim

II. RELATED WORKS

There has been a lot of commendable research work has been done in the field of Waste to energy production. Afew has been selected for study related to the subject.

Saini et. al [1] in their research have made a thorough techno-economic study of adopting the WTE technologies in India. They have made a study of about 75 cities. They have based their calculation on the paper and research of Rao et all 2000.

The research also highlights the Comparison of WTE technologies in India (Lal & Reddy 2009; *MSW Manual 2000; **Matt Crowe *et al* 2002) which shows the capital requirement for various WTE technologies.

Jain et al [2] in their work have done a study on the present scenario in the country of WTE generation. They have done a comparative study of the various WTE plants in the different states and done a case study of the WTE plant in Delhi.

III. POTENTIAL OF MSW TO ENERGY PLANT IN THE STATE OF SIKKIM

The total MSW produced in the State stand at 106 Tonnes per day which is to grow to about 142 Tonnes per day in the next 5 years. The composition of the waste as the report of the North-Eastern Region Capital Cities Development Investment Program – Gangtok Solid Waste Management Subproject, the following is the composition of MSW generated in Gangtok.

No.	**Physical Parameters**	**Average**
1	Bulk Density	410.68 Kg/m3
2	Paper	6.42 %
3	Textile	3.72 %
4	Plastic and Rubber	3.99 %
5	Metals	1.31 %
6	Glass	1.96 %
7	Stone, Brick etc	1.78 %
8	Ash and Fine Earth	13.22 %
9	Leaves and Wood	4.11 %
10	Food Waste	63.49%
No.	**Chemical Parameters**	**Average**
1	Moisture	44.77 %
2	pH	7.23
3	Ash Content	23.16 %
4	Carbon as C	35.70 %
5	Nitrogen as N	1.65 %
6	Volatile Matter	24.73 %
7	Phosphorous as P	0.65 %
8	Gross Calorific value	1043.31 KCal/Kg

Table 1: Physical and Chemical Characteristics of MSW in Gangtok

Calculation of potential of energy which can be produced by MSW generated in the state of Sikkim

The calculation is based upon the equations 1,2 & 3 given above and is for the MSW generated in the year 2015 in whole of the state of Sikkim.The power produced from MSW is calculated using the following mathematical (Rao *et al* 2000) [3]:

Net Power Generation Potential (kW) = P x Q (1)

Where, $P = X \times Y \times Z \times L \times W_1 \times 10^3$ (2)

$Q = W_2 \times CV \times h$ (3)

X = 7.65 (calculated as per http://www.fovbiogas.com/biogas-calculator/)

Y = 0.75 (as per http://www.fovbiogas.com/biogas-calculator/)

Z = 0.9 (as per Table 2)

L = 0.63 (as per table 2)

$^{W}1$ = 106 (data as per year 2015)

h = 0.6 (assumed)

W_2 = is a constant = $(860 \times 24)^{-1}$

CV = 1043.31 Kcal/kg (as per table 2)

From the above – P = 325316.25, Q = 0.001258721

Thus Net Power Generation potential **= 409.4823 kW**

= 0.409 MW

The potential of MSW to Energy has been calculated using values taken from literature reviews of several research. The projected MSW to Waste potential for the state of Sikkim has been calculated.

IV. MSW TO ENERGY TECHNOLOGIES

A. Incineration

a. Depolymerisation

This uses a process of thermal decomposition wherein, in the presence of water, the organic compounds are heated at a very high temperature. This process is called as Hydrous Pyrolysis.

The process if done without the use of oxygen is known as Pyrolysis. The process takes plastic and bio-mass as their main ingredient. The rest of the ingredients works as thermos chemical decomposition. This process involves a simultaneous change in the physical and chemical composition.

This process is often known as replication of the conditions under which fossil fuels were created.

b. Gasification

This process converts carbonaceous substance into carbon dioxide, carbon monoxide and some amount of hydrogen. This process also employs high temperature. However in this process combustion does not take place. Steam and/or oxygen is used as a fuel.

A gas is produced in this process which is known as Synthesis Gas or Syngas and is a good source of alternate energy.

c. Pyrolysis

It is like Hydrous Pyrolysis but without the use of oxygen. This process involves the use of agricultural waste or organics waste from industries.

d. Plasma Arc gasification

This process involves the use of plasma torch to ionize the gas and obtain Syngas. The process generates electricity while compressing the waste.

The following table, Table 2 shows the thermal efficiency of each thermal process technology was determined by URS Corporation U.S, which reported the net energy production of electricity to the Grid per ton of MSW (see Table 2), Siani et al [1]

Type of Thermal Process Technology	Net Energy Production to Grid	Net Energy Capacity to Grid (calculated)
Mass burn (Incineration)	544 kWh/ton MSW	2.267 MW/100 ton MSW
Pyrolysis	571 kWh/ton MSW	2.379 MW/100 ton MSW
Conventional Gasification	685 kWh/ton MSW	2.854 MW/100 ton MSW
Plasma Arc Gasification	816 kWh/ton MSW	3.40 MW/100 ton MSW

Table 2: Thermal Process Technology and Net Energy to Grid

B. Non thermal technologies.

a. Anaerobic digestion

It involves fermentation. It is slow process. This process uses micro organism to destroy the biodegradable content. There is no presence of oxygen in this process. It is used both in domestic and commercial level to tap the release of energy. This process helps to reduce the greenhouse gases from the atmosphere. This process is commercially known as Bio Gas.

V. COMPARISON OF WTE TECHNOLOGIES IN INDIA

The following table, table 3 shows the comparison of the infrastructure requirement for various WTE technologies predominant in India (Lal & Reddy 2009; *MSW Manual 2000; **Matt Crowe *et al* 2002)

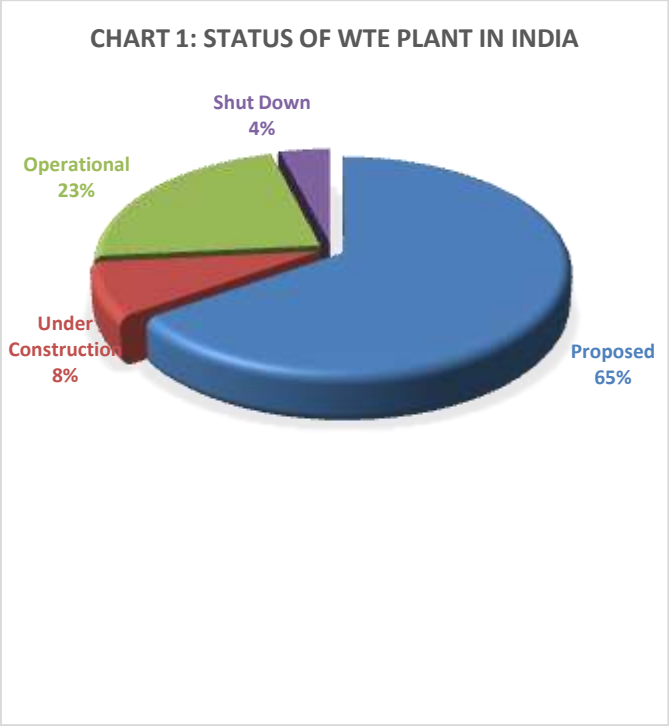
Description	Plasma Gas Vitrification	Biomethanation	Mass Incineration	Gasification / Pyrolysis
MSW Treatment Capacity (TPD)	500	300	500	500
Quantity of Final MSW treated (TPD)	165	300	160	500
Land Requirement (acres)	24.71 for 22.7 MW	-	9-10 / MW	10 / MW
Level of Automation	High	Moderate	Moderate	Moderate
Power Generation Capacity	22.7MW (4.5)	5.6MW (1.9)	6MW (1.2)	11MW (2)

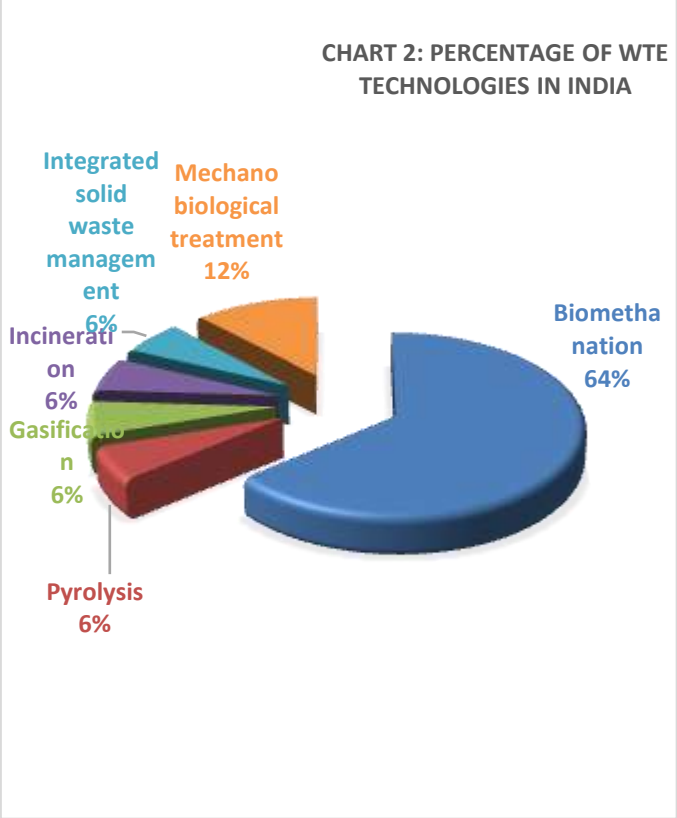
(MW/100TPD)				
PLF %	90%	-	70%	90%
Capital Cost in crores (million Rs/MW)	187 (82.3)	76 (135.71)	25 (41.6)	11 (10)
Cost of Power Generation (Rs/kWh)	4.11	-	2.6 – 2.8	-
Land Required for 300TPD plant*	2 hectares	0.8 hectares	0.8 hectares	0.8 hectares
Waste Acceptance**	All waste is acceptable	Source separated waste only	All Waste since air cleaning technology is good	Source separated dry waste only unless combined with better cleaning technology
Water Requirement**	High	High	Medium-High	Medium-High

Table 3: Comparison of the infrastructure requirement for various WTE technologies predominant in India

VI. WASTE TO ENERGY IN INDIA

As per the study made by Jain et al [2] there are a total of 48 WTE plants including 32 proposed, 4 under construction and 11 are operational. Chart 1 shows the status of WTE plants in India and Chart 2 shows the type of WTE technologies used in India.





There is a predominance of the Biomethanation technology in India as it was advertised and supported by government in rural India as Bio Gas. This however is a slow process and not suitable for large scale energy production.

The plant being built in Delhi is using an incineration based technology wherein the MSW is converted to Refuse – derived fuel (RDF) which is then burnt to produce power. The advantage of this is that it is cleaner to the environment.

VII. CONCLUSION

The capital expenditure for plant using RDF is however quite high as a separate unit has to be set up for conversion of MSW to RDF and could be more suitable for plants handling large amount of MSW volume per day.

It is proven that incineration is the best option for WTE production in a large scale. This however has an adverse effect as burning of MSW produces harmful gases to the environment. This however can be very well treated using flue gas treatments which reduces the harmful gas effluent to almost 0%.

Hence to conclude, the best suited WTE technology for the state of Sikkim is Incineration with Flue Gas treatment producing around 409 KW energy per day.

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