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FEASIBILITY STUDY OF POWER GENERATION FROM MUNICIPAL SOLID WASTE OF HARIDWAR CITY

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ABSTRACT

Energy plays significant role in the development of a nation. The conventional sources, though exhausting and not environment friendly are being increasingly used. Looking at limited supplies and various environment problems associated with its uses, renewable energy sources are getting attention. Municipal solid waste (MSW) is getting importance in recent years. Having fewer disposal problems, it is being considered as valuable bio-energy resources. The MSW management involves collection, transportation, handling and conversion to energy by biological and thermal routes.

The present paper reports the results of physical, proximate and TGA/DTA analysis, used to select the most appropriate method of energy conversion. Based on the energy potential available, the feasibility of energy conversion through biogas production using available waste has been carried out. The CDM benefits have also been considered. The cost of generation with and without CDM benefits is Rs. 2.72/- and Rs. 2.81/- per KWH of energy, when biogas in IC engine in dual mode and Rs. 1.41/- and Rs. 1.36/- per KWH of energy, when using biogas in IC engine in pure mode against the energy from grid.

Key words : Municipal solid waste (MSW), Power generation.

INTRODUCTION

Municipal solid waste management (MSWM) in one of the major environment problems of mega cities. Various studies reveal that about 90% of MSW is disposed off unscientifically in open dumps and landfills, creating problems to public health and the environment[1]. Rapid industrialization and population explosion in India has led to the migration of people from villages to cities, generating thousands of tons of MSW per day which is expected to increase significantly in the near future, as the country is striving to attain a status of industrialized nation by the year 2020[2-5]. Poor collection and inadequate transportation are responsible for the accumulation of MSW. Its management is passing

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through a critical phase, due to the unavailability of suitable facilities to treat and dispose off wastes in metropolitan cities, Unscientific disposal causes an adverse impact on all components of the environment and human health[6-12]. There are various categories of MSW such as food waste, rubbish, commercial waste, institutional waste, street sweeping waste, industrial waste, construction and demolition waste, sanitation waste, etc. MSW contains recyclables (paper, plastic, glass, metals etc.), toxic substances (paints, pesticides, used batteries, medicines), compostable organic matter (fruit and vegetable peels, food waste) and other soiled waste (blood stained cotton, sanitary napkins, disposals syringes)[13-16]. The composition and the quantity of MSW generated is the basis on which the management system is to be planned, designed and operated. In India, MSW differs greatly with regards to the composition and hazardous nature, when compared to MSW in the western countries[10, 17, 18].

With changing life styles, Indian cities now generate eight times more MSW than they did in 1947.Presently, about 90 MT of solid waste are generated annually as byproducts of industries, mining, municipal, agricultural and other process. The amount of MSW generated per capita is estimated to increase at a rate of 1-1.33% annually[4,19, 20]. A host of researches[3-5, 8, 21-27] have reported that the MSW generation rates in small towns are lower than those of metrocities and the per capita generation rate of MSW in India ranges from 0.2 to 0.5 kg/day. It is also estimated that the total MSW generated by 217 million people living in urban areas was 23.86 MT/yr in 1991 and 39 MT in 2001.

The two leading innovative mechanisms of waste disposal being adopted in India are – composting (aerobic composting and vermin-composting) and waste-to-energy (WTE) (incineration, pelletisation, biomethanation). WTE projects for disposals of MSW are a relatively new concept in India and these have been tried in developed countries with positive results. These are yet to get off the ground in India largely because of the fact that financial viability and sustainability is still being verified[28]. MSW generated in Indian cities is usually disposed in unmanaged solid waste disposal sites which leads to uncontrolled methane emission from the anaerobic decomposition of organic matter in MSW[29].

The present paper deals with the collection and characterization of MSW samples from Haridwar city of Uttarkhand. The paper discusses the physical and chemical characteristics, TGA/DTA analysis, assessment/selection of suitable disposal method based on the result of the study, computation of energy, selection of technology, power availability and techno economic analysis of WTE project. The benefits under CDM scheme and its impact on the cost of energy generation is also reported in this paper.

EXPERIMENTAL

About MSW of Haridwar city

It has been that Haridwar city generates about 190 Tonnes of MSW per day. The main sources of MSW are domestic, shops and commercial establishments, hotels, restaurants, dharamshalas and fruit and vegetable markets. Number of registered hotels, restaurants and dharamashalas in the city are 270, 250 and 280, respectively apart from 3 fruit and vegetable markets. Quantities of waste generated form various sources are given in Table 1, as per Haridwar Nagar Palika Parishad (HNPP) source.

Table 1.Solid waste generated from different sources (Ton/day) (HNPP)

Source	Generation (Tonnes / day)
Domestic	155
Fruit and vegetable markets	5
Shop and commercial establishments	12
Hotel, restaurants and dharamshalas	4
Construction / demolition activities	2
Other	12
Total	**190**

The major contribution to Haridwar city MSW is from domestic sector. At present HNPP dumps the city waste to the site located at the national highway-74 at a distance of about 8 km from the city. HNPP owns about 14.50 hectare of land at Sarai village located at a distance of about 12 km from the city for collection of solid waste in future (HNPP).

Characterization of MSW

The MSW samples were analysed for its constitutents manually by sorting/segregation before and after drying in shadow. Samples are collected from various location of dumping site. The physical and chemical analysis was conducted as per standard methods. The TGA/DTA was conducted using TGA instruments. The results indicates that biodegradable constituents consists of considerable energy as compared to whole MSW and specify the need of segregation for the separation of biodegradable from non-biodegradable. The former can be subjected to suitable energy conversion method.

Table 2. Composition of MSW and % (w/w) of each component on as received and dry basis

S. No.	Composition		Biodegradable				Non-biodegradable					Total (%)	Moisture content (%)
	Sample		YW	VEG	PW	CL	GL	PL	TH	SL	CL		
1	A	**AR**	25.2	28.5	9.2	1.15	1.6	6.5	0.6	26.0	1.2	100.0	
		DB	21.5	23.6	8.0	1.0	1.6	6.5	0.4	20.0	1.0	83.6	16.4
2	B	**AR**	30.2	12.6	14.5	-	2.6	4.8	1.8	33.5	-	100.0	
		DB	27.5	9.2	13.2		2.6	4.8	1.5	28.0	-	86.8	13.2
3	C	**AR**	28.6	29.5	10.2	1.7	0.2	7.8	-	22.0	-	100.0	
		DB	25.2	24.8	8.7	0.15	0.2	7.8	-	17.5	-	85.7	14.3
4	D	**AR**	21.5	28.2	8.5	0.6	0.5	5.8	-	34.0	0.9	100.0	
		DB	18.6	26.2	6.8	0.5	0.5	5.8	-	29.5	0.8	88.7	11.3
5	E	**AR**	30.4	24.2	7.8	1.1	-	1.1	-	35.4	-	100.0	
		DB	28.0	22.8	5.9	0.9	-	1.1	-	30.5	-	89.2	10.8
6	F	**AR**	31.5	12.8	9.2	-	0.8	2.8	-	42.9	-	100.0	
		DB	29.2	10.2	6.3	-	0.8	2.8	-	38.0	-	87.3	12.7
7	G	**AR**	17.5	28.6	9.8	1.8	-		0.8	41.1	0.4	100.0	
		DB	15.8	25.5	6.7	1.6	-		0.6	37.2	0.3	87.8	12.2
8	H	**AR**	24.5	30.2	4.8	0.7	-	4.0	-	35.0	0.8	100.0	
		DB	20.4	17.8	2.9	0.6	-	4.0	-	30.2	0.6	76.5	23.5
9	I	**AR**	20.5	17.8	4.2	-	2.7	1.7	-	53.1	-	100.0	
		DB	18.5	15.2	3.1	-	2.7	1.7	-	47.2	-	88.4	11.6
10	J	**AR**	31.7	14.8	4.7	-	0.2		1.4	47.2	-	100.0	
		DB	19.2	12.3	3.8	-	0.2		1.1	40.8	-	77.4	22.6
11	K	**AR**	31.8	12.5	8.2	1.1	-	1.0	-	42.4	3.0	100.0	
		DB	30.2	9.8	6.9	0.95	-	1.0	-	37.5	2.55	88.9	11.1
12	L	**AR**	34.5	21.5	9.7	1.0	0.9	4.8	-	27.6	-	100.0	
		DB	32.4	18.3	7.4	0.8	0.9	4.8	-	24.0	-	88.6	11.4

Where, YW : Yard waste ; GL : Glass ; VEG : Vegetable waste; PL : Plastic; PW : Paper waste; TH : Thermacol; CL : Clothes; SL : Silt/boulders/clay; AR : As received basis; DB : Dry basis.

Table 3.shows that the average energy contents of biodegradable is about 16048 KJ/kg and of MSW (as received basis) is about 8217 KJ/kg, i. e., half of the biodegradables. The results are indicated in Table 3.

Table 3.Energy contents of biodegradable portion and whole MSW (KJ/kg)

S. No.	Sample	CV of biodegradable only (KJ/kg)	CV of whole MSW (KJ/kg)
1	A	17770	10726
2	B	17130	7524
3	C	13928	6403
4	D	14888	8805
5	E	17290	8805
6	F	14568	8645
7	G	17130	8645
8	H	13447	8164
9	I	16169	8965
10	J	16809	8004
11	K	16809	7204
12	L	16649	6723
	Average	16049	8217

Proximate analysis

The volatile matter (VM), fixed carbon (FC), moisture content (MC) and ash contents were determined as per ASTM standards and the results are reported in Table 4.

The results further show that fixed carbon and volatile matter is 17% and 21%, respectively with 20.5% moisture contents and 41% ash contents. Looking at 21% moisture contents, the resource appear to be suitable for biological process where moisture removal is not required.

Table 4.Proximate analysis of MSW samples (as received basis)

S. No.	Sample	Moisture (%)	VM (%)	Ash (%)	FC (%)
1	A	19.4	17.1	39.5	24
2	B	18.2	15.9	45.9	20
3	C	22.3	31.2	28.5	18
4	D	18.3	26.1	38.6	17
5	E	14.8	24.6	37.6	23
6	F	21.7	20.5	42.8	15
7	G	16.2	15.7	48.1	20
8	H	32.5	16.7	36.8	14
9	I	18.6	18.5	50.9	12
10	J	28.6	7.5	48.9	15
11	K	18.1	18.9	46	17
12	L	18.4	36.8	31.8	13
Average		20.5	21	41.2	17.3

TGA/DTA Analysis

The technique involves the measurement of physical property of a substance as a function of temperature when the substance is subjected to controlled temperature conditions. The TGA/DTA analysis was done using TGA/DTA analyzer available at Institute Instrumentation Center under the following conditions : Max temperature 1200^0C; rate of heating 100^0C/min and air is the medium of test. The results are reported in Table 5.

From the table, it is clear that the average weight loss of 24.6% occurred between 100-300^0C, 43.84% between 300-500^0C, 15.9% between 500-800^0C and 1.65% between 800-1200^0C. The major loss occurred between 300-500^0C; this indicates that the MSW of Haridwar city is not suitable for incineration at high temperature (1200^0C). The major loss of 44% occurred between 300^0C-500^0C. between 100^0C-500^0C, it comes out as 48.4%. This behavior conclude that material has high volatile matter, which can be converted into biogas by suitable technology without the need of drying the material. It means Haridwar city waste can be best managed using biomathenation after segregation with no need of moistrure removal and therefore, Haridwar city waste is best suited for biomethanation.

Table 5. TGA/DTA analysis (% weight loss vs temperature range)

Sample	% Weight loss with temperature range			
	100^0C-300^0C	300^0C-500^0C	500^0C-800^0C	800^0C-1200^0C
A	18.00	30.20	13.90	0.60
B	25.60	34.00	13.90	1.00
C	32.90	40.90	16.30	2.64
D	27.00	47.00	12.40	2.30
E	36.50	38.80	18.10	2.32
F	18.90	56.40	9.90	2.04
G	19.60	48.60	16.20	1.66
H	28.60	49.50	10.15	1.65
I	24.21	46.55	18.84	2.24
J	27.96	40.87	16.21	0.72
K	18.18	46.24	19.48	1.31
L	18.00	47.00	25.40	1.40
Average	24.60	43.84	15.90	1.65

The suitability of this waste for biomethanation can be further authenticated by the fact that at high temperature of thermal incineration at 1200-1400^0C, weight loss is only of the order of 17%[30, 31]. On the basis of thermogram, it may be concluded that extraction of energy would not be feasible for power generation.

Fig. 1 gives the energy triangle which is a three component diagram showing the suitability of Indian MSW for biomethanation process.

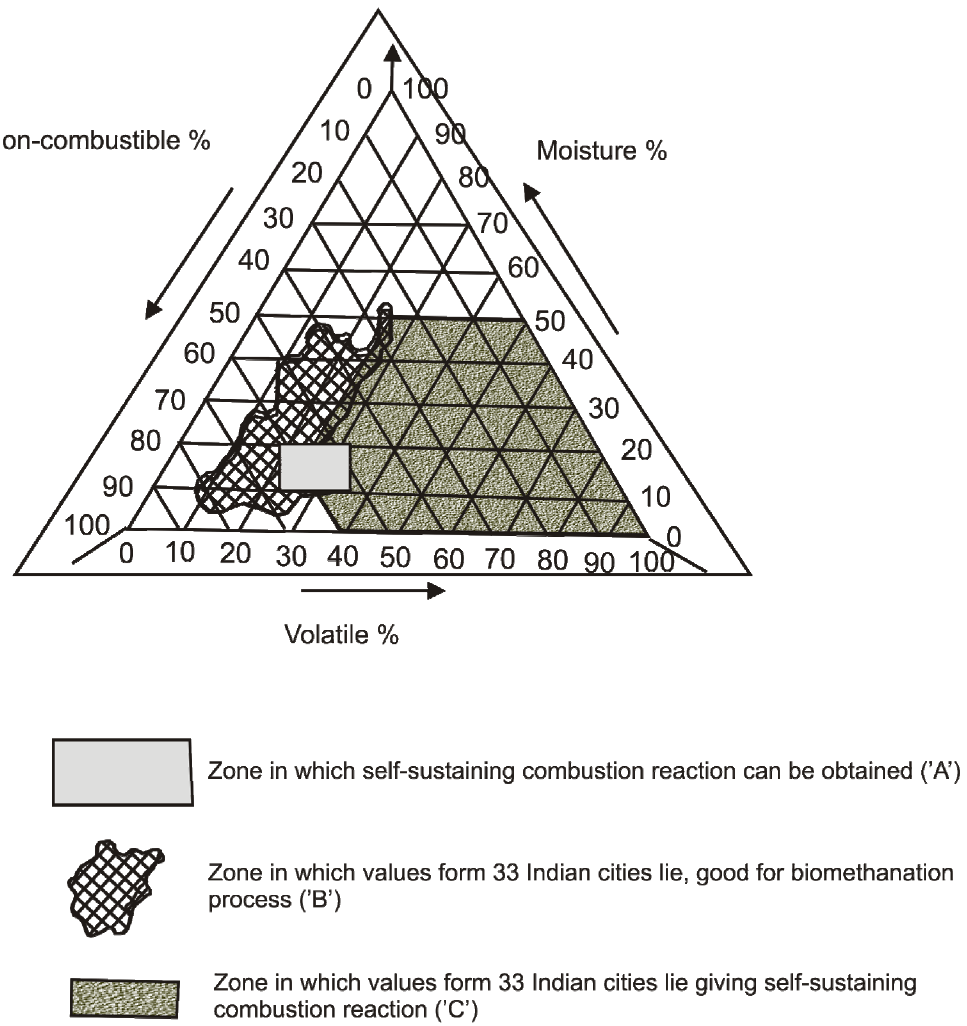

Fig. 1: Energy triangle or three component diagram illustrating suitability of Indian MSW for biomethanation process[32]

Zone 'A', 'B' and 'C' as shown with in the diagram gives an idea about the suitability of conversion technologies on the basis of VM, non-combustible and moisture contents. If the MSW qualifies for 'A' zone, self sustained combustion becomes suitable for energy conversion. Zone 'C' is suitable for self sustained combustion. Zone 'B' indicates its suitability for 33 indian cities, where waste is suitable for biomethanation process[32]. The suitability of Haridwar city MSW is indicated by square marked as 'X' for biomethanation process.

All the above analysis indicate that the waste is very well suitable for biomethanation. The result of % FC and VM, when applied to energy triangle, it was found that the given MSW falls in the zone of 33 Indian cities and that is suitable for biomethanation process as evidenced by the maximum heat loss of 44% between 300^0C-500^0C indicating that almost all VM are eliminated between this temperature range. These high VM material is suitable for biomethanation process for producing biogas as the main product.

Energy potential of the resource

As per data provided by M/S SKG Sanga, a consultancy group in field of biogas, (Table 6), the assumption for computing the energy potential has been used to calculate the potential.

Table 6. Biogas generation parameter

Parameters	Observations
Biogas production per ton of MSW	140 m^3
Calorific value	20 MJ/m^3
Total biogas generated per day	26.60 x 10^3 m^3
Energy in the biogas	53.20 x 10^4 MJ/day

The firm supplies biogas plants 25-20, 000 m^3 / day of biogas with HRT of 10-15 days. Digested material obtained may be used as manure after dewatering. The biogas can be used for power generation or for thermal application.

Biogas can be used to generate motive power for various agro-industrial and other applications like water pumping, chaff cutting, threshing, washing, small scale electricity generation, in flour mills, milk chilling units, etc. The biogas can be used in IC engine. Use of biogas in engines necessitates minor to major engine modifications. Today, the technologies are available in which it is possible to use biogas in IC engine purely[33].

Dual fuel mode requires a minimum of 10-15% of diesel oil injected in the conventional manner for initiation and completion of combustion of biogas air mixture inducted during the suction stroke. The performance characteristics of the engine having dual fuel operation with biogas as the principal fuel (85-90% biogas) and diesel introduced as the secondary fuel are around to be similar to that obtained, when the engine was operated with only diesel as the fuel. There is a reduction in the smoke number and nitric oxide for a higher percentage of biogas substitution; where as the exhaust gas temperature and unburnt hydrocarbon content increases with the increase in biogas substitution. Heating of intake air could increase the rate of combustion, which might improve the combustion process, thereby increasing the thermal efficiency of the engine. Similarly, biogas gives a better performance, if the engine compression ratio is increased. This, however, involves major engine modification[33].

Today, purely biogas engines are available, which make use of 100% biogas as fuel for generating power (M/s NATH MOTORS Pvt. Ltd.) Gas need to be free from moisture and other impurities.

Cost analysis of the biogas plant

Looking at the resource potential, it is proposed to install there 100 biogas digesters of 250m^3 capacity each. As per data supplied by the supplier M/s SKG Sangha, the cost of one plant is Rs. 2.5 lacs. Total cost of all the digesters comes out as Rs. 2.5 crores @ Rs. 2.5 lacs/plant.

When biogas is used in IC engine in dual mode with diesel

Assuming 0.6 m^3 of biogas is used per kWH of electricity production using IC engine operated in dual fuel mode. A potential of about 44333 KWH/day of energy is available. The 15% diesel requirement as pilot fuel is about 664995 liter per day assuming 300 days in a year, annual energy generation potential is about 1.8 MW and therefore, a DG set of 1800KVA rating with maximum rating of 2000KVA shell be required. Price of diesel is taken Rs. 33 per liter. Interest during construction is 12%, depreciation on biogas plant and DG set is assumed 10% for the calculation of annual working expances. Table 7 gives the details of cost of energy generation in case of plant is running in dual mode.

It is clear from Table 7 that cost of energy from biogas operated in dual mode with diesel in DG set with and without carbon credit at 80% load factor is Rs. 2.72/- and Rs. 2.81/- , respectively.

Table 7. Cost of energy generation in case of plant is running in dual mode

S. No.	Item				Amount
1	Total project cost including cost of biogas digester, DG set, land cost, etc. (lacs Rs.)				754.30
2	Annual working expenses (lacs Rs.)	Without subsidy	With carbon credits		377.10
			Without carbon credits		387.60
		With subsidy	With carbon credits		344.30
			Without carbon credits		354.80
3	Return on carbon credits (lacs Rs.)				10.50
	Capital subsidy as per MNRE (lacs Rs.)				360.00
4	Annual energy generation (lacs)	At 80% load factor			126.10
		At 60% load factor			94.60
5	Cost of generation per kWH (Rs.)	Without subsidy	With carbon credits	At 80% load factor	2.99
				At 60% load factor	3.97
			Without carbon credits	At 80% load factor	3.07
				At 60% load factor	4.10
		With subsidy	With carbon credits	At 80% load factor	2.81
				At 60% load factor	3.75
			Without carbon credits	At 80% load factor	2.72
				At 60% load factor	3.64

CDM Benefits in case, when biogas is used in dual mode with diesel

GHG emission reduction by the project, leakage[34].

1.Emission reduction by the project

Reduction are calculated by using the following formula

Emission reduction by the project = Base line emission (A) – Project emission (B).

(A) Baseline emission

Base line emission = Base line emission from avoided MSW disposal (a) + Base line emission from grid connected power plants (b)

(a.) Baseline emission from avoided MSW disposal

$$a = x.\ y.\ i.\ j.\ k.\ (16/12).\ L.\ e.^{-k(y-t)}.\ (1\text{-}0).\ G$$

Base line emission from avoided MSW disposal in first year

$= 0.05 \times 0.18 \times 0.88 \times 0.4 \times 0.5 \times (16/12) \times 190\ (1 - 0.1426) \times 365 \times e^0\ (1 - 0) \times 21$

= 2783.71 tonnes of CO_2

Where,

Sign	Measure	Value used
x	Methane generation rate	0.05 (IPCC default value)
y	Degradable carbon fraction in the MSW (%)	0.18 (for India)
i	Fraction of DOC that actually degrades (%)	0.88
j	Methane correction factor for land fill	0.4
k	Fraction of methane in the project landfill gas	0.5(IPCC default value)
L	MSW generated per day in tones	190*(1-0.1426)*365
O	Oxidization factor	0
G	Global warming potential of CH_4	21
t	Year during the crediting period	-
y	Year for which methane emissions are calculated	-

(b) Baseline emission from grid-connected power plants of similar capacity

It can be calculated by calculating base line emission grid electricity, which can be measured using the total electricity supplied to the grid multiplied by OM (emission factor for conventional sources for northen region, i. e., 0.71 per MWH)

Base line emission of grid electricity = Electricity supplied to the grid * OM

Where,

OM = Emission factor for conventional sources for the northen region

= 0.71per MWH

Annual generation = 1.8 x 300 x 24 MWh

= 12960MWH

Base line emission of grid electricity = 12960 x 0.71

= 9201.6 tones

Base line emission (A) = (a) + (b)

= 2783.71 + 9201.6

= 11985.31 tones of CO_2

(B) Emission from the project

Project emission = Project emission from burning of biogas in the project plant (c) + Project emission from fossil fuel consumption for the project (d)

Emission from the burning of biogas for power generation

Combustion equation of biogas or land filling gas is –

$$CH_4 + 2\,O_2 \longrightarrow CO_2 + 2\,H_2O$$

Considering biogas composition of CO_2 (44.5%) and CH_4 (55.5% v/v) and density of CO_2 and CH_4 is 1.96 kg/m^3 and 0.714 kg/m^3 respectively. 1 m^3 of biogas contains 0.396 kg of CH_4 and 0.87 kg of CO_2 0.396 kg of CH_4 generates 1.08 kg CO_2. Therefore, total amount of CO_2 generated by burning of 1 m^3 of biogas is 1.08 kg. Taking biogas generation of 7.98 x 10^6 m^3/year, the total emission from the burning of biogas for power generation will be about 8618 tonnes of CO_2 per year.

Emission for fossil fuel consumption for the project

Amount of diesel used per year is 664995 liter.

Per MWH CO_2 emission has been assumed as 0.0024 (AS per CEA, 0.0024 kg CO_2 is emitted per MWH of power production resulting in the CO_2 emission of 31 tonnes / year.

Total project emission, thus, comes out as –

= 8618 + 31

= 8649 tones per year

Emission reduction by the project = Base line emission (A) – Project emission (B)

= 11985 - 8649

= 3336 tonnes per year

As according to IPCC norms, 1 ton of CO_2 is equivalent to 7.5 USD.

(1USD = 42 INR) The total benefits in terms of money is about Rs. 10.5 Laces per year.

This shows the effect of CDM on the cost of generation.

When biogas is used in pure mode in biogas engine

Let us consider the case of using biogas 100%. Assuming that 0.72 m^3 biogas is used per KWH of electricity production using pure biogas engine. A potential of 36944 KWH/day of energy is available. Accordingly, annual energy generation potential of about 1.5MW power is available from waste of Haridwar city. Accordingly 7 DG set of 200KVA and 1 DG set of 100KVA will be required. Diesel price is same as in previous case. In this case cost of processing MSW before use is higher than the previous case and therefore, salary of staff is assumed to be 50000/person/year. OandM cost, interest, depreciation on biogas plant and DG set is taken as 2%, 12% and 10%, respectively.

Company name – NATH MOTORS,

Table 8 gives the details of cost of energy generation in case of plant is running in pure mode with biogas.

Table 8. Cost of energy generation in case, plant is running in pure biogas mode

S. No.	Item				Amount
1	Total project cost including cost of biogas digester, DG set, land cost, etc. (lacs Rs.)				688.00
2	Annual working expenses (lacs Rs.)	Without subsidy	With carbon credits		175.70
			Without carbon credits		181.40
		With subsidy	With carbon credits		148.00
			Without carbon credits		142.80
3	Return on carbon credits (lacs Rs.)				5.70
4	Capital subsidy as per MNRE (lacs Rs.)				300.00
5	Annual energy generation (lacs)		At 80% load factor		105.00
			At 60% load factor		78.00
6	Cost of generation per kWH (Rs.)	Without subsidy	With carbon credits	At 80% load factor	1.39
				At 60% load factor	1.86
			Without carbon credits	At 80% load factor	1.44
				At 60% load factor	1.92
		With subsidy	With carbon credits	At 80% load factor	1.41
				At 60% load factor	1.88
			Without carbon credits	At 80% load factor	1.36
				At 60% load factor	1.81

As it is clear from Table 9, in case of using biogas in gas engine in pure mode (100%), the cost of unit generation with and without carbon credit 80% load factor is Rs. 1.36/- and Rs. 1.41/-, respectively.

Table 9. Comparison of different technologies

S. No.	Comparison parameter	Different modes of running			
		Dual fuel mode		100% Biogas in gas engine	
		Without CDM	With CDM	Without CDM	With CDM
1	Total project cost (lacs Rs.)	753.4	753.4	688	688
2	Annual working expanses with subsidy (lacs Rs.)	354.8	344.3	14.8	142.8
3	Carbon credit achieved (tonnes)	0	3336	0	1819.71
4	CDM benefits in terms of money (lacs Rs.)	0	10.5	0	5.7
5	Cost of unit generation with subsidy at 80% part load factor (Rs.)	2.81	2.72	1.41	1.36
6	Cost of unit generation with subsidy at 60% part load factor (Rs.)	3.75	3.64	1.88	1.81

CDM Benefits in case, when biogas is used in dual mode with diesel

GHG emission reduction by the project, leakage[34].

1. Emission reduction by the project

Reduction are calculated by using the following formula –

Emission reduction by the project = Base line emission (A) – Project emission (B)

(A) Base line emission

Base line emission = Base line emission from avoided MSW disposal (a) + Base line emission from grid-connected power plants (b)

(a) Base line emission from avoided MSW disposal

$$A = x.\ y.\ i.\ j.\ k.\ (16/12).\ L.\ e.^{-k\,(y-t)}.\ (1-O).\ G$$

Where,

Sign	Measure	Value used
x	Methane generation rate	0.05 (IPCC default value)
y	Degradable carbon fraction in the MSW (%)	0.18 (for India)
i	Fraction of DOC that actually degrades (%)	0.88
j	Methane correction factor for land fill	0.4
k	Fraction of methane in the project landfill gas	0.5(IPCC default value)
L	MSW generated per day in tones	190x(1-0.1426)x365
O	Oxidization factor	0
G	Global warming potential of CH_4	21
t	Year during the crediting period	-
y	Year for which methane emissions are calculated	-

Base line emission from avoided MSW disposal in first year

$= 0.05*0.18*0.88*0.4*0.5*(16/12)*\ 190(1-0.1426)*365*e^{0}*(1-0)*\ 21$

= 2783.71 tonnes of CO_2

Baseline emission from grid-connected power plants of similar capacity

It can be calculated by calculating base line emission of grid electricity which can be measured using the total electricity supplied to the grid multiplied by OM (emission factor for conventional sources for northern region, i. e., 0.71 per MWH)

Base line emission of grid electricity = Electricity supplied to the grid * OM

Where,
OM = Emission factor for conventional sources for the northern region

= 0.71per MWH

Annual generation = 1.5x 300x 24 MWH = 10800 MWH

Base line emission of grid electricity = 10800 x 0.71 = 7668 tones

Base line emission (A) = (a) + (b)

= 2783.71 + 7668 = 10451.71 tones of CO_2

Emission from the project

Project emission = Project emission from burning of biogas in the project plant (c) + Project emission from fossil fuel consumption for the project (d).

Emission from the burning project of biogas for power generation

Combustion equation of biogas or land filling gas is –

$$CH_4 + 2\,O_2 \longrightarrow CO_2 + 2\,H_2O$$

Considering biogas composition of CO_2 (44.5%) and CH_4 (55.5% v/v) and density of CO_2 and CH_4 is 1.96 kg/m^3 and 0.714kg/m^3, respectively. 1 m^3 of biogas contains 0.396 kg of CH_4 and 0.87 kg of CO_2. 0.396 kg of CH_4 generates 1.08 kg CO_2. Therefore, total amount of CO_2 generated by burning of 1m^3 of biogas is 1.08 kg. Taking biogas generation of 7.98 x 10^6 m^3/year, the total emission from the burning of biogas for power generation will be about 8618 tonnes of CO_2 per year.

Emission for fossil fuel consumption for the project

Amount of diesel used per year is 6000 liter

Per MWH CO_2 emission has been assumed as 0.0024 (As per CEA, 0.0024 kg CO_2

is emitted per MWH of power production resulting in the CO_2 emission of 14 tonnes / year.

Total project emission thus comes out as –

= 8618 + 14 = 8632 tones per year

Emission reduction by the project = Base line emission (A) – Project emission (B)

= 10451.71 – 8632 = 1819.71 tones per year

As according to IPCC norms, 1 ton of CO_2 is equivalent to 7.5 USD.

(1 USD = 42 INR) The total benefits in terms of money is about Rs. 5.73 lacs per year.

This shows the effect of CDM on the cost of generation.

RESULTS AND DISCUSSION

The MSW of Haridwar city is chemically analyzed in institute's laboratory. Various analysis such as proximate analysis and TGA/DTA analysis has been done to check the chemical properties of MSW and it is suggested that the biomethanation is the best technology for energy conversion. A detailed analysis has been done to check the economic viability of each technology and suggested that using biogas in biogas engine with a 1.5MW capacity of plant is the best option with cost of generation with and without CDM benefits is Rs. 1.36/- and Rs. 1.41/- per KWH of energy against the energy from grid (Rs. 3.50/- per KWH). Further it is suggested that use of biogas in IC engine is the second best option with a capacity of 1.8 MW with cost of generation with and without CDM benefits is Rs. 2.72/- and Rs. 2.81/- per KWH of energy against the energy from grid. CDM analysis is also carried out for different technologies and it is found that carbon credits achieved in case of using biogas in biogas engine in pure mode is 1820 tones of CO_2. Therefore, power generation from MSW of Haridwar city using biomethanation technology is feasible.

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