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APPLICATION OF BIOGAS PLANT TECHNOLOGY AS A SUSTAINABLE SOURCE OF ENERGY SUPPLY IN DEBRE BERHAN UNIVERSITY OF ETHIOPIA

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ABSTRACT

This paper provides a thorough research for the utilization of bio-wastes as alternate source of energy in Debre Berhan city of Ethiopia. This city is endowed with major occupation of animal husbandry like donkeys, cows, sheep, goat, hen etc. and 70 - 80% households own some kind of animal either for domestic use or commercial purpose. Since the waste composition in the city consists of animal dung waste, agriculture waste, food waste and kitchen waste with high organic content and high amount of biomass, this is the ideal composition as resource waste fuel for production of Biogas in the city. The pilot study is carried out in the Debre Berhan University to analyse the feasibility of this biogas technology. National Biogas Programme Ethiopia is working in the second phase of Biogas Installation

KEYWORDS: *Biogas technology, Acidogenesis, Methanogenesis, Biomass, Anaerobic Digestion, Sustainable energy*

1. INTRODUCTION

Ethiopia is a landlocked country lying in the north-eastern part of the Horn of Africa having a total area of 1.1 million km2 and the country shares its boundaries with Eriteria to the north, Djibouti to the east, Kenya to the south and Sudan to the west. The country has a population of 106.86 million(2017) and 34% people of this population live below the poverty line .84% of the population is rural so primarily the energy supply is based on biomass. In the Energy sector the contribution of hydropower is 1.6% while the natural gas and coal contributes 6% and the major contribution is given by biomass, nearly 92.2%**.**The country's total electricity generation in 2010 was 3,981.7GWh.87% are the domestic consumers and the average consumption per household is 50kWh/year per capita.

Since for the past few decades there is rise in demand for the consumption of energy which has led to the increase in fuel consumption causing a large number of environmental problems. This justified the energy needs to be fulfilled for the present and future generations by development of alternate sources of energy. So, there is development of renewable energy sources and technologies based on them. Biogas is considered to be one of the renewable energy sources which derive the energy from organic waste materials. The forest vegetation is almost lost and there is scarcity of wood fuel in Northern Ethiopia. In Tigre region the dung fuel accounts for about 22.8% while it is 20.4% for Amhara of the total energy consumption. Specifically, fuel-wood, dung, crop residues and charcoal account 81.4%, 8.1%,7.8% and 1.3% respectively whereas electricity and petroleum together contribute 1.4% of the total household energy consumption.

1. MATERIALS AND METHODS

1.1 Need and purpose of Study

The main objective to carry out this study is to find an alternate sustainable source of energy which can reduce the usage of fossil fuels and to reduce the ecological carbon footprint of the campus area by resorting to improved and efficient biogas plant technology

1.1.1 National Biogas Programme Ethiopia

The biogas technology in Ethiopia can be dated back to 1960s when these plants were installed in a very small number of only about 1000.But after the establishment of NBP the scenario showed transition after 2008.This programme provided a standardized domestic biogas model, subsidies, sharing cost with the beneficiaries. During the year 2008 98 domestic biogas digesters were installed for demonstration purpose in four regional states. After the completion of first installation phase the country is working for the second implementation phase.

2.1.2 Biogas composition and utility systems

Biogas is a clean fuel resulting from the anaerobic digestion of organic wastes coming from different sources like kitchen waste, animal waste, agriculture waste, sewage waste or slaughter house waste. This is a natural decomposition process of any dead animal or plant organic matter due to anaerobic bacteria decomposition which works in the absence of oxygen. This gas is composed of various gases like methane (65%), carbon dioxide, water vapour and trace gases like hydrogen sulphide and nitrogen gas. The conversion of organic wastes to methane production takes place in different phases like hydrolysis and acidogenesis and the final phase of methane production methanogenesis.

1.2 Study Area

Debre Berhan City is near to capital city Addis Ababa towards North east direction at 135 kilometres. The city is situated in Amhara National Region in the North Shoa Zone administration. The temperature variation in the city is very little throughout the year which is below 40°F or above 74°F (MERRA-2 Modern-Era Retrospective, 2016).The geographical coordinates of Debre Berhan are 9.680 degree latitude, 39.533 degree longitude, and 9,131 ft elevation.

The area within 2 miles of Debre Birhan is covered by cropland (92%), within 10 miles by cropland (86%) and shrubs (14%), and within 50 miles by cropland (64%) and shrubs (30%) (NASA's Jet Propulsion Laboratory).In the Tabase Area of the city Debre Berhan University is the Government University with an area of 102 hectors. The total university population is 13,538 in the year 2017 – 18.The study area is suitable for this study since the university rears various types of livestock including cow, sheep, goat, ox and hens for the organic biomass production of wastes. Another important activity is agricultural production and cultivation of various crops like Teff, Beans, Corn, Sesame, Endemic plants and Wheat crop carried out in the university campus area.

1.3 DATA COLLECTION AND RESEARCH DESIGN

1.3.1 Data Collection

Primary data collection was done with the use of both close ended and open ended questions in the questionnaire. This questionnaire served as a means to collect data both in local Amharic language and English language. Personal interviews were done with the interviewees rearing the livestock including supervisors, daily waste collectors and other local staff members. The conversations were recorded in local Amharic language with the help of local departmental colleagues who translated them into English.

1.3.2 Research Design

Bio-digester size and production which is the main utility systems depends on few important factors, the energy consumption per capita on daily basis, the availability of feedstock, water availability and the optimum temperature of the digester as provided in Table A.1

2. RESULTS AND DISCUSSION

2.1 Category of Waste types

2.1.1 Animal Dung Waste is one of the major feedstock for the bio-digester since it is quantified as daily basis dung load given in Annexure Table A 2.Various types of livestock, total number of livestock and total dung quantity on average daily basis is observed and evaluated from the cow shed, goat shed, sheep shed, pig farm and poultry farm for hens.

2.1.2 Food waste is generated from food lounges, dormitories food mess and cafeteria as provided in Annexure Table 3.This waste is quantified and essentially a good source of raw material for bio-digestion. This is composed of high organic food material like cooked rice, maize porridge, bread, vegetables, teff, barley which can be mixed with water and provides an excellent feedstock material

2.1.3 Agricultural waste residues are generated by the cultivation of various crops utilized either as commercial market commodity like Bean, Teff, Corn, Sesame, Endemic plants or some crops cultivated under specific departmental projects like Cabbage and Potato. This waste type is quantified since it has very high calorific value and highly suitable for bio-digestion and given in Annexure Figure A.1 and Table A.3.

2.2 Feasibility study of Debre Berhan University

Methane gas has a very high calorific value of 20MJ/m^3 and it is the cleanest fuel that can be used both for lighting and cooking purposes. The basic requirements for the biogas production and installation of bio-digester are fulfilled by the Debre Berhan University. The accesses to feedstock and water requirements are available within the university campus area. It has two very big water storage tanks nearly 5Kl each near the suitable location for the installation since the feedstock is mixed with water to form low solid slurry. The anaerobic bacterial digestion requires a suitable temperature for the digester in the range of 20°C – 37°C and Debre Berhan City has a daily temperature range between 22°C – 35°C.This daily temperature range is suitable for the bacterial digestion of the organic waste.

2.3 Selecting Bio-digester Size and Type

For the calculation of the bio-digester size two input factors are required, daily feedstock and the retention time.

$V_d = S_d\left(\frac{liter}{day}\right) * R_T(days)$, where

V_d =Volume of the digester in litre

S_d =Daily feed stock in liter/day

R_T =Retentions time in days, and also we have

$S_d = Food\ waste + Green\ waste + Poultry\ waste + Cow\ waste$

$(Total\ solid\ waste\ have\ 1{:}1\ ratio)$

$\Longrightarrow S_d = (200 + 40 + 55 + 400 + 150) * 5 = 4225/day$

For a cold region like Debre Berhan the retention time is between 50 and 70 days

$R_T = \frac{50+70}{2} = 60\ days$

$V_d = (4225/day\ )* 60\ days = 253{,}500$ Litres

The suitable size of the Digester should be 20 m^3

The size corresponding to the quantity of biomass produced in the university is 20 cubic meters and the type suitable is fixed dome digester.

2.4 Financial Costs

The construction cost for 20cubic meter of biogas plant suitable for the university campus is given in Annexure Table.4

2.5 Economic Impact of the Project

The quantity of methane produced in cubic meter per year is given in Annexure Table A.5

Energy Production per year

Energy produced = Calorific value of methane * volume of methane =9.94kWh/m^3 * 38,142,500 = 379,136,450 kWh

Energy saving per year

For 5% of energy loss by the engine

Energy saved=0.95*379,136,450 kWh =360,179,627.5kWh

Energy Supply In One Hour

Energy= Energy saved/ 365*24 =360,179,627.5kWh/365*24=41116.40 kWh

Energy Supply in One Month

Energy=41116.40 kW*24*30=29,603,805kWh

3. SUMMARY AND CONCLUSIONS

Biogas technology is a renewable source of energy. It provides major economic benefits by reducing the demand for wood and charcoal for cooking purposes. This in turn helps in the reduction of greenhouse gases. The methanization of the waste is totally pathogen free and the slurry waste left over in the plant is a high quality fertilizer. The health benefits are numerous by reduction of indoor smoke, improved sanitation and lighting or cooking facilities with lot of time saving. The electric consumption of the university on monthly basis is 19,6294kWh while the energy supply from biogas technology is 29,603,805kWh.Biogas technology can easily reduce the electricity cost. This alternate renewable source of energy can easily replace the traditional sources of energy both for lighting, heating or cooking purposes and helps to make the university campus area more eco-friendly and environmentally sound.

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ANNEXURE

Tables

Table A.1-Different Sizes of Biogas Plants

S. No	*Size of Plant*	*Daily Fresh Dung(kg)*	*Daily Water (litres)*	*No. of Cattle*
1.	*4*	*24*	*24*	*2 - 3*
2.	*6*	*36*	*36*	*3 – 4*
3.	*8*	*48*	*48*	*4 – 6*
4.	*10*	*60*	*60*	*6 – 9*
5.	*15*	*90*	*90*	*9 – 14*
6.	*20*	*120*	*120*	*14 and more*

Table A.2 Daily Basis Average Dung Load from Livestock, Debre Berhan University

Type of Livestock	*No. of Livestock*	*Daily Dung Load(kg)*
Cows	*40*	*400*
Sheep and goat	*300*	*150*
Poultry	*100*	*55*

Table A.3 Bio methane Potential values from Organic Wastes

Biomass	Methane $CH_4(M^3/t)$	Quantity (Kg/day)
Food Waste	220	200
Green Waste	110	40
Poultry waste	50	55
Cow waste	25	400
Sheep and goat waste	25	150

Table A.4 Construction Cost for 20cubic Meter of Biogas Plant

A. ITEMS	B. NO.OF UNITS	C. COST(BIRR)
D. BRICK	E. 2800	F. 3733
G. CEMENT	H. 68	I. 1519
J. GRAVEL	K. 4	L. 240
M. SAND	N. 5	O. 180
P. PAINT	Q. 4	R. 275
S. PVC PIPES10cm	T. 2	U. 15
V. IRON BARS	W. 20	X. 47
Y. BINDING WIRE	Z. 0.5	AA. 1.5
BB. OUTLET PIPE	CC. 1	DD. 18
EE. G.I.NIPPLE	FF. 6	GG. 8
HH. MAINGASVALVE	II. 1	JJ. 5.5
KK. PVC ELBOW	LL.12	MM. 12

NN. GLUE FOR PVC	OO. 1	PP. 34
QQ. WATER DRAIN	RR. 1	SS. 15
TT. PVCpipeϕ0.5	UU. 10	VV. 43.5
WW. GAShosePipeϕ0.5	XX. 2	YY. 8.5
ZZ. BIOGAS BURNER	AAA. 1	BBB. 2000
CCC. SOCKET	DDD. 6	EEE. 20
FFF. GAS TAPE	GGG. 2	HHH. 40
III. TEFLON TAPE	JJJ. 4	KKK. 6.5
LLL. TEEϕ0.5	MMM. 5	NNN. 6.5
OOO. Liquid gas rubber	PPP. 1	QQQ. 5
RRR. LAMP	SSS. 1	TTT. 1.5
UUU. HDPE	VVV. 50	WWW. 117
XXX. LABOUR	YYY. 5	ZZZ. 5000
AAAA. TOTAL COST	BBBB.	CCCC. 14,000

Table A.5 Methane Production Per year

Biomass	Methane $CH_4(m^3/ton)$	Quantity (kg/day)	Quantity (ton/year)	Methane produced $(m^3/year)$
Food waste	220	200	73, 000	16,060, 000
Green waste	110	40	14, 600	1,606, 000
Poultry waste	50	55	20, 075	1,003, 750
Cow waste	25	400	14, 600	1,606, 000
Sheep waste	25	150	54, 750	1,368, 750
TOTAL				38, 142, 500

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Figures

Fig.A.1