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Assessment Of Production Of Biogas And Electricity Generation From Kitchen Waste Utilizing Solid Oxide Fuel Cell

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Abstract: The management of municipal solid waste has always been a problem for both developed and developing countries. The proper management of waste resources can improve resource efficiency as well as develop a suitable substitute for fossil fuels. A number of management options are available, but biogas recovery using anaerobic digestion is often recommended as an attractive option. Biogas production potential varies from source to source. In our institute we have twenty eight hostels and all having their own individual mess, where daily a large amount of kitchen waste is obtained which can be utilized for biogas production. The amount of waste is being classified into organic and inorganic. The anaerobic digestion of kitchen waste produces biogas, a valuable energy resource. Anaerobic digestion is a microbial process for production of biogas which is primarily of consist methane (CH_4) & carbon dioxide (CO_2).The main objective of this study is to identify the power generation capability of the process and assessing to investigate its scope to become a competitive renewable energy source. Moreover, the biogas application toward Solid Oxide Fuel cell and its efficacy on power generation capability are investigated. Results observed to be motivates and makes it promising toward new sustainable energy future for greater energy demands.

Index Terms - biogas production, kitchen waste, fossil fuels, sustainable energy

I INTRODUCTION

Due to the gradual increase in population around the globe there might be a scarcity of the existing energy resources. Moreover the usage of fossil fuels creates environmental problems like air pollution, soil pollution, etc. Solar energy, wind energy, different thermal and hydro sources of energy, biogas are all primary renewable energy resources. But among those, Biogas is distinct from other renewable energies because of its efficient and simple characteristics of using, controlling and collecting organic wastes and at the same time producing fertilizer for use in agricultural irrigation. The process of energy production from Biogas does not have any geographical limitations also it does not require any advanced technology. Overall it is very simple to use and apply. [1]

Kitchen waste is organic material having the high calorific value and nutritive value to microbes, that's why energy generation. Specifically anaerobic digestion of kitchen waste or food waste is achievable from different wastes due to various advantages like simple production process and easy to operate.

For the efficient production of biogas from the waste, an appropriate digester must be selected. There are a total of seven biogas plants have been officially recognized by the MNES. But among them, Floating-drum plants are one of the most commonly used biogas digester in India for small scale or medium scale production of bio gas from different organic efficiency of methane production can be increased by several orders of magnitude. It means higher efficiency and size of reactor and cost of biogas production is reduced. [2] Also in most of cities and places, kitchen waste is disposed in landfill or discarded which causes the public health hazards and diseases like malaria, cholera, typhoid. It not only leads to surface pollution and groundwater through leachate and also further promotes the breeding of flies, mosquitoes, and other disease bearing factors. In addition to these, it emits unpleasant odors & methane which is a major greenhouse gas contributing to Global Warming which is now-a-days a burning problem worldwide. [3]

Anaerobic digestion is a biological degradation process which results efficient production of biogas (approx. 60% methane and 40% carbon dioxide) for composition of food waste which yields different amount of methane.[4]

For the production of electricity from biogas, there are many types of fuel cells can be used. A solid oxide fuel cell (or SOFC) is an electrochemical conversion device that produces electricity directly from oxidizing a fuel. SOFC has

got highest power generation efficiency among all types of fuel cell. [5]

II.LITERATURE REVIEW

Vinayak R. Gaikwad etl (2014),Department of Electrical Engineering, Dr Babasaheb Ambedhkar Technological University, Lonere, Maharashtra, India studied that Biogas is distinct from other renewable. The process of energy production from Biogas does not have any geographical limitations also it does not require any advanced technology. [1]

Dr. Anand Karve, 2007 (President, Appropriate Rural Technology of India ARTI) developed a compact biogas system that uses starchy or sugary feedstock material. The biogas plant is sufficiently compact to be used by both urban and rural households. His results shows that, from the point of view of conversion of feedstock into methane the system is 20 times as efficient as the conventional system and from the point of view of reaction time it is 40 times as efficient. Thus overall system is 800 times more efficient than conventional biogas plants.[6]

K Mehraj Pesha etl (2015) , Associate Professor, Department of Civil Engineering, Kuppam Engineering College studied Kitchen waste is organic material having the high calorific value and nutritive value to microbes, that's why efficiency of methane production can be increased by several orders of magnitude. It means higher efficiency and size of reactor and cost of biogas production is reduced.

Mohammad Moulod etl (2016), Department of Electrical Engineering Islamic Azad University Boukan,Iran investigated the process of generating electrical power from the total amount of obtainable methane through anaerobic digestion of MSW and then the achievable power generation capacity by using the obtained biogas are computed using the electrochemical relations inside the SOFC.[5].

Navadol Laosiripojanaa etl (2009), The Join graduate school of energy and environment , King Mongkut's University of Technology Thonburi Bangkok 10140 Thailand , Investigated on Solid Oxide Fuel Cell Technology they concluded that Solid Oxide Fuel Cell (SOFC) is a type of fuel cell that appears to be one of the most promising fuel cell systems. The min advantage of SOFC type fuel cell in comparison to other types of fuel cells is that its tolerance limit to the impurities of inlet fuel. In other words various types' fuel can be applied with SOFC. [7]

III. MOTIVATION

It starts, with the reviewing of literature and striking of the thoughts to do a project which is different than conventional electrical projects. We feel this is an area which is less explored in terms of projects. It's not only related to electrical but at the same time includes environmental concern as well as it's related to the concern of our college. It also gives us a chance to explore other disciplines. It also deals with the management of one of the most common problem of the society i.e. waste. Hence it not only solves the environmental problems but also gives us an additional advantage. So all this leads to the selection of the project for the assessment of biogas production and electricity generation.

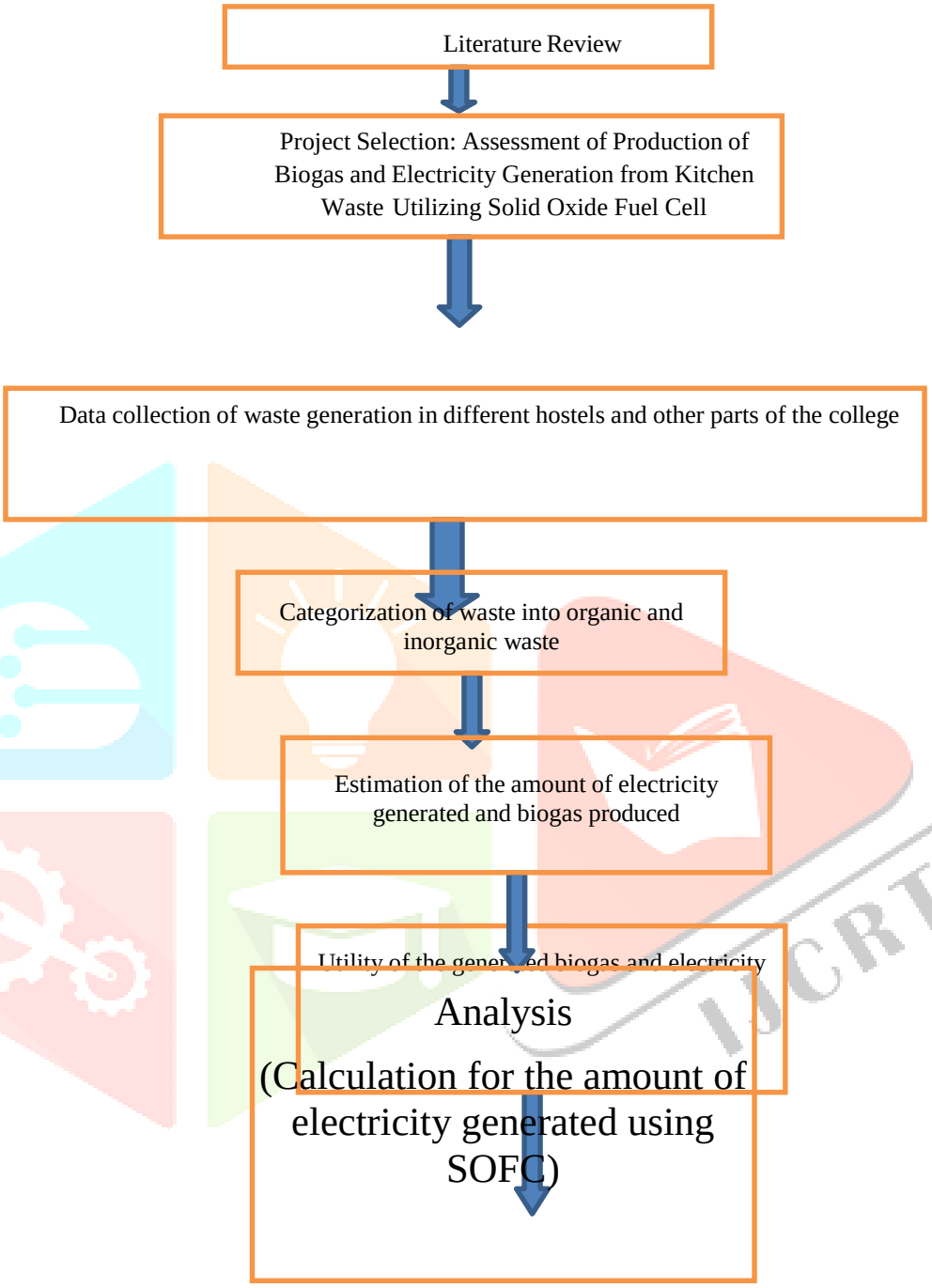
IV. OBJECTIVES

A lot of researches are being carried out in utilizing waste treatment plant for power production using SOFC. But there is no present article available using SOFC from organic fraction of food waste. So in our project work we have estimated the amount of biogas that can be produced from kitchen

waste generated and thereafter estimating the amount of electricity generated

V. METHODOLOGY

Methodology for estimating the amount of electricity generated is as follows



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VI. APPROXIMATE AMOUNT OF WASTE GENERATED FROM DIFFERENT HOSTEL

Places	**Waste amount (in kg)**	**Organic waste (in kg)**
H1	5.5	4
H2	5.5	4
H3	6	5
H4	6.5	5
H5	6.5	5.5
H6	8	7
H7	8	7
H8	8	7
H9	7	6
H10	4	4
H11	25	10
PG Hostel	8.5	7.5
GH1	6.5	4.5
GH2	6.5	4.5
GH3	6	4
GH4	8	6
Staff Quarters	6	3
BIT Canteen	6	3
Guest House	6	3
Total	**137.5**	**100**

Table No. 1

VII. CALCULATION

Biogas is produced by bacteria through the bio-degradation of organic material under anaerobic condition. Biogas is mainly composed of methane (CH_4) and carbon dioxide (CO_2). The composition is as follows:

CH_4(Methane) = 55%

CO_2(Carbon dioxide) = 24% Others are trace gases =21%
Total waste per day- 137.5kg organic waste per day-100 kg

$$M = P*T*\left(\frac{\text{Molecular Weight of the substance}}{\textit{Atomic weight of carbon}}\right) \quad [5] \qquad \text{(i)}$$

M= Mass of the substance P= percentage composition
T=total weight of organic waste

CH_4 mass = 0.55*100*(16/12) = 73.33 kg per day
CO_2 mass = 0.24*100*(44/12) = 88 kg per day mass number of CH_4 = 16
mass number of CO_2 = 44 Mass number of carbon = 12
mass ratio of methane to carbon = 16/12 = 1.33

The density of biogas at standard temperature and pressure conditions of 15 degree Celsius and 1.013 atm per day would be 1.1kg/m^3[5]

Volume of biogas produced per day

$$= \frac{(\text{mass of } CH_4/\text{day} + \text{mass of } CO_2/\text{day})}{\textit{Density of biogas at standard Temperature and Pressure}} \quad [5] \qquad \text{(ii)}$$

$$= \frac{(73.33\text{kg } CH_4/\text{day} + 88\text{kg/day})}{(1.1\text{kg/m}^3)}$$

$$= 146.66 m^3/\text{day}$$

VIII. CALCULATION OF ELECTRICITY GENERATION FROM HOSTEL WASTE USING SOFC

A Solid Oxide Fuel Cell (or SOFC) is an electrochemical conversion device that produces electricity directly from oxidizing a fuel. The efficiency during conversion from chemical to electrical energy is about 50-60%.

When CH_4 is used as the fuel for the SOFC, the following reactions happens :

$CH_4 + 4O_2 \rightarrow 2H_2O + CO_2 + 8e^-$ (Oxidation) [5] (i)

½ O_2 + $2e^-$ □O^- (Reduction) [5] (ii)

1 electron = 1.6 X 10^{-19} Coulomb

1 mole electron = 6.022 X 10^{23} X 1.6 X 10^{-19} Coulomb

= 96487 Coulomb

1 Ampere = 1 Coulomb/ 1 sec

1 mole of electron will produce (96487 C/1 sec) = 96487 A current in 1 sec

1 mole of electron will produce (96487 C/3600 sec) in 1 hour = (96487/3600) A current

Therefore we need ($\frac{3600}{96487}$) mole of electron to produce 1 A current for 1 hour

1 molecule of gives 8 electrons

1 mole of CH_4 will give 8 mole of electrons

Therefore we'll get 1 mole of electrons from (1/8) mole of CH_4

Therefore to get 1 A for 1 hour we need = (^{1}X ^{3600}) mole of CH_4

8 96847

=0.004664 g mol/(hA)

(Note: g mole and mole is same)

Amount of methane in kg required for production of 1KA for 1hr

$$= \frac{0.004664 \text{ g mol}}{\text{Ha}} * \left(\frac{16\text{g}}{1\text{g mol } CH_4} \right) * \left(\frac{1\text{kg}}{1000\text{g}} \right) * \left(\frac{1000}{1\text{KA}} \right)$$

=0.074624 kg/(hkA)

0.074624 kg methane is required to generate 1kA current flow for 1 hour. So for generating 1.0 MW dc power using a Fuel Cell stock with a cell voltage of 0.7 volt, the current will be:

Current(I) = $\frac{Power(P)}{Voltage(V)}$ (iii)

$= \frac{1\ MW\ 0.7V}{}$

= 1429kA

Thus amount of methane needed is

= (1429)*(0.074624 kg per hour per KA)

= 106.6377 CH_4 per hour

But, entire methane fed into the SOFC is not consumed during electricity production process. Thus a factor called 'utilization of fuel' (U(f)= 0.8) is defined as:

$U(f) = \frac{CH_4(consumed)}{CH_4(input)}$ (iv)

so, the fuel flow rate required to generate 1MW dc power for 1 day from biogas can be evaluated as:

CH_4 (input) = $\frac{\mathbf{CH_4\ consumed}}{(f)}$ **x** $\frac{24h}{1day}$ **[5]** (v)

= (**106**.637713 kg per hour **) x (** $\frac{24h}{1day}$) **80**%

= 3199.13 kg CH_4 per day

The amount of DC power generated per day (MW dc)

$= \frac{\text{methane available per day 3199.13 kg } CH_4 \text{ per day}}{}$

$= \frac{73.33\ kg\ CH_4}{3199.13\ CH_4\ per\ day}$

= 0.0229 MW (dc)

Assuming a typical inverter's efficiency to be 96%, the output AC power can be calculated as:

Generated capacity (MW ac) =0.0229 MW (dc) x (inverter efficiency)

=0.0229MW (dc) x 0.96

= 0.0219 MW (ac)

IX. RESULTS AND DISCUSSIONS

From the assessment, the amount of biogas generated is found to be:

- 146.66 m^3/day. This Biogas can be used for cooking purposes, Biogas lambs. It can also be compressed like a natural gas to control motor vehicles.
- The amount of electricity that can be produced from the generated waste is 0.0219 (MW ac) using Solid Oxide Fuel Cell.
- Solid Oxide Fuel Cell (SOFC) is a very highly efficient fuel cell. , the electrical efficiency of a typical SOFC is around 40%. However, with the use of a hybrid SOFC–GT system, the overall electrical efficiency is increased to over 70%. The idea of using SOFC as a CHP system and in combination with a GT could be of great advantage because of the higher electrical efficiency of the overall system. It means that not only is the electrical power capability of the system increased but the final electricity price is also considerably reduced.

X.CONCLUSION

In the present project work we have successfully done the assessment on production of biogas from the kitchen waste of different hostels shops, faculty quarters etc., we have also calculated the amount of electricity generated using SOFC. The amount of electricity produced from the waste is not sufficient to supply any considerable load, but can be used for small scale purposes. But if we include waste of larger scale the amount of generated electricity would be large enough.

XI.SCOPE FOR FUTURE WORK

Further work can be carried in the field of power generation using Solid Oxide Fuel Cell incorporation with Combined Heat and Power generation. Moreover, sensitivity analysis and economic analysis can be done

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