Investigation and Analysis of Renewable Energy from Bio and Solid Waste

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Abstract. This investigation explores the possibility of utilizing bio and solid waste to produce power as renewable energy in every residential house. Fossil fuels are depleting very fast and environmental pollution is also caused due to their combustion. An effort is taken to generate electric power by the high combustion rate methane gas released by the bio and solid wastes from the residence. Anaerobic digestion is adopted to produce methane gas from the waste dumped in any house. This methane gas is made to run a single cylinder diesel engine coupled to a single phase alternator. Power thus generated will be sufficient to any single residential house.

Keywords: Renewable Energy; Bio and Solid Waste; Anaerobic Digestion; Methane Gas; Diesel Engine; Alternator

1. Introduction

Rapid depletion of coal, natural gas and petroleum fossil fuels are taking place due to the high demand in energy faced by the world. Ozone layer depletion, greenhouse effect and acid rains are caused globally due to the combustion of fossil fuels. The pollution to the environment thus created poses great difficulty to the total life on the planet. Only if a system of cleaner energy is replacing the existing system of fossil fuels, the problems faced globally can be solved. Ozone layer depletion, greenhouse effect, acid rains and pollution will be eliminated if a clean and efficient fuel like methane is used for combustion. Energy produced from the renewable sources like solar, wind and methane results in a permanent energy system.

Non-renewable energy system of fossil fuels emits pollutants which cause greater damage than the renewable energy system of methane. Efforts on long-term research are to be taken using solar energy and water to economically produce methane. Worldwide CO\textsubscript{2} emission is to be lowered to reduce the greenhouse effect and the climate change. For lowering the emissions of CO\textsubscript{2} and reducing various environmental pollutions, use of methane is an alternative on long-term, even though it is not economically viable at present. Fossil fuel to methane conversion can solve most of the problems. Best way is to produce methane from pollution free sources.
2. MATERIALS AND METHODS

2.1. Bio Mass Gas Preparation

Bio and solid wastes generate more power and the cost is also cheaper compared to power generation from the cow dung. Anaerobic digestion and Aerobic digestion are two methods for bio gas production. In Anaerobic digestion, methane is released along with water and carbon-dioxide by the conversion of biodegradable organic matters without using oxygen. The anaerobic process reduces and inactivates pathogens.

\[
\text{Organic matter} + \text{H}_2\text{O} \rightarrow \text{CH}_4 + \text{CO}_2 + \text{H}_2\text{O}
\]

Anaerobic digestion reduces volatile solids to 60 per cent by oxidation of biodegradable and microbial cellular matter with a major mass reduction in sludge by generating and stabilizing cell mass.

The action of heterotrophic bacteria in aerobic digestion hydrolyses and converts biodegradable particulate organic matter into water, carbon dioxide and active biomass. Nitrate-N or dissolved oxygen is used for oxidation as terminal electron acceptor. Raw sludge properties control the aerobic digestion progress. Aerobic digestion process is costly and energy recovery is also nil. Because of above facts, anaerobic digestion process is preferred to the production of methane gas for power generation.

2.2. CHEMICAL PROCESS

The following chemical processes are normally adopted for converting natural gas to methane:

- MSR process (Methane steam reforming)
- POX process (Partial methane oxidation)
- ATR process or Casale’s process (Auto thermal reforming)

MSR process is a mature technology, cost effective and most common method. Mass and heat transfer issues are the significant disadvantages. Hydrogen and methane conversion take place due to endothermic reaction at a temperature of 850°C and at a pressure of 2.5 MPa with nickel as catalyst.

\[
\text{Stage 1. } \text{H}_2\text{O (steam)} + \text{CH}_4 \rightarrow 3\text{H}_2 + \text{CO} \quad \Delta H = 206 \text{ kJ}
\]

\[
\text{Stage 2. } \text{H}_2\text{O (steam)} + \text{CO} \rightarrow \text{H}_2 + \text{CO}_2 \quad \Delta H = -41 \text{ kJ}
\]

Heat needed in stage 1 is got from surplus heat in stage 2 and combustion of methane feedstock.

POX process is a mild exothermic process without external heating and thereby a compact design for the conversion of methane. Only a limited amount of oxygen reacts with methane. In the final product, other compounds and small amount of carbon dioxide exist.

\[
\text{CH}_4 + \text{O}_2 \rightarrow \text{CO} + 2\text{H}_2 \quad \Delta H = -36 \text{ kJ}
\]
ATR process is the manifestation of both the reactions of MSR and POX. In general, ATR operates at a temperature between 950 to 1050°C and a pressure of 30 to 50 bars. H\textsubscript{2} is injected along with steam to produce CH\textsubscript{4}. Efficiency is reduced due to purification of output gas and large investment is also needed. Hence Partial oxidation with anaerobic digestion is adopted for the production of methane gas.

In Prototype model shown in Fig.1, three barrels of each 200 lit. Capacity is used for the biogas preparation from the bio and solid wastes generated from the residential house. For every 25 lit. of waste 1 cft. Methane gas is produced which is sufficient to light a 25W bulb for 6 hours.

2.3. DIESEL ENGINE AND ALTERNATOR
2.3.1 Engine Specification

| Type          | Kirloskar AVI 4-stroke water cooled          |
|---------------|---------------------------------------------|
| Cylinder      | Single                                      |
| BHP           | 5HP                                         |
| Speed         | 1500 rpm                                    |
| Fuel          | Dual Fuel (Diesel/Bio gas)                  |
| Bore          | 87.5mm                                      |
| Stroke length | 110mm                                       |
| Compression ratio | 16:1                                     |

2.3.2 Alternator

| Type          | Single phase | Range | 1.5 KVA | Speed | 1500 rpm |

3. RESULTS AND DISCUSSION

3.1 Performance trails and results

Kirloskar engine with dual fuel is used for the performance trails. A single phase alternator is coupled to the engine. Resistive loads are applied during the trails. At various loads trails are conducted and
the performance output results are tabulated as shown in the tables 1, 2 and 3. And Performance analysis results are shown in figures 2 to 8.

### Table 1. Total fuel consumption and efficiencies at various kW brake power

| S.N | BRAKE POWER kW | TFC Kg/Hr | BTE % | ITE % | ME % |
|-----|----------------|-----------|-------|-------|------|
|     | Diesel         | Dual mode |       |       |      |
| 1   | 1.0            | 0.65      | 13.2  | 28    | 53   |
| 2   | 2.0            | 0.71      | 23.0  | 38    | 62   |
| 3   | 3.0            | 0.89      | 28.0  | 39    | 68   |
| 4   | 3.5            | 0.95      | 26.0  | 38    | 67   |

| S.NO | BRAKE POWER kW | FUEL CONSUMPTION % |
|------|----------------|---------------------|
| 1    | 1.606          | Diesel: 84          |
|      |                | Biogas: 16          |
| 2    | 2.120          | Diesel: 81          |
|      |                | Biogas: 19          |
| 3    | 2.620          | Diesel: 77          |
|      |                | Biogas: 23          |
| 4    | 3.520          | Diesel: 75          |
|      |                | Biogas: 25          |

### Table 2. Fuel consumption at various kW brake power

| S.NO | BRAKE POWER kW | FUEL CONSUMPTION % |
|------|----------------|---------------------|
| 1    | 1.606          | Diesel: 84          |
|      |                | Biogas: 16          |
| 2    | 2.120          | Diesel: 81          |
|      |                | Biogas: 19          |
| 3    | 2.620          | Diesel: 77          |
|      |                | Biogas: 23          |
| 4    | 3.520          | Diesel: 75          |
|      |                | Biogas: 25          |

### Table 3. Exhaust emission results in ppm

| S.NO | FUEL                        | EMISSION (ppm) |
|------|-----------------------------|----------------|
| 1    | DIESEL                      | CO: 70         |
|      |                             | CO₂: 107       |
|      |                             | NO: 50         |
|      |                             | CH₄: 90        |
| 2    | DIESEL AND BIO GAS         | CO: 57         |
|      |                             | CO₂: 37        |
|      |                             | NO: 41         |
|      |                             | CH₄: 85        |

### 3.2 Total Fuel Consumption Vs Brake Power

![Figure 2. Total Fuel Consumption Vs Brake Power](image-url)
3.3 Brake Thermal Efficiency Vs Brake Power

![Graph of Brake Thermal Efficiency vs Brake Power]

*Figure 3. Brake Thermal Efficiency vs Brake Power*

3.4 Indicated Thermal Efficiency Vs Brake Power

![Graph of Indicated Thermal Efficiency vs Brake Power]

*Figure 4. Indicated Thermal Efficiency vs Brake Power*

3.5 Mechanical Efficiency Vs Brake Power

![Graph of Mechanical Efficiency vs Brake Power]

*Figure 5. Mechanical Efficiency vs Brake Power*
3.6 Fuel Consumption for Dual Mode at Various Load Condition

![Figure 6. Load Condition Vs Fuel Consumption](image)

3.7 Average Fuel Consumption for Dual Mode (Diesel – Biogas)

![Figure 7. Average fuel consumption](image)

It is noticed from the analysis as shown in fig.7 that the diesel consumption is 69% and 31% in the dual mode.
3.8 Emission Result

**Engine Load:** Ideal Load  
**Room Temperature:** 25±5°C

![Emission Result](image)

*Figure 8. Emission*

In the dual mode emission is also found to get reduced as shown in Fig.8.

4. SUMMARY AND CONCLUSION

The investigation and analysis of renewable energy from bio and solid waste observation reveals that smaller power generation set ups are possible and feasible in every residence. In a simpler manner and at a lower cost, the daily demand of every residence can be met. The production of renewable energy by this way, waste disposal also becomes easier. During analysis, power loss due to friction in dual mode is found to get reduced by 23% along with a reduction of 21% in diesel consumption. Mechanical efficiency is found to increase by around 16% on average in dual mode as compared to diesel mode. Similarly, emission of carbon monoxide, carbon dioxide, nitrogen oxide and hydro carbon are found to get reduced from 70 to 57 ppm, 107 to 37 ppm, 50 to 41 ppm and 90 to 85 ppm respectively from diesel mode to dual mode. This investigation and analysis clearly shows that the renewable energy from bio and solid waste is more beneficial.

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