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Design and Development of Kitchen Waste into Biogas

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Abstract: *The growing demand for electricity and the depletion of fossil fuels have increased the need for renewable and eco-friendly energy sources. Biogas is a clean and sustainable fuel produced from kitchen waste through anaerobic digestion. In this project, electricity is generated from biogas using a Thermoelectric Generator (TEG) based on the Seebeck effect. When biogas is burned, a temperature difference is created across the TEG module, producing electrical energy without any moving parts. The experimental setup produced an output voltage of approximately 0.6 V from a single TEG module. The generated power can be stored in a battery using a boost converter for low-power applications. This system offers a low-cost, silent, and pollution-free method of converting biogas heat energy into electricity. The proposed system is simple in construction and does not require complex mechanical components, making it reliable and easy to maintain. The absence of moving parts increases system lifespan and reduces mechanical losses. Even with low-temperature heat from biogas combustion, the TEG produces usable electrical output. This study proves the feasibility of small-scale electricity generation using renewable biogas energy.*

Keywords: Biogas, Thermoelectric Generator, Seebeck Effect, Renewable Energy, Kitchen Waste

I. INTRODUCTION

Energy scarcity and environmental pollution are major global concerns. Biogas, obtained from biodegradable kitchen waste, provides a renewable fuel for cooking and heating. However, the thermal energy released during biogas combustion is often wasted. Thermoelectric Generators (TEGs) can convert this waste heat directly into electricity using the Seebeck effect. This project focuses on utilizing biogas heat to generate electrical power in a simple and efficient manner, suitable for small-scale and rural applications. In many rural and semi-urban areas, biogas plants are already in use, but electricity availability remains limited or unreliable. Recovering waste heat from biogas improves overall energy efficiency of the system. Thermoelectric technology offers a direct energy conversion method without additional fuel consumption. This makes the system suitable for decentralized and off-grid energy applications.

II. PROBLEM STATEMENT

Although biogas is widely used for cooking, its heat energy is not fully utilized for power generation. Conventional electricity generation methods require turbines and generators, which are costly and complex. There is a need for a compact, low-cost, and maintenance-free system to convert biogas heat into electricity for small electrical loads. Most renewable energy systems require high initial investment and skilled maintenance, limiting their adoption in rural regions. Low-temperature heat sources like biogas flames are often ignored due to poor conversion efficiency in conventional systems. There is a need for a simple technology that can convert this heat directly into electrical energy. The system must be affordable, compact, and easy to operate. Most renewable energy systems require high initial investment and skilled maintenance, limiting their adoption in rural regions. Low-temperature heat sources like biogas flames are often ignored due to poor conversion efficiency in conventional systems. There is a need for a simple technology that can convert this heat directly into electrical energy. The system must be affordable, compact, and easy to operate.

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III. LITERATURE REVIEW

Several studies show that biogas can be effectively used for power generation through engines, micro-turbines, and fuel cells. However, these systems are expensive and require skilled maintenance. Recent research highlights the use of Thermoelectric Generators for waste heat recovery due to their simple structure, reliability, and eco-friendly operation. Studies confirm that TEGs are suitable for low-power applications using biomass and biogas heat sources. Previous research confirms that kitchen waste has high biogas yield potential due to its organic composition. Studies on thermoelectric generators show that they are effective for low-power generation and waste heat recovery. However, limited experimental work is available on integrating biogas burners with TEG modules. This project focuses on bridging this research gap using a practical laboratory setup.

IV. METHODOLOGY

In this project, kitchen waste is used to produce biogas through the anaerobic digestion process. The generated biogas is collected and supplied to a biogas burner, which serves as the heat source for the thermoelectric generator (TEG). The TEG module is placed above the burner so that its hot side receives heat from the biogas flame.The cold side of the TEG is exposed to ambient air and attached to a heat sink to maintain a temperature difference across the module. Due to this temperature difference, electrical energy is generated based on the Seebeck effect. The output voltage produced by the TEG is measured using a digital multimeter. Since the generated voltage is low, a DC boost converter is used to increase the voltage to a usable level. The boosted output is stored in a rechargeable battery and can be used for low-power electrical applications. The system is tested under normal operating conditions to evaluate its performance.

V. WORKING

The system operates by utilizing biogas produced from kitchen waste as a heat source for electricity generation. Biogas is supplied from the digester to a burner, where it is combusted to produce heat. This heat is transferred to the hot side of the thermoelectric generator (TEG), while the cold side remains at a lower temperature due to natural air cooling and the use of a heat sink. The temperature difference across the TEG results in the generation of DC electrical voltage. The produced voltage is initially low and is therefore boosted using a DC boost converter. The boosted output can be stored in a battery or directly used to power low-power electrical loads such as LEDs. The system works continuously as long as biogas supply and temperature difference are maintained.

WORKING PRINCIPLE

Step 1: Kitchen waste is fed into the biogas plant, where anaerobic digestion produces biogas.
Step 2: The generated biogas is supplied to a biogas burner and ignited to produce heat.
Step 3: The heat from the biogas flame is applied to the hot side of the thermoelectric
Step 4: The cold side of the TEG is maintained at a lower temperature using ambient air and a heat sink.
Step 5: Due to the temperature difference across the TEG, electrical voltage is generated based on the Seebeck effect.
Step 6: The generated low-voltage DC output (approximately 0.6 V) is measured.
Step 7: A DC boost converter increases the voltage to a usable level.
Step 8: The boosted voltage is stored in a battery or used to power low-power electrical loads.

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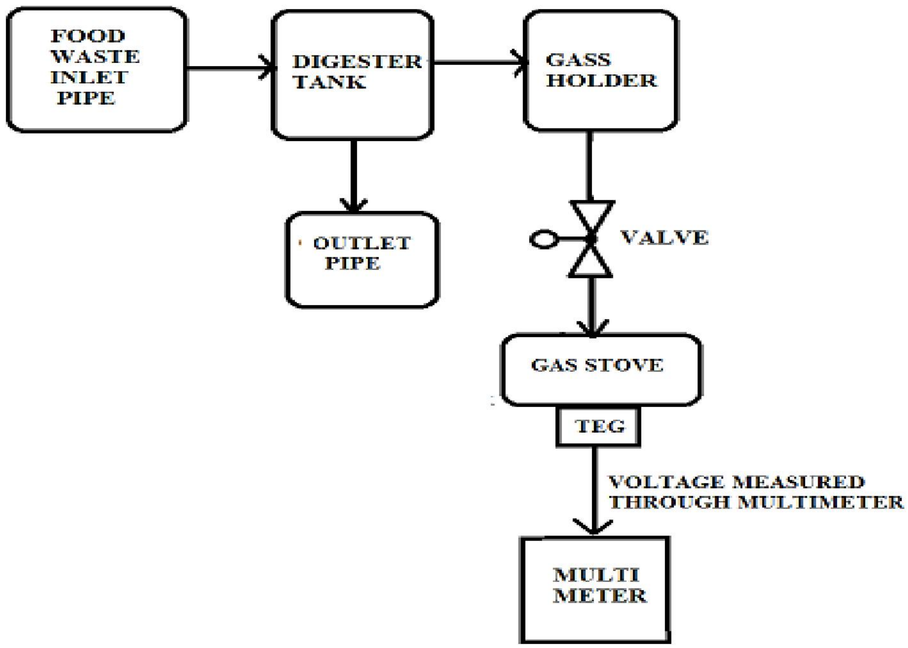
VI. BLOCK DIAGRAM



COMPONENTS USED

Food waste inlet pipe
Digester tank
Gas holder
Valve
Gas stove
Outlet pipe
TEG
Multimeter

VII. COMPONENTS DESCRIPTION

Food waste inlet pipe

The food waste inlet pipe is used to feed kitchen waste slurry into the digester tank. It provides a controlled and hygienic method of introducing biodegradable waste into the system. The pipe is designed to prevent leakage and blockages during feeding.

Digester tank

The digester tank is the main component of the biogas plant where anaerobic digestion takes place. Inside the tank, microorganisms break down food waste in the absence of oxygen and produce biogas. The tank is made airtight to maintain anaerobic conditions required for effective gas generation.

Gas holder

The gas holder is used to collect and temporarily store the biogas produced in the digester tank. It maintains slight pressure and ensures continuous gas supply to the gas stove. The gas holder helps regulate gas flow and prevents sudden pressure variations.

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Valve

The valve is used to control the flow of biogas from the gas holder to the gas stove. It ensures safe operation by allowing the user to start or stop the gas supply whenever required. Valves also help prevent gas leakage and improve system safety.

Gas Stove

The gas stove acts as the combustion unit where biogas is burned to produce heat. This heat is utilized as the input energy for the thermoelectric generator. The stove provides a steady and controlled flame suitable for experimental analysis.

Outlet Pipe

The outlet pipe is used to remove the digested slurry from the digester tank after the digestion process. The slurry obtained is rich in nutrients and can be used as organic fertilizer. The outlet pipe helps maintain proper slurry level inside the digester.

Thermoelectric Generator (TEG)

The thermoelectric generator converts heat energy into electrical energy based on the Seebeck effect. When a temperature difference exists between the hot side and cold side of the TEG, a DC voltage is generated. In this project, the hot side is heated by the biogas flame, producing an output voltage of approximately 0.6 V.

Multimeter

The multimeter is used to measure the electrical output generated by the thermoelectric generator. It is used to measure voltage accurately during experimentation. This helps analyze the performance of the TEG system.

VIII. ADVANTAGES

- Utilizes renewable biogas energy effectively.
- Simple construction and easy operation.
- No moving parts in electricity generation.
- Low maintenance and long life.
- Eco-friendly and pollution-free.
- Suitable for rural and small-scale applications.

IX. LIMITATIONS

- Low electrical power output
- Efficiency depends on temperature difference
- Not suitable for high-power applications
- Performance reduces with poor cooling.

X. CONCLUSION

The project "Design and Development of Kitchen Waste into Biogas" demonstrated that kitchen waste can be converted into renewable energy using a simple floating-drum biogas system. Using a mild steel digester and HDPE gas holder, the plant produced 8–10 L/day of biogas with 60–65% methane. The leftover slurry served as organic fertilizer. The system is low-cost, environmentally friendly, and easy to construct and operate. Waste-heat recovery with a Thermoelectric Generator produced 0.6 V, showing potential for small-scale electricity generation alongside biogas production.

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XI. FUTURE SCOPE

The biogas-based energy system can be expanded by using the produced biogas to run generators for electricity, connecting them to microgrids for small communities, or upgrading the gas to Bio-CNG for higher-efficiency engines. Smart IoT or Arduino-based controls can monitor gas pressure, generator performance, and load management, while battery storage and inverters ensure stable power supply. Integration with solar panels can create a hybrid renewable system, and multiple TEG modules can be connected to increase voltage for sensors or small electronic devices, enhancing overall energy efficiency and reliability.

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