

Design and Estimation of Biogas Plant for Canteen Waste: A Case Study of RD's Rajgad Technical Campus, Dhangwadi, Bhore, Pune

N. J. Sathe^{1,*}, K. V. Shingate², Y. V. Bachhav³

Abstract

Today's economy and society rely on energy. In the end, conventional fossil fuels like oil will run out, and an alternate primary energy source will be required to close the widening gap between rising demand and declining supply. Biogas is a great energy source in light of rising petroleum prices, declining foreign exchange reserves, and the rupee-dollar exchange rate. Organic matter breaks down to produce biogas, a fuel. The primary goal of this research project is to design and estimate the generation of biogas from food waste collected from a canteen at RD's Rajgad Technical Campus, Bhore. It also concentrates on biogas theoretical estimation, which is a first step in establishing a biogas plant in the side yard of the canteen. For the RTC canteen, a model has been created that allows for the efficient use of waste and energy generated on campus. The primary component of natural gas, which is a significant greenhouse gas and a contributing factor to the issue of global warming, is methane. In light of this, an effort is made to turn waste into electricity through the use of fuel cells, which produce electricity through an electrochemical reaction in which oxygen and a fuel rich in hydrogen combine to form water. This makes fuel cells extremely energy-efficient, and cogeneration can increase efficiency even further. A typical fuel cell produces a voltage of 0.6 to 0.8 V when operating at full rated load.

Keywords: Canteen waste, organic manure, biogas, methane, fuel cell

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INTRODUCTION

The energy crisis and waste management are two of the world's most pressing issues. Solid waste management and energy requirements have become major issues owing to rapid population expansion and unchecked urbanization. The shortage of coal and petroleum puts the world's fuel supply at risk. Additionally, the issue of their combustion motivates studies in other fields to access new energy sources, such as renewable energy supplies [1]. Renewable energy sources include biogas, wind and solar energy, and various thermal and hydropower sources. Entropy is the primary issue that lowers the efficiency of most renewable energy sources. However, biogas stands out from other renewable energy sources because of its special ability to consume, manage, and collect organic waste while simultaneously creating water and fertilizer for use in agriculture. Biogas is easy to use

and implement, has no geographical restrictions, and does not require sophisticated technology to produce energy [2]. Biogas was first used to heat bath water in Assyria in the tenth century, and combustible gases may have developed from decomposing organic substances in the seventeenth century. In Bombay 1859, the first digesting factory was built in a leper colony in, Bombay India. Biogas is a gas created when organic matter breaks down biologically without oxygen. Biogas can be produced from a variety of materials, including animal dung, farm residues, sewage effluent, kitchen garbage, and cellulose. Biogas is generated when garbage from the kitchen is anaerobically digested. One component of biogas, which has a lot of potential as an alternative fuel, is methane, a clean energy source. Methane may be produced from the abundant biomass of different institutions, where it would be advantageous to combine waste treatment with energy generation. Anaerobic fermentation of organic molecules produces biogas, a combustible gas. Methane and carbon (IV) oxide are present, along with traces of water vapor and hydrogen sulfide [3].

Kitchen garbage is the best option for producing biogas in a community-level biogas plant. It is formed when bacteria degrade organic material in the absence of oxygen. Methane constitutes approximately 55–65% of biogas, whereas carbon dioxide constitutes 30–40%. Biogas has a significant calorific value (approximately 4700 kcal or 20 MJ at 55% methane content). After the gas is dewatered and cleaned, it can be efficiently used for power generation through a biogas-based power-generating system. Furthermore, the slurry created during this process offers useful organic manure for farming and maintaining soil fertility [4].

A pilot study on generating biogas from cooking garbage demonstrated the enormous potential of this eco-friendly energy source. As society seeks long-term solutions to the ever-increasing energy demand and environmental issues, biogas production from cooking waste has emerged as a potential path to a greener and more sustainable future. We may make tremendous progress toward a cleaner and more sustainable world by utilizing kitchen garbage to create a circular economy in which waste is turned into useful resources [5].

Wipro's mission to carry out projects like this under its CSR program and the adequate resources available to support the investment are the main advantages of this case. The lack of internal technical capacity to oversee the biogas plant and the acreage needed for it is a problem. The biogas plant owned by Wipro occupies approximately 300 square meters of space. Except in the improbable event of considerable price subsidies on LPG for commercial use, there are no serious risks to the investment in LPG. The opportunity is enormous because this can be readily duplicated on additional Wipro campuses and the campuses of other major firms and academic organizations [6].

Every day, a significant volume of kitchen garbage that may be used for better purposes was collected from the institute canteen of Ram Meghe College of Engineering and Management, Badnera, which has its own separate mess. Anaerobic digestion is essential for biogas production. The goal of the project was to build an organic processing facility that would produce biogas, which would be more economical, environmentally beneficial, reduce landfill trash, produce a superior renewable fuel, and lower emissions of carbon dioxide and methane. Kitchen garbage is anaerobically digested to produce biogas, which is a useful energy source [7]. The microbial process of anaerobic digestion produces biogas, which is primarily composed of carbon dioxide (CO_2) and methane (CH_4). Sodium hydroxide (NaOH) must be added to the continuously fed digester to maintain the pH and alkalinity at 7. To create their own inoculum for this reactor, researchers developed an inoculum that was placed in batch reactors. This inoculum was then combined with kitchen waste and an inoculum of the previously prepared cow dung slurry. These mixed inocula were combined to produce biogas at 37°C in a small-scale laboratory reactor with a 20 L capacity. The production of methane and biogas from starch-rich and sugary materials has been measured at the laboratory scale using basic digesters [8].

Waste material examination provides a detailed picture of how biogas is produced. The properties of the waste were thoroughly examined. Utilizing garbage to produce biogas could lower the cost of

production, increase its availability, and lower its price. Human energy needs might be readily satisfied if biomass is used efficiently [9]. The researcher concluded that using waste materials at a 75:25 ratio minimizes global warming, provides more gas for the project, and is more cost-effective than other fuels. Approximately 5.692×10^9 ml/week of biogas may be recovered if all institutions use this 75:25 mix [10].

Problem Statement

The goal of this project was to build an anaerobic digester that uses food waste to produce biogas and to determine how food waste from the RTC canteen could be turned into biogas. This plant can process kitchen waste, including vegetable waste, stale cooked and uncooked meals, waste milk, and milk products. According to research, 25 kg of kitchen waste can generate 365 m³ of biogas annually. As an output, canteen garbage disposal can be done in an economically and environmentally friendly manner.

Biogas

Bacteria produce biogas by biodegrading organic materials in anaerobic environments. The natural production of biogas is an essential component of the biogeochemical carbon cycle. Both rural and urban areas can use it [11]. Table 1 shows the concentration (by volume) of various components in the composition of biogas, and Figure 1 shows the concentration of the components of biogas.

Fuel Cell

Fuel cells generate electricity through chemical processes. Fuel cells for spacecraft and other specific applications generate current from hydrogen, which combines with oxygen to produce water as a byproduct, although they can also use liquor, fuel, or methane. A basic fuel cell composed mostly of household materials can be built to learn how fuel cells work

Table 1. Composition of biogas.

Component	Concentration (by volume)
Methane (CH ₄)	55 - 60 %
Carbon dioxide (CO ₂)	35 - 40 %
Water (H ₂ O)	2 - 7 %
Hydrogen Sulphide (H ₂ S)	20 - 20,000 ppm (2%)
Ammonia (NH ₃)	0 - 0.05 %
Nitrogen (N)	0 - 2 %
Oxygen (O ₂)	0 - 2 %
Hydrogen (H)	0 -1 %

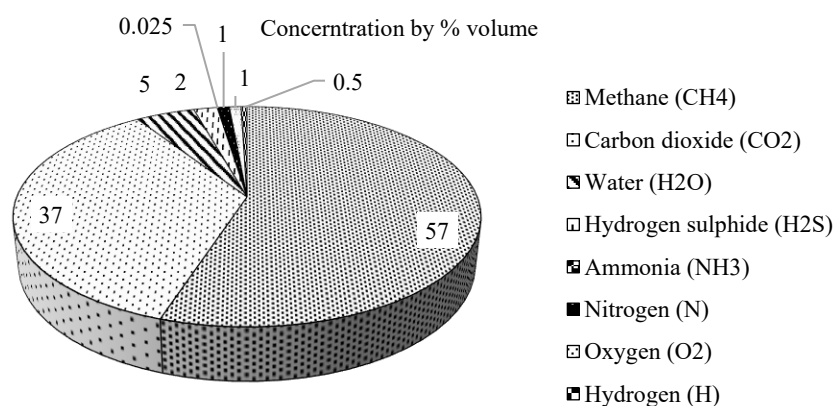


Figure 1. Composition of biogas showing the concentration of volume by percentage.

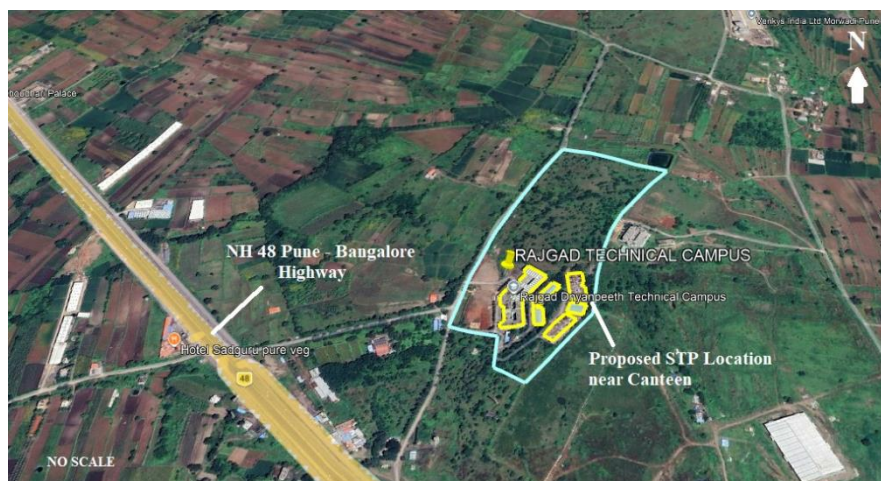


Figure 2. Aerial view of Rajgad technical campus (courtesy, google maps).

Table 2. Materials required for the construction of biogas plant.

S.N.	Material list	Quantity in no's	Prices
1	PVC Tank of Capacity 3750 L	1	20000
2	PVC Tank of Capacity 2500 L	1	15000
3	1.25" PVC Pipe (25 kg/cm ²)- 10.00-Feet	1	800
4	1. 25" PVC Male Threaded Adaptor (MTA)	2	720
5	1. 25" PVC Female Threaded Adaptor (FTA)	2	400
6	1. 25" PVC –Tee (heavy)	1	200
7	1. 25" PVC-Elbow (heavy)	1	80
8	1.5" X 1.25" PVC Reducer Collar (heavy)	1	40
9	1.5" GI Collar (ISI)	1	60
10	1.5" GI 'Tank' nipple (ISI)	1	60
11	200 mL Solvent	1	100
12	Teflon Tape	5	25
13	M-Seal	5	150
14	1.5" UPVC Tank Nipple	1	400
15	Washer (Flange washer 90mm)	5	1000
16	Drip Tee 16 mm	3	600
17	Drip Valve 16 mm	3	750
18	¾" Stainless steel Hose Clamp	12	200
19	Shel lock	1	300
Approximate Estimated Cost =			40885

METHODOLOGY

Description of Study Area

RD's Rajgad Technical Campus (RTC) is located in Dhangwadi, Bhore Taluka, on NH 46 Pune-Bangalore Highway (18°12'45.13"N, 73°56'8.25"E), and is set up over a vast 25-acre area with educational and administrative infrastructure surrounded by a lush green environment. RTC is also known for its disciplined academic ambience. Since its foundation, the Rajgad Dnyanpeeths Trust (RTC) has grown to become one of the top educational institutions in the Bhore taluka of Pune District, offering everything from primary schools to undergraduate colleges in engineering. Figure 2 shows an aerial view of the study area.

Table 3. Specification of 25 kg/day organic/kitchen waste biogas plant.

Input to the plant	25 kg of kitchen waste
Area required	4m ²
System elements	Digester, gas holder dome, gas flow pipe line, moisture trap system, biogas burner
Type of feed	Kitchen waste like rice starch , wash water of rice, used tea powder, coffee powder, waste atta, left over rice, leftover chapatti, over ripened fruits, vegetable waste, fruit peels ,waste edible oil and other cooked waste from kitchen

Material and Specification

This study used RTC Canteen garbage to produce biogas. A trial project was conducted to breakdown canteen garbage in an anaerobic digester. Initially, a trial biogas plant was erected in the side yard of the canteen. Based on the results and the amount of garbage created, a biogas plant should be built to effectively use canteen waste. Table 2 shows the materials and costs required to construct a biogas plant, whereas Table 3 shows the specifications required to run the biogas plant.

Experimental Setup

To separate hydrogen molecules from carbon molecules, methane gas was transferred to a boiling flask filled with activated charcoal. The separate hydrogen molecules were transported to the fuel cell setting, where an electrolysis reaction occurred. The multimeter detected the voltage generated by the positively charged hydrogen molecules. Figure 3 shows the experimental setup.

RESULT AND DISCUSSION

Biogas Generation

It is predicted that 25 kg of canteen garbage produces 2.5 m³ of biogas each day.

Power Generation Using Fuel Cell

The maximum efficiency that can be achieved with a hydrogen fuel cell is 3.0 m³ of methane gas, as shown in Table 4, which yields voltages of 4.5, 4.175, and 4.075 V, respectively, as shown in the histogram in Figure 4. According to the survey, hydrogen fuel cells are the least expensive and can produce the same voltage as other fuel cells.

Design and Estimation

The RTC canteen is thought to create approximately 25 kg of canteen trash every day. To properly use the garbage, a 25 kg biogas plant needs to be erected, which will cost approximately Rs. 60885. Table 5 displays a detailed estimate of the building and installation of a biogas plant. Table 6 provides a detailed calculation of the potential returns and savings from the biogas plant.

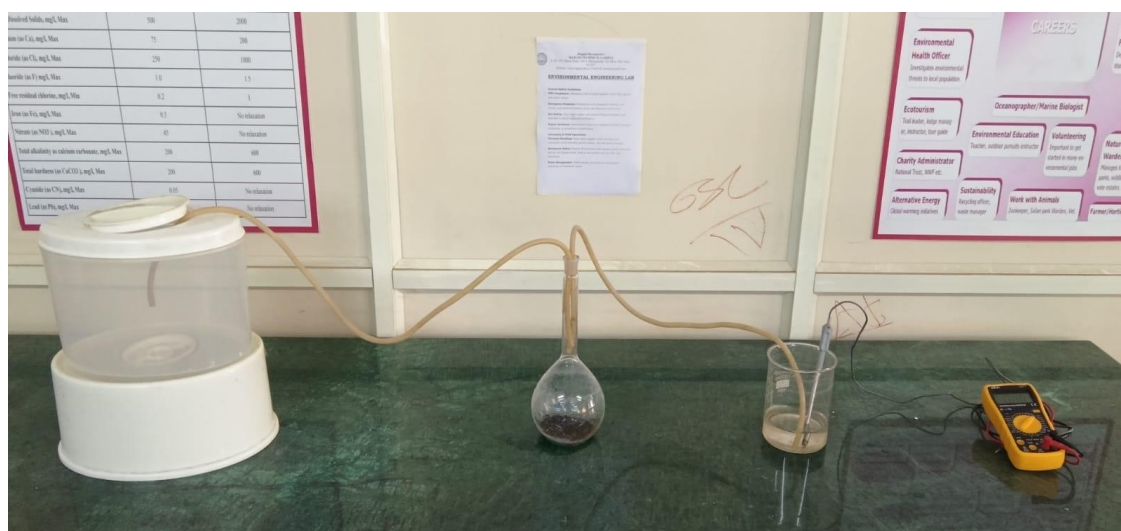
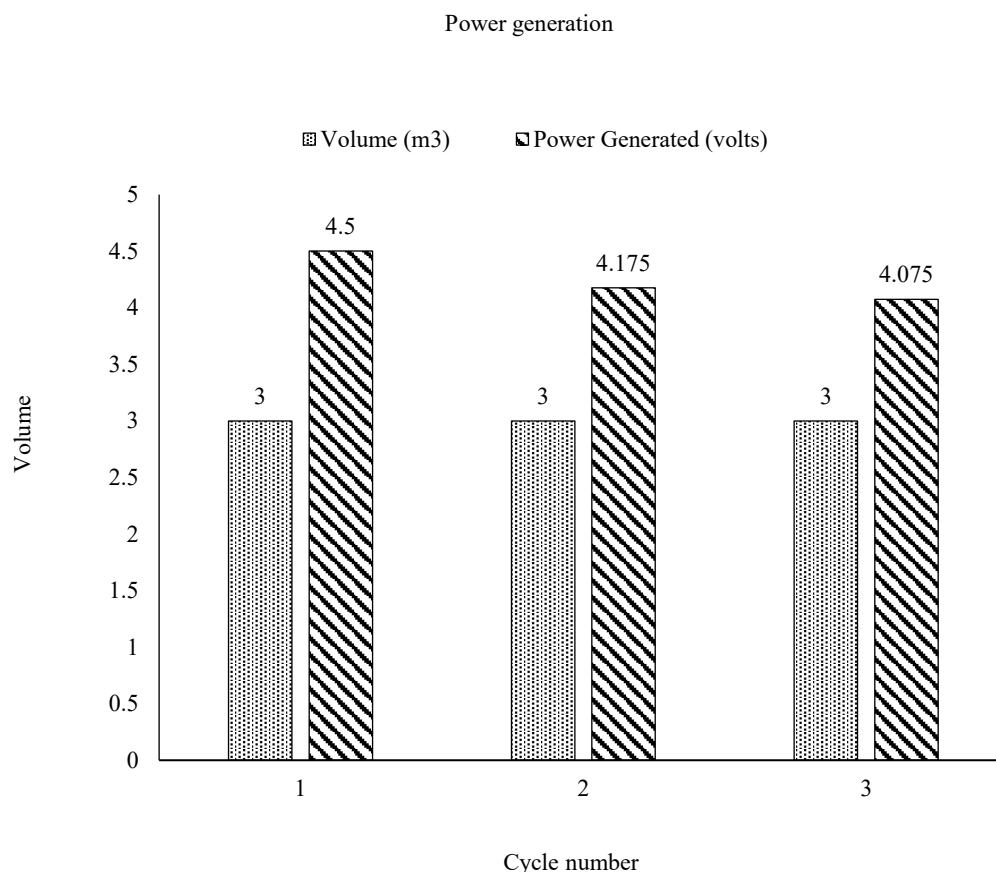


Figure 3. Fuel cell connection to setup.

Table 4. Table showing power generation.

Cycle no	Volume (m ³)	Power generated (volts)
1	3.0	4.5
2	3.0	4.175
3	3.0	4.075

**Figure 4.** Power generation with respect to volume/cycle.**Table 5.** Estimation and costing for biogas plant.

S.N.	Component	Cost/plant (Rs)
1	Materials	40885/-
2	Labour and Installation	20000/-
Total =		60885/-

Table 6. Returns of savings that can be expected from the biogas installation.

Input to the plant	1 to 5 kg of Canteen waste	
Area required	4m ²	
System Elements	Digester, Gas Holder, Gas flow pipe line, Moisture trap systems, Biogas Burner	
Type of feed	Kitchen waste like rice starch , wash water of rice, used tea powder, coffee powder, waste atta, left over rice, leftover chapatti, over ripened fruits, vegetable waste, fruit peels ,waste edible oil and other cooked waste from kitchen	
Application	Bio gas for cooking at Canteen Slurry as manure for gardening	
Daily biogas and	Generation of biogas per day (Max.)	3.0 m ³ →(1)
Manure	LPG Equivalent of biogas per day	1.35 kg → (2)

	Savings through LPG per day	Rs. 54.73 → (3)
	Savings through manure per day	Rs. 1.20
	Total returns per day through biogas and manure	Rs. 55.93 → (4)
Monthly biogas and manure	Generation of biogas per month	30.42 m ³ /Month
	LPG Equivalent of biogas per month	37.8 kg
	Savings through LPG per month	Rs. 1532
	Savings through manure per month	Rs. 33.6
	Total returns per month through biogas and manure	Rs. 1565.6
Annual biogas and manure	Generation of biogas per year	365 m ³ /Yr
	LPG Equivalent of biogas per year	453.6 kg (24 Cylinders)
	Savings through LPG per year	Rs. 18390
	Generation of Manure per year	6616 Kg
	Minimum cost of manure per kg	Rs. 3/-
	Savings through manure per year	Rs. 19848/-
	Total returns per year through biogas and manure	Rs. 38238

CONCLUSION

Based on the observations and data gathered, the subsequent findings are drawn:

- Biogas digester systems produce ammonia-rich residual organic waste that can be used as manure.
- Hydrogen may be generated in an environmentally acceptable way.
- Fuel cells can be produced for portable electronic gadgets.
- Cells are more efficient than combustion systems because they generate energy through an electrochemical process rather than by burning fuel.
- It is projected that approximately 25 kg of canteen garbage is generated daily, demanding the installation of four biogas plants, which will result in a cost estimated at Rs. 60,885.
- Approximately 6616 kg of manure, 365 cubic meters of biogas, and 730 kW of power are generated annually from one biogas plant. The manure created can be utilized for the green belt creation of the campus, while the biogas generated can be employed for cooking in the canteen, resulting in savings of approximately 24 LPG cylinders annually. Additionally, the electricity produced can be used to illuminate LED and small-capacity CFL lamps throughout the campus.
- According to the estimates made during the studies, biogas plants save Rs 38,238 each year for a one-time expenditure of Rs 60885.

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