

# SMART BIOGAS SYSTEM : IoT and Sensor Integration in Agricultural Biogas Plants

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## Introduction

The increasing global demand for renewable energy has renewed interest in biogas production, especially through agricultural biogas plants. These facilities convert organic waste into methane-rich biogas, which can be used for energy generation. However, conventional biogas plants often face challenges related to operational efficiency, monitoring, and process management. The integration of Internet of Things (IoT) technologies and sensors presents a promising solution to optimize biogas yields and enhance overall plant performance. This literature review explores current research on smart biogas systems, with a focus on the role of IoT and sensor-based technologies in agricultural biogas plants.

## 1. Overview of Biogas Production

Biogas is generated through anaerobic digestion, a biological process in which microorganisms break down organic matter in the absence of oxygen, producing methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>). Methane constitutes the primary energy component of biogas (Zhang et al., 2020). The efficiency of biogas production is influenced by several factors, including temperature, pH, and feedstock composition (Khan et al., 2021).

## 2. Challenges in Traditional Biogas Systems

Traditional biogas plants face several limitations, including:

- Inconsistent feedstock quality
- Inadequate monitoring of digestion parameters
- Difficulty in managing the anaerobic digestion process

These challenges often result in reduced biogas yields and higher operational costs (Müller et al., 2019), emphasizing the need for innovative solutions to improve performance and reliability.

## 3. Role of IoT in Biogas Systems

### a. Real-Time Monitoring and Data Collection

IoT devices and sensors enable continuous monitoring of critical parameters such as temperature, pH, gas composition, and substrate quality. The data collected can be used to maintain optimal conditions for anaerobic digestion, ensuring maximum methane production. Advanced IoT systems can even automatically adjust these parameters to enhance efficiency.

### b. Predictive Maintenance

By monitoring equipment performance in real time, IoT technologies enable predictive maintenance. Sensors can detect anomalies in components such as pumps or mixers, allowing timely interventions that prevent equipment failures. This reduces downtime and lowers maintenance costs, improving overall system efficiency.

### **c. Enhanced Decision-Making**

Data from IoT sensors can be analyzed using machine learning and advanced algorithms to provide actionable insights. For instance, operators can determine the optimal feedstock composition or process conditions, enabling data-driven decisions that maximize biogas yields.

## **4. Technologies in Smart Biogas Systems**

### **a. Automated Feeding Systems**

Sensors integrated into automated feeding systems assess feedstock quality and availability, delivering precise amounts of organic material to the digester at the optimal time. This improves digestion efficiency and maximizes biogas output.

### **b. Remote Monitoring and Control**

IoT platforms allow operators to monitor and control biogas plants remotely via computers or smartphones. This is particularly advantageous for managing multiple sites or for operators with limited access to physical locations.

### **c. Integration with Renewable Energy Sources**

Smart biogas systems can be combined with other renewable energy technologies, such as solar or wind power, to enhance energy security. Surplus energy can be stored or sold, promoting energy independence for farmers and sustainable energy management.

## **5. Future Prospects: Toward Sustainable Biogas Systems**

Advancements in IoT and sensor technologies, along with increasing digitalization in agriculture, present a promising future for smart biogas systems. Wider adoption of these technologies, supported by policymakers and stakeholders, can overcome current challenges and promote sustainable energy production in agriculture.

**Live Classroom Activity: Prototype DIY Biogas Plant Experiment for Biogas Generation Using Cow Dung**

This activity demonstrates small-scale biogas production using cow dung, designed for rural settings or student laboratories. It uses simple materials and manual indicators to measure gas production and efficiency without digital sensors.

### **Materials**

- 250 ml plastic bottle (anaerobic digester)
- Fresh cow dung and water (1:1 ratio)
- Rubber/plastic tube for gas outlet
- Balloon or small gas bag for gas collection
- Clay or tape to seal bottle cap
- Thermometer for temperature monitoring
- Litmus paper/pH strips for pH testing
- Spoon or small container for slurry sampling
- Eucalyptus leaves (to aid biogas formation)

### Experimental Setup

The plastic bottle serves as an anaerobic digester as shown in figure 2. A gas outlet tube is inserted through the cap and sealed with clay or tape. Cow dung slurry mixed with eucalyptus leaves is added to the bottle. Gas produced during digestion inflates a balloon, allowing volume measurement. Temperature is monitored using a thermometer, while pH and slurry characteristics are checked periodically using litmus paper or pH strips. This hands-on experiment provides a cost-effective demonstration of biogas production for educational purposes.

### Conclusion:

Integrating IoT and sensors into agricultural biogas plants revolutionizes sustainable energy production and waste management. Real-time monitoring, predictive maintenance, and data-driven decisions optimize anaerobic digestion, boosting biogas yields and efficiency. As technology evolves, adopting these innovations is crucial for a sustainable, energy-secure future in agriculture.



Fig-1 Biogas production after 40 days of interval



Fig-2 Formation of the scum and biogas.

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