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# Study of Bio Gas Plant for Small Villages

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**Abstract:** *The increasing imbalance in natural ecological systems, driven by rapid industrialization, population growth, and rising energy demands, has become a critical global concern. Since the formation of Earth, elemental resources have remained constant, cycling naturally through ecosystems. However, human activities have significantly disrupted these cycles, particularly through excessive emissions of carbon dioxide and methane, intensifying the greenhouse effect and contributing to climate change. Modern technological advancements, while beneficial, have also led to environmental degradation and a growing disconnect from nature, emphasizing the urgent need to adopt sustainable practices. Waste management has emerged as a major challenge due to inadequate segregation and poor societal attitudes. The misconception of waste as useless material has hindered effective recycling and resource recovery. The mixing of biodegradable and non-biodegradable waste not only reduces their potential utility but also contributes to soil degradation. Declining organic carbon levels in soil, caused by improper waste handling, excessive use of chemical fertilizers, and over-irrigation, have adversely affected soil fertility and agricultural productivity. Restoring soil health through organic matter is essential for sustainable agriculture and long-term environmental stability.*

*Energy production remains heavily dependent on fossil fuels, leading to significant environmental impacts, particularly greenhouse gas emissions. In response, there is a global shift towards renewable energy sources and cleaner technologies. Among these, biogas technology presents a practical and sustainable solution, especially for small villages. By converting organic waste into usable energy, biogas plants address both waste management and energy needs simultaneously. Additionally, emerging alternatives such as hydrogen energy offer promising pathways toward decarbonized energy systems. This study focuses on the development and implementation of biogas plants in small villages, highlighting their potential to reduce environmental pollution, improve waste utilization, enhance soil fertility, and provide a reliable source of renewable energy, thereby contributing to sustainable rural development....*

**Keywords:** Biogas system, design, village, waste treatment plan

## I. INTRODUCTION

The Earth's elemental resources have remained constant since its origin, continuously cycling through natural systems without any net increase or decrease. These biogeochemical cycles have historically functioned in a balanced and self-sustaining manner. However, human interventions—particularly since the industrial era—have disrupted this equilibrium. The excessive release of greenhouse gases such as carbon dioxide and methane has intensified the greenhouse effect, leading to global environmental concerns. Maintaining a stable concentration of these gases is essential for sustaining life, yet rapid industrial growth, population expansion, and escalating energy demands have significantly disturbed this balance. Addressing these challenges requires a conscious shift toward reducing emissions and adopting environmentally responsible practices.

Modern society, driven by technological advancements, often exhibits a growing disconnection from natural systems. While technology has improved living standards, it has also contributed to environmental degradation. One of the most pressing issues today is ineffective waste management, largely influenced by societal attitudes. Materials commonly labeled as "waste" still possess significant resource value, yet improper handling—particularly the lack of segregation at the source—limits opportunities for reuse and recycling. Household, commercial, and institutional sectors frequently fail to separate biodegradable and non-biodegradable waste, resulting in inefficient waste processing and environmental harm.

Improper waste practices have also contributed to soil degradation. The mixing of organic and inorganic waste reduces the potential for composting and leads to the gradual decline of soil organic carbon, which is crucial for maintaining soil fertility. The excessive use of chemical fertilizers and improper irrigation practices have further weakened soil health, causing long-term damage to agricultural productivity. Rebuilding soil quality through organic inputs is therefore essential for sustainable farming and food security.

Energy plays a vital role in economic development, yet current systems are still largely dependent on fossil fuels, which contribute significantly to greenhouse gas emissions. This has accelerated the global transition toward renewable energy solutions. Among these, biogas technology offers a practical and sustainable approach, especially for rural communities. By converting organic waste into energy, biogas systems address both waste disposal and energy generation. This study explores the potential of biogas plants in small villages as an effective solution for environmental management, renewable energy production, and sustainable rural development.

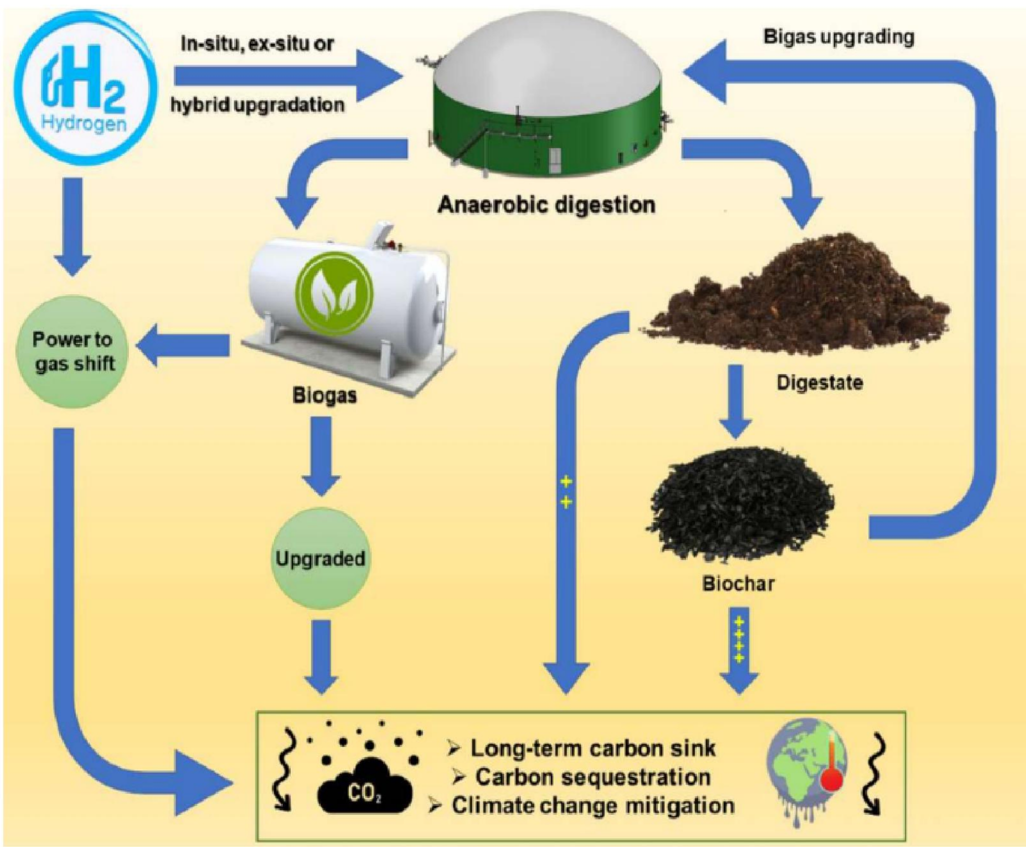


**Fig.1. Process of hydrogen making from biogas to hydrogen**

## II. LITERATURE REVIEW

A review of existing literature highlights the growing importance of biogas technology as a sustainable solution for rural energy generation and waste management. Early work by Khandelwal and Mahdi (1986) emphasized the potential of biogas plants in developing countries, particularly in utilizing cattle dung and agricultural residues for energy production. Similarly, Fulford (1988) discussed the practical design and operation of small-scale biogas systems, identifying them as suitable for rural applications due to their simplicity and adaptability.

Studies by Bond and Templeton (2011) examined the environmental benefits of biogas technology, noting its role in reducing greenhouse gas emissions and improving waste management practices. Their findings suggest that biogas systems significantly reduce methane emissions by capturing and utilizing organic waste efficiently. In addition, Surendra et al. (2014) analyzed the integration of biogas production with waste management systems and highlighted improvements in sanitation and resource recovery.

Research focusing on rural development by Singh and Sooch (2004) demonstrated that biogas plants enhance energy accessibility in villages, reducing reliance on traditional fuels such as firewood and kerosene. This transition not only conserves natural resources but also improves indoor air quality. Furthermore, Amigun et al. (2012) explored the socio-economic feasibility of biogas systems, concluding that long-term benefits outweigh initial investment costs, especially when supported by government policies and community participation.

The role of biogas by-products has also been widely studied. Yadvika et al. (2004) reported that digestate produced from biogas plants serves as an effective organic fertilizer, improving soil fertility and increasing crop yield. This aligns with findings by Holm-Nielsen et al. (2009), who emphasized the dual benefits of energy generation and nutrient recycling through biogas systems.

More recent research by Scarlat et al. (2018) highlighted the role of biogas in achieving sustainable energy goals and reducing carbon emissions globally. Their study also discussed policy frameworks supporting the adoption of renewable energy technologies. Overall, the literature indicates that biogas technology is an effective and sustainable solution for addressing energy shortages, improving waste management, enhancing soil health, and promoting rural development, particularly in small village settings.

## III. METHODOLOGY

The methodology adopted for the study of biogas plants for small villages is based on a systematic and practical approach that integrates data collection, analysis, design considerations, and performance evaluation. The study begins with the selection of a representative rural area where the availability of organic waste such as cattle dung, agricultural residues, and household biodegradable waste is sufficient to support biogas production. A preliminary survey is conducted to understand the demographic profile, number of households, livestock population, existing energy consumption patterns, and current waste management practices. This baseline assessment helps in estimating the quantity of feedstock available for biogas generation.

Following the survey, the potential for biogas production is calculated based on standard yield values of organic waste. The daily availability of raw materials is analyzed to determine the size and capacity of the biogas plant suitable for the selected village. Design parameters such as digester type, volume, retention time, temperature conditions, and gas storage requirements are carefully considered. A suitable model, such as a fixed-dome or floating-drum biogas plant, is selected based on economic feasibility, ease of maintenance, and local adaptability.

The next phase involves the preparation of a structural and functional design of the biogas plant. This includes layout planning, material selection, and construction methodology. Emphasis is given to the use of locally available materials and cost-effective construction techniques to ensure affordability and sustainability. The process flow—from waste collection and segregation to anaerobic digestion and gas utilization—is clearly defined.

Experimental or observational analysis is carried out to evaluate the performance of the system. Parameters such as biogas yield, methane content, digestion efficiency, and retention time are monitored. In addition, the quality and usability of the by-product (digestate) as an organic fertilizer are assessed. Comparative analysis is performed between conventional energy sources and biogas in terms of cost, efficiency, and environmental impact.

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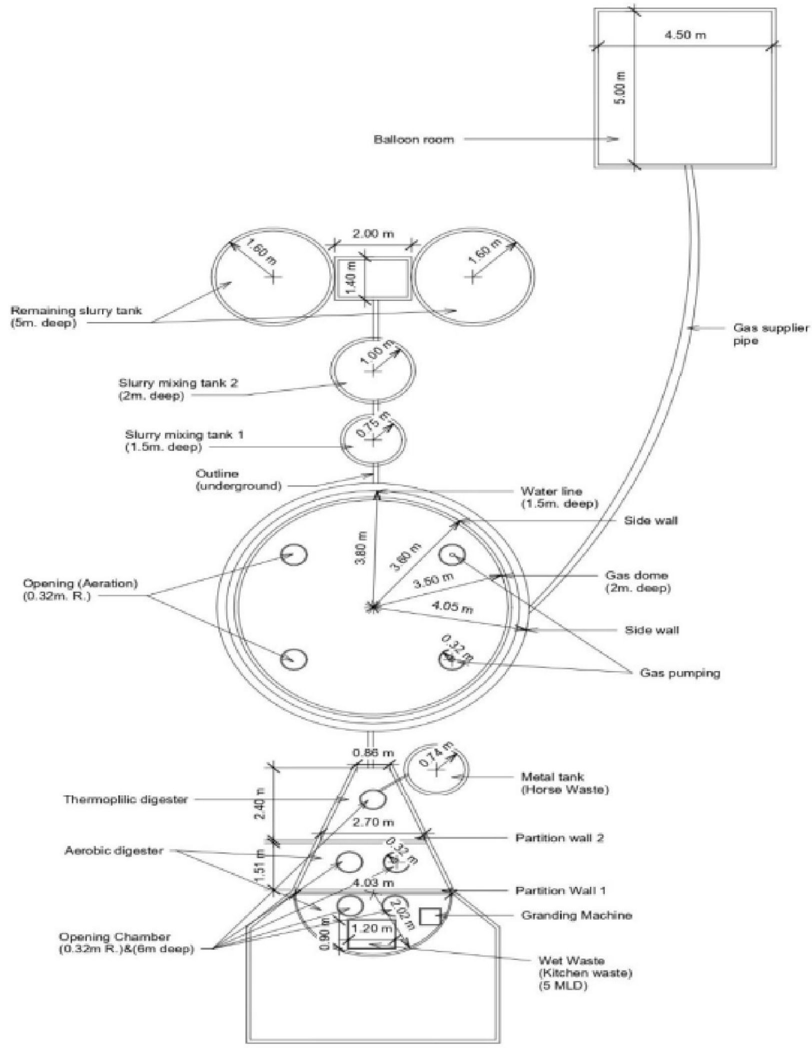


Fig 2. Layout of Nisargruna Biogas Plant Matheran

Finally, the economic and environmental feasibility of the proposed system is evaluated. Cost estimation includes installation, operation, and maintenance expenses, while benefits are measured in terms of energy savings, waste reduction, and improvement in soil fertility. The methodology ensures a comprehensive assessment of biogas technology as a viable and sustainable solution for small village applications.

## IV. BIOGAS PRODUCTION CALCULATIONS

Biogas production in small villages can be estimated based on the quantity of organic waste available, particularly cattle dung and biodegradable household waste. The calculation primarily depends on the daily input of feedstock, its biogas yield potential, and operating conditions of the digester.

The first step involves estimating the total quantity of raw material available per day. For example, an average cow produces about 10–15 kg of dung per day. If a village has 50 cattle, the total dung availability can be approximated as 500 kg/day. In addition to cattle dung, kitchen waste and agricultural residues may contribute an additional 50–100 kg/day of biodegradable material.

The biogas yield from cattle dung is generally taken as 0.03–0.04 m³ of biogas per kg of fresh dung. Assuming an average yield of 0.036 m³/kg, the daily biogas production can be calculated as:

Biogas Production (m³/day) = Quantity of dung (kg/day) × Gas yield (m³/kg)

= 500 × 0.036 = 18 m³/day

If additional organic waste of 80 kg/day is included with a similar yield factor, then:

Additional gas = 80 × 0.04 = 3.2 m³/day

Total biogas production = 18 + 3.2 = 21.2 m³/day

Next, the digester size is calculated based on the hydraulic retention time (HRT), which typically ranges from 30 to 50 days depending on climatic conditions. Assuming an HRT of 40 days and daily slurry input equal to the dung-water mixture (usually in 1:1 ratio), the total slurry input becomes 1000 kg/day (500 kg dung + 500 kg water ≈ 1 m³).

Digester Volume (m³) = Daily slurry input (m³/day) × HRT (days) = 1 × 40 = 40 m³

Thus, a digester of approximately 40 m³ capacity is required.

In terms of energy equivalence, 1 m³ of biogas is roughly equal to 0.43 kg of LPG. Therefore, total daily biogas production of 21.2 m³ is equivalent to:

21.2 × 0.43 ≈ 9.1 kg LPG/day

This indicates that the system can significantly reduce dependence on conventional fuels. The calculation demonstrates that even a small village can generate sufficient energy through proper utilization of organic waste, making biogas plants a viable and sustainable solution.

## V . CONCLUSION

The transition from a Biogas Plant to Hydrogen Production represents a pivotal shift in how we approach the global energy crisis. By integrating organic waste management with advanced hydrogen extraction, we move beyond simple waste disposal and into the realm of high-efficiency, circular energy systems. The integration of biogas and hydrogen technology is more than just a technical upgrade; it is a commitment to a circular economy. It proves that sustainable development doesn't require us to choose between the environment and energy—it allows us to power the future using the remnants of the past.

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