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TECHNO-ECONOMIC ASSESSMENT OF A CHICKEN-MANURE-FED BIOGAS GENERATOR SYSTEM IN A PHILIPPINE FARM

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ABSTRACT

Chicken manure is an abundant agricultural waste stream capable of supporting decentralized biogas power systems. This study presents a techno-economic assessment of a 160 kW biogas generator operating on chicken-manure-derived biogas in a tropical Philippine farm. Using realistic but generic technical parameters, the system consumes approximately 90 Nm^3/hr of biogas at 55% methane content and generates an estimated 1.27 gigawatt-hours (GWh) of electricity annually. Methane mitigation totals roughly 260,000 kg/year, equivalent to 6,500 tons of carbon dioxide equivalent (CO_2eq) using a Global Warming Potential over 100 years (GWP100) of 25. Diesel displacement exceeds 380,000 liters annually. With a capital cost of PHP 6.5 million and annual operating expenses of PHP 1.4 million, the system achieves net annual savings of approximately PHP 15 million, yielding a payback period of about five months and a Return on Investment (ROI) exceeding 200%. Findings demonstrate that chicken-manure-fed biogas generator systems offer strong technical, environmental, and economic benefits suitable for rural energy applications.

Keywords: Chicken Manure, Renewable Energy, Generator System, Techno-Economic Analysis, Methane Mitigation

INTRODUCTION

Agricultural waste-to-energy systems present both challenges and opportunities for developing countries such as the Philippines. Large-scale poultry operations generate significant quantities of chicken manure, which, if unmanaged, decomposes anaerobically and emits methane. Methane is a greenhouse gas with a global warming potential approximately 27–30 times greater than carbon dioxide over a 100-year period, making it a particularly potent contributor to climate change U.S. Environmental Protection Agency (n.d.). Converting chicken manure into biogas therefore supports both waste mitigation and renewable energy adoption.

Electricity demand in the Philippines continues to increase annually. The Department of Energy reported that total electricity consumption for 2024 reached 126,941 GWh Department of Energy (Philippines) (2024). Alongside grid supply, many rural agricultural operations still rely on diesel generators to meet their power needs, resulting in higher operating costs and exposure to volatile fuel prices. These challenges underscore the importance of alternative, locally sourced renewable energy solutions.

Chicken manure offers substantial potential as a substrate for anaerobic digestion due to its high biodegradability and organic content. Controlled digestion produces methane-rich biogas suitable for combustion in generator sets. The system not only stabilizes waste but also reduces uncontrolled methane emissions, supporting broader climate objectives.

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Transparency: The authors affirm that this manuscript presents an honest, accurate, and transparent account of the study. All essential aspects have been included, and any deviations from the original study plan have been clearly explained. The writing process strictly adhered to established ethical standards.

This paper evaluates the feasibility of operating a 160-kW biogas generator using chicken manure-derived biogas in a tropical Philippine farm. Realistic, standardized assumptions were applied to estimate biogas requirements, methane utilization, greenhouse gas mitigation, and economic returns. The study employs an integrated engineering and management perspective to determine the system's viability as a renewable energy solution for agricultural settings.

MATERIALS AND METHODS

BIOGAS POTENTIAL OF CHICKEN MANURE

Chicken manure contains high nitrogen, volatile solids, and readily biodegradable organic material, making it a strong substrate for anaerobic digestion Gerardi (2003), Kelleher et al. (2002). Typical biogas yields range from 0.035–0.060 m^3/kg of fresh manure, with methane concentrations of 50–65%, as reported in both foundational and recent studies Kelleher et al. (2002), Mozhi et al. (2021), Al et al. (2020). These parameters confirm poultry manure as a reliable, energy-rich feedstock suitable for farm-scale biogas-to-electricity systems.

ANAEROBIC DIGESTION PROCESS

Anaerobic digestion (AD) is a microbiological process in which organic substrates are decomposed in the absence of oxygen, producing methane-rich biogas and a stabilized digestate byproduct. It is widely recognized as an effective method for waste treatment, renewable energy generation, and greenhouse gas mitigation Appels et al. (2008), Metcalf and Eddy (2014). It progresses through four sequential stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis Meegoda et al. (2018), Anukam et al. (2019). Stable biogas production is supported by mesophilic operating temperatures of approximately 35–39 °C, which encourage optimal microbial activity for chicken manure digestion Elsayed et al. (2024), Steiniger et al. (2023), Nie et al. (2021). Maintaining a near-neutral pH (typically 6.8–7.4) prevents acidification and process inhibition, while appropriate organic loading rates and hydraulic retention times promote steady methane formation Kumar et al. (2024), Harirchi et al. (2022). Collectively, these parameters ensure efficient conversion of manure into combustible biogas suitable for generator-set applications.

SITE CHARACTERISTICS

The site is located in a tropical Philippine region with ambient temperatures of 22–33°C and relative humidity above 80%. These conditions are typical for Southeast Asian poultry operations.

SYSTEM DESCRIPTION

The biogas-to-power system evaluated in this study consists of a chicken-manure-fed anaerobic digester and a spark-ignited internal combustion generator designed to operate solely on biogas. The generator is rated at 160 kW, suitable for continuous electrical load operation common in agricultural facilities.

Collected chicken manure is conveyed into the digester, where controlled anaerobic conditions convert organic matter into biogas. The produced biogas undergoes preliminary purification, including removal of hydrogen sulfide (H_2S) and moisture through gas scrubbers and condensate traps. This treatment preserves engine life and ensures consistent combustion quality. The conditioned biogas is fed to the generator with an assumed methane concentration of 55%. This value falls within standard performance ranges reported in literature for poultry-based biogas systems. Electrical output is converted through an integrated switchgear system, enabling safe distribution either to farm operations or as supplemental power for local consumption.

This configuration represents a realistic farm-scale renewable-energy installation capable of lowering reliance on grid electricity or diesel generators. The system description forms the basis for the techno-economic calculations presented in this study.

COMPUTATIONAL METHODS

BIOGAS ENERGY CONTENT (MJ/NM³)

$$LHV_{biogas} = CH_4\% \times LHV_{CH4} \quad (1)$$

CH4% is the methane concentration assumed at 55%

LHV_{CH4} is the Lower Heating Value of methane (35.8 MJ/Nm3) based on its concentration level

BIOGAS FLOW REQUIREMENT (NM3/HR)

$$Q = P\eta \times LHV_{biogas} \tag{2}$$

P is the rated power

η is the generator efficiency assumed at 33%

LHVbiogas is the calculated Lower Heating Value of the biogas (1 kWh = 3.6 MJ)

METHANE MASS FLOW RATE (KG CH_4/HR)

$$\dot{m}_{CH4} = Q_{biogas} \times CH_4\% \times \rho_{CH4} \tag{3}$$

Qbiogas is the biogas flow rate

ρCH4 is the density of methane at normal conditions at 0.67 kg/Nm3

ANNUAL METHANE UTILIZATION (KG CH_4/YEAR)

$$m_{CH4\_annual} = \dot{m}_{CH4} \times H \tag{4}$$

H is the Annual Operating Hours (24 hrs/day × 330 days/yr)

GREENHOUSE GAS MITIGATION (TONS/YEAR)

$$CO_{2eq\_annual} = m_{CH4\_annual} \times GWP \times 1\ ton/1000\ kg \tag{5}$$

GWP is the 100-year Global Warming Potential of methane

ANNUAL ELECTRICITY GENERATION (KWH/YEAR)

$$E_{annual} = P \times H \tag{6}$$

DIESEL DISPLACEMENT (LITERS/YEAR)

$$Diesel = E_{annual} \times SFC \tag{7}$$

SFC is the specific fuel consumption of a typical diesel generator at 0.30 Liters/kWh

ECONOMIC METRICS

ANNUAL REVENUE OR COST SAVINGS FROM ELECTRICITY (PHP/YEAR)

$$Revenue = E \times T \tag{8}$$

T is the electricity tariff at PHP 13/kWh

NET ANNUAL SAVINGS (PHP)

$$\textbf{Savings = Revenue - OPEX} \tag{9}$$

OPEX is the operating expenses estimated at PHP 1,400,000.00 (Powercity data)

PAYBACK PERIOD (MONTHS)

$$Payback = \frac{CAPEX}{Savings} \tag{10}$$

CAPEX is the capital costs in the generator installation at PHP 6,5000,000.00 (Powercity data)

RETURN ON INVESTMENT (ROI)

$$ROI = \frac{CAPEX}{Savings} \times 100 \tag{11}$$

RESULTS AND DISCUSSIONS

TECHNICAL PERFORMANCE

The biogas generator operated consistently at its rated output of 160 kW, supported by an estimated fuel requirement of 90 Nm^3/hr. This value is directly obtained from the energy balance in the methodology, which incorporates a generator efficiency of 33% and a biogas lower heating value of 19.7 MJ/Nm^3 derived from a methane concentration of 55%. The conformity of these results with established anaerobic digestion and biogas engine performance ranges suggests that the assumed biogas quality is sufficient to sustain stable combustion and continuous operation.

Based on 7,920 operating hours per year, the system is projected to generate approximately 1.27 GWh of electricity annually. This output represents a substantial portion of the energy demand for typical farm operations and demonstrates the system's capacity to replace or reduce reliance on diesel generators and grid electricity. The calculated performance indicates that, under the given assumptions, a chicken-manure-fed biogas generator can provide a dependable and decentralized energy source.

ENVIRONMENTAL IMPACT

The environmental benefits of the system were assessed by quantifying methane utilization and the resulting reduction in greenhouse gas emissions. Based on a biogas consumption rate of 90 Nm^3/hr and a methane fraction of 55%, the methane mass flow was calculated at approximately 33 kg/hr using the density of methane at standard conditions. When applied over 24 hours and 330 operational days, annual methane utilization reaches roughly 260,000 kg. This captured methane would otherwise be released during unmanaged manure decomposition, making its conversion to energy a direct mitigation of agricultural methane emissions.

Using the GWP100 factor of 25, the annual methane utilization corresponds to an estimated 6,500 tons of CO_2-equivalent emissions avoided. In addition to methane mitigation, the system offsets approximately 380,000 liters of diesel annually, based on the calculated energy output of 1.27 GWh and a typical diesel generator specific fuel consumption of 0.30 L/kWh. The displacement of diesel contributes further to emission reductions and reduces reliance on fossil fuels. These results demonstrate that the system provides meaningful environmental gains.

ECONOMIC FEASIBILITY

Economic performance was evaluated using the projected annual energy generation and the corresponding monetary value of displaced electricity costs. With an annual output of 1.27 GWh and an electricity tariff of PHP 13/kWh, the system yields an estimated annual revenue or avoided cost of PHP 16.5 million. After accounting for operating expenses of PHP 1.4 million, net annual savings amount to approximately PHP 15.1 million. These results are grounded in the methodology's financial equations, which link electrical output to revenue and operational costs, providing a clear basis for economic interpretation.

The system's capital cost of PHP 6.5 million is recovered in an estimated 0.43 years, or about five months, when divided by the calculated net savings. This rapid payback period reflects the economic strength of biogas-to-power systems, particularly in settings where electricity prices are high and organic waste is readily available. The implied return on investment exceeds 100 percent in the first year alone, suggesting that the technology is not only viable but financially advantageous for agricultural operations while simultaneously contributing to environmental sustainability.

CONCLUSIONS AND RECOMMENDATIONS

This study demonstrated that a chicken-manure-fed biogas generator can operate dependably under typical farm conditions and can provide a practical source of on-site power when supplied with biogas of adequate quality. The assessment showed that transforming manure-derived methane into a usable energy stream offers tangible environmental benefits by reducing emissions associated with unmanaged waste. In parallel, the economic evaluation indicated that the system can offset energy-related expenses of agricultural facilities.

These findings should be interpreted within the limits of the analytical assumptions, as actual performance may vary with site-specific manure characteristics, digester management, and equipment maintenance practices. Nonetheless, the integrated methodological approach used in this study illustrates how technical, environmental, and economic indicators can collectively inform feasibility assessments for decentralized energy systems.

Future studies may benefit from investigating how variations in manure characteristics, digester loading strategies, and operational conditions influence biogas yield and generator stability. More detailed field measurements such as real-time gas composition and digester temperature profiles would help validate and refine the assumptions used in this assessment. Exploring co-digestion or pre-treatment techniques may also provide insight into whether enhancements in substrate degradability can improve system performance.

In addition, evaluating long-term operational behavior through extended monitoring of generator efficiency and component longevity would offer valuable information about lifecycle performance and system reliability. Assessing the agronomic value of digestate under field conditions could also identify opportunities for circular resource use. Collectively, these avenues for further research can help strengthen both the methodological foundation and practical application of biogas technologies, supporting their continued development as viable renewable energy solutions for agricultural settings.

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REFERENCES

Al-Masri, M., Bani-Hani, E., Abu-Qdais, H., and Hayajneh, M. (2020). Biogas Production from Poultry Manure Under Optimized Conditions. Bioresource Technology Reports, 12, 100577.

Anukam, A., Mohammadi, A., Naqvi, M., and Granström, K. (2019). A Review of the Chemistry of Anaerobic Digestion: Methods of Accelerating and Optimizing Process Efficiency. Processes, 7(8), 504. https://doi.org/10.3390/pr7080504

Appels, L., Baeyens, J., Degrève, J., and Dewil, R. (2008). Principles and Potential of the Anaerobic Digestion of Waste-Activated Sludge. Progress in Energy and Combustion Science, 34(6), 755–781. https://doi.org/10.1016/j.pecs.2008.06.002

Department of Energy (Philippines). (2024). Summary of Electricity Consumption 2024.

Elsayed, M., Mahmoud, M., Abdelkreem, M., Azab, M., and Abdelwahab, O. (2024). Enhancing Anaerobic Digestion Efficiency: Advances in Process Optimization and Microbial Performance. Energy Conversion and Management, 307, 117902. https://doi.org/10.1016/j.enconman.2024.117902

Gerardi, M. H. (2003). The Microbiology of Anaerobic Digesters. John Wiley and Sons. https://doi.org/10.1002/0471468967

Harirchi, S., Liu, D., Chen, J., Niu, Q., Zhang, L., Dou, X., Yang, Q., and Liu, Y. (2022). Microbiological Insights into Anaerobic Digestion for Biogas Production: Microbial pathways and Engineering Implications. Bioengineered, 13(3), 6072–6090. https://doi.org/10.1080/21655979.2022.2037767

Kelleher, B., Leahy, J. J., Henihan, A. M., O'Dwyer, T. F., Sutton, D., and Leahy, M. J. (2002). Advances in Poultry Manure Disposal. Bioresource Technology, 83(1), 27–36. https://doi.org/10.1016/S0960-8524(01)00133-X

Kumar, S., Shrestha, R., Maharjan, S., Paudel, S., Sharma, H., Raut, B. K., and Tripathi, R. (2024). A Comprehensive Study on Anaerobic Digestion of Organic Waste: Process Mechanisms, Operational Factors, and Stability Considerations. Cleaner Engineering and Technology, 16, 100561. https://doi.org/10.1016/j.clet.2024.100561

Meegoda, J. N., Li, B., Patel, K., and Wang, L. B. (2018). A Review of the Processes, Parameters, and Optimization of Anaerobic Digestion. International Journal of Environmental Research and Public Health, 15(10), 2224. https://doi.org/10.3390/ijerph15102224

Meegoda, J. N., Li, B., Patel, K., and Wang, L. B. (2018). A Review of the Processes, Parameters, and Optimization of Anaerobic Digestion. International Journal of Environmental Research and Public Health, 15(10), 2224. https://doi.org/10.3390/ijerph15102224

Metcalf and Eddy. (2014). Wastewater Engineering: Treatment and Resource Recovery (5th ed.). McGraw-Hill Education.

Mozhi, A. R., Harikumar, A., Lakshmipathy, C., Ramalakshmi, S., Maheswari, M., Thangavel, S., and Arun, A. (2021). Anaerobic Digestion of Poultry Manure and Co-Substrates: A Review. Renewable Energy, 179, 1577–1590.

Nie, Y., Li, H., Xue, Y., Chen, S., Wang, Q., Zhang, X., and Liu, Y. (2021). How Temperature Regulates Anaerobic Digestion? A Review of Microbial Mechanisms and Process Stability. Renewable and Sustainable Energy Reviews, 152, 111640. https://doi.org/10.1016/j.rser.2021.111640

Steiniger, D., Tánczos, I., Pérez-Romero, A., Dörsch, P., Rebak, A., Eberl, L., García-Martín, H., and Horn, M. A. (2023). Exploring Anaerobic Digestion from Mesophilic to Thermophilic Conditions: Microbial Dynamics and Process Performance. Fermentation, 9(9), 798. https://doi.org/10.3390/fermentation9090798

U.S. Environmental Protection Agency. (n.d.). Understanding Global Warming Potentials.