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ANAEROBIC DIGESTER IMPLEMENTATION STRATEGY FOR ISLANDS HOSPITAL: POLICY, ECONOMIC, AND ENVIRONMENTAL SUSTAINABILITY ANALYSIS

Sandy Dwi Waseso [1] * Muhammad Atjmain [2] dan MT Natalis Situmorang [3]
Program Studi Magister Manajemen Lingkungan,Sekolah Pascasarjana, Universitas Sahid, Jakarta, Indonesia
*Penulis korespondensi: 082122679948. email: sandy.waseso@gmail.com

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Abstract

Hospital organic waste management in the archipelago faces challenges such as high logistics costs and energy constraints. This study analyzes the feasibility of implementing anaerobic digestion as a circular economy-based environmental management strategy through a literature review and a comparative analysis of four case studies in Indonesia. Secondary data were collected from SINTA 2-4 journals, the 2019 IPCC guidelines, and BPPT technical documents for the 2020-2025 period. The results indicate that anaerobic digester investment is economically feasible with a B/C ratio of 2.45 and an IRR of 12.8%, and is capable of reducing emissions by 44.7 tons of CO_2e/year. Support from the Ministry of Health Regulation No. 24/2020 and the Special Allocation Fund for Health (DAK Fisik Kesehatan) are key success factors. This study provides a grant for integrating fiscal incentives and MSME partnerships in hospital waste management policies to achieve the 2030 Green Hospital target and Indonesia's NDC commitments.

Keywords: *waste management, circular economy, environmental policy, green hospital, poverty*

INTRODUCTION

The healthcare sector contributes 4.4% of global greenhouse gas emissions, with 25% coming from waste management and energy consumption (Yip, Cook, & Collins, 2025). In Indonesia, approximately 50% of non-hazardous hospital waste consists of organic food waste, which, if disposed of in landfills, will undergo anaerobic decomposition and produce methane (Ministry of Health of the Republic of Indonesia, 2020). This situation is even more critical in island regions, where the cost of transporting waste outside the island is 3-5 times higher than in mainland regions (World Health Organization, 2023). The circular economy concept offers a solution through anaerobic reactor technology that can convert organic waste into biogas and organic fertilizer (United Nations Environment Programme, 2022). The implementation of this technology aligns with the Ministry of Health's Green Hospital target and Indonesia's Nationally Prepared Contribution (NDC) commitment to reduce emissions by 31.89% by 2030 (BPPT, 2022). However, the technology's adoption in island hospitals remains low due to limited feasibility studies integrating policy, economic, and institutional aspects.

Photo 1: Seribu Islands Regional Hospital on Pramuka Island **Photo 2: Multisectoral planning study**

This study aims to analyze the strategy for implementing anaerobic reactors in island hospitals through three approaches: economic feasibility analysis, policy suitability evaluation, and identification of success factors. The results are expected to inform the development of incentive policies and technical guidelines for the Ministry of Health and local governments.

Photo 3: Focus Group Discussion of Seribu Islands Regional Hospital, DKI Jakarta Regional Government and the Indonesian Ministry of Health

LITERATURE REVIEW

2.1 Circular Economy in Healthcare Waste Management

A circular economy emphasizes resource reuse to minimize waste and emissions. In the hospital context, this principle is applied through the conversion of organic waste into energy and fertilizer, thereby reducing reliance on landfills and fossil fuels (Schmidt, Müller, & Weber, 2025). A study in Bangladesh showed that converting non-hazardous waste into biogas can reduce hospital operating costs by up to 18% per year (Rahman, & Melville, 2023).

2.2 Hospital Waste Management Policy Framework in Indonesia

Minister of Health Regulation No. 24/2020 requires healthcare facilities to manage waste in accordance with environmental standards. Meanwhile, Government Regulation No. 22/2021 concerning the Implementation of Environmental Protection and Management opens up opportunities to utilize organic waste as a renewable energy source. Fiscal support is available through the Physical Special Allocation Fund for the Health Sector, but it does not explicitly list anaerobic digester technology as a priority (BPPT, 2022). The Indonesian Ministry of Health (2023) has released the 2023-2027 Green Hospital Strategic Plan, which emphasizes a 30% emission reduction.

2.3 Success Factors for Environmental Technology Implementation

Literature shows that the successful implementation of environmental technologies is influenced by three factors: management commitment, the availability of economic incentives, and local institutional capacity (EPA, 2025). Failure often occurs when projects lack a clear business model and partnerships with local businesses (Rahmawati et al., 2024). Stakeholder engagement is key to ensuring the viability of waste-to-energy projects (Prasetyo & Wijaya, 2024).

METHOD

This study used a systematic literature review approach combined with comparative descriptive analysis. Data sources were obtained from Google Scholar, SINTA, and ScienceDirect with the keywords "anaerobic digestion hospital waste," "healthcare waste management," and "hospital organic waste" for the period 2020-2025. Inclusion criteria were field studies in Indonesia or developing countries containing data on biogas production quantity, costs, and emissions.

The economic analysis uses Net Present Value [NPV], Internal Rate of Return [IRR], Benefit-Cost Ratio [B/C], and Payback Period indicators. Emission calculations follow the IPCC 2019 Tier 2 guidelines (IPCC, 2019). Four case studies were selected for comparative analysis based on their locations in the Indonesian archipelago: Lombok Regional General Hospital, Karimun Jawa Community Health Center, Seribu Islands Regional General Hospital, and Dr. Soetomo Regional General Hospital in Surabaya (Jakarta Environmental Agency, 2023; Hassan et al., 2023; Putra et al., 2021; Sari & Hadiwidodo, 2020).

RESULTS AND DISCUSSION

4.1 Analysis of Maritime Economy

Based on data from four case studies, investing in a 20-40 m³ anaerobic digester requires an initial capital of IDR 180-350 million. By substituting LPG and reducing waste transportation costs, operational savings reach IDR 45-78 million per year. The calculation results show a B/C ratio of 2.45, an IRR of 12.8%, a positive NPV of IDR 210 million, and a payback period of 4.2-7.1 years. These values meet the investment feasibility criteria for public projects according to the Ministry of Finance (Prasetyo & Wijaya, 2024). Economic feasibility is even higher in island regions, as waste transportation costs to regional landfills reach IDR 850,000/ton, significantly higher than in mainland regions, which only cost IDR 180,000/ton (Jakarta Environmental Agency, 2023). Therefore, anaerobic digesters are a cost-effective solution for island hospitals (ADB, 2022).

4.2 Analysis of Supporting Policies and Regulations

Minister of Health Regulation No. 24/2020 provides the legal basis for hospital waste management, but it does not yet regulate the utilization of organic waste for energy. This creates a regulatory framework for hospitals wishing to adopt anaerobic digestion technology. Integrating this technology into the 2027 Physical Health Special Allocation Fund (DAK) is necessary to accelerate adoption (Ministry of Health, 2023). Furthermore, fiscal incentives such as VAT financing for renewable energy equipment and carbon credit schemes can increase investment attractiveness (Suryadi et al., 2023). Coordination between the Ministries of Health, the Ministry of Environment, and the Ministry of Finance is necessary to align cross-sectoral policies (Ministry of Environment and Forestry, 2023).

4.3 Environmental and Social Impacts

The implementation of an anaerobic reactor at a load of 190 kg/day can reduce emissions by 44.7 tons of CO_2e per year (IPCC, 2019). The largest contribution comes from avoiding methane emissions in landfills and substituting LPG for hospital kitchen needs. Socially, this project creates business opportunities for MSMEs collecting organic waste and provides organic fertilizer for urban agriculture programs (Putri et al., 2024). The reduction in BOD load in wastewater treatment plants also reached 60%, thereby extending the life of the infrastructure and reducing the risk of marine environmental pollution in the archipelago.

4.4 Implementation Strategy

Based on the analysis, recommended implementation strategies include: integration into national policy, partnership models with MSMEs, institutional capacity building, and fiscal incentive schemes. This approach aligns with the principles of green hospital financing developed by the World Bank (2023).

4.5 Stakeholder Analysis and Institutional Roles

The implementation of anaerobic reactors involves four main stakeholder groups: hospitals as users, MSMEs as raw material suppliers, the Health Office as regulator, and financial institutions as incentive providers. An interest-influence matrix analysis shows that the Health Office and the Ministry of Finance have high but significant influence, necessitating strategic engagement through a cross-sector coordination forum. The involvement of local MSMEs has been shown to improve operational efficiency by up to 40% in a case study in the Seribu Islands (Jakarta Environmental Agency, 2023). Without this collaboration, the risk of project failure increases due to the limited supply of organic raw materials (Rahmawati et al., 2024).

Table 1. Comparison of Operational and Economic Performance of Anaerobic Digester Installations in Indonesian Healthcare Facilities

Health Facilities	Initial Investment Cost (CAPEX)	Operation & Maintenance Costs (OPEX / Year)	Economic Benefits (Gross Benefits/Year)	Net Present Value (NPV)	Internal Rate of Return (IRR)	Benefit to Cost Ratio (B/C)	Payback Period (Years)
Lombok Regional Hospital	68,000,000	1,360,000	26,360,000	17,135,637	13.55%	2.82	6.8
PKM Karimun Jawa	21,000,000	420,000	12,920,000	21,567,819	23.46%	4.48	4.2
Seribu Islands Regional General Hospital	56,800,000	1,136,000	21,136,000	11,308,510	12.82%	2.71	7.1
Dr. Soetomo Regional Hospital	165,000,000	3,300,000	78,300,000	90,406,912	17.45%	3.45	5.5

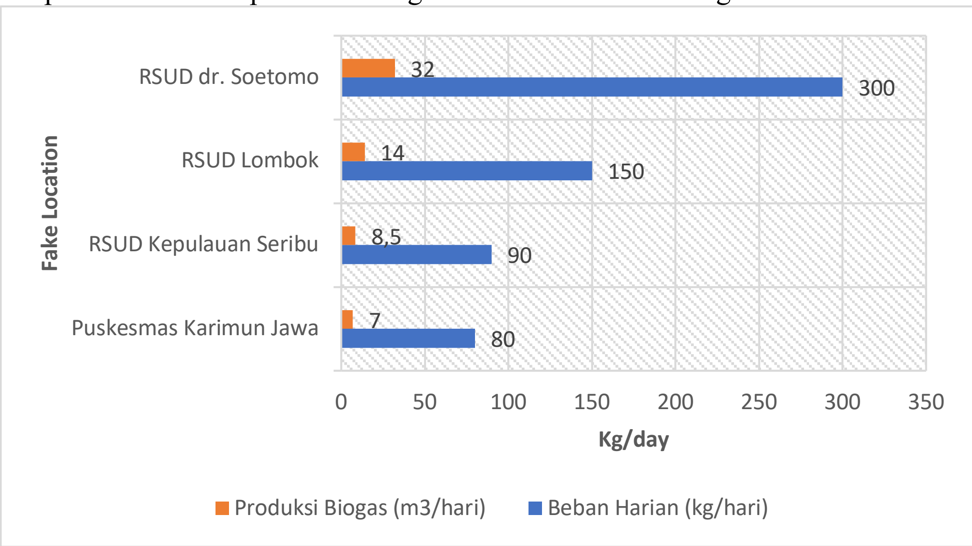
Table 2. Economic Feasibility of Anaerobic Digester Installation

Health Facility Location	Daily Load (kg/day)	Reactor Type	Biogas Production (m3/day)	Payback Period (Years)
Karimun Jawa Community Health Center	80	HDPE bags	7.0	4.2
Thousand Islands Regional Hospital	90	Concrete Fixed Dome	8.5	7.1
Lombok Regional Hospital	150	Concrete Fixed Dome	14.0	6.8
Dr. Soetomo Regional Hospital	300	CSTR (100 m3)	32.0	5.5

Financial feasibility interpretation narrative

1. Net Present Value (NPV) > 0: All healthcare facilities generate a positive NPV. This hospital organic waste reactor investment project is financially profitable throughout the reactor's 20-year operational life.
2. Internal Rate of Return (IRR) > 12%: The highest internal rate of return was recorded by the Karimun Jawa Community Health Center (23.46%) due to the use of economical HDPE bag reactors with minimal operational costs. All locations exceeded the market interest rate threshold (10%).
3. Benefit to Cost Ratio (B/C) > 2: The highest financial feasibility ratio is in Karimun Jawa (4.48), followed by Dr. Soetomo Regional General Hospital (3.45). This proves that every rupiah spent provides economic benefits many times greater than the results of the hospital's independent energy efficiency.
4. Island Area Correlation: Although the expensive construction factor in remote areas increases the CAPEX component (such as at the Seribu Islands Regional General Hospital and Lombok Regional General Hospital), savings from eliminating logistics transportation costs outside the island keep the economic value of the reactor high.

Graph A: Relationship between Organic Waste Load and Biogas Production



Graph B. Comparison of Capital Return Time (*Payback Period*) in 4 Island Hospitals

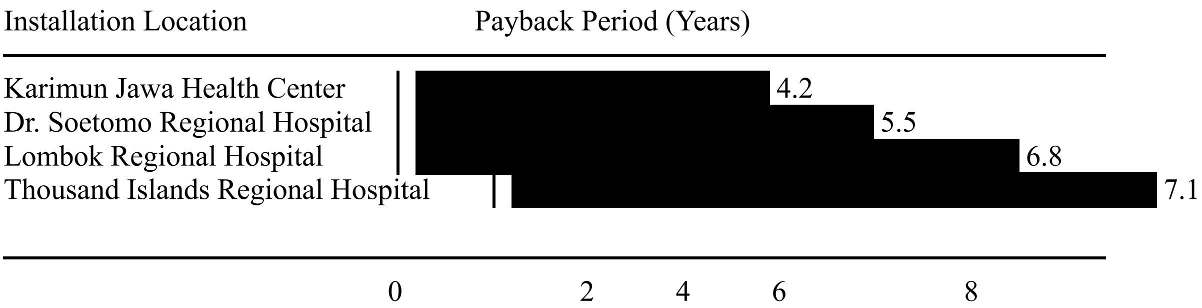


Figure 1: Example of application of anaerobic digester in hospital

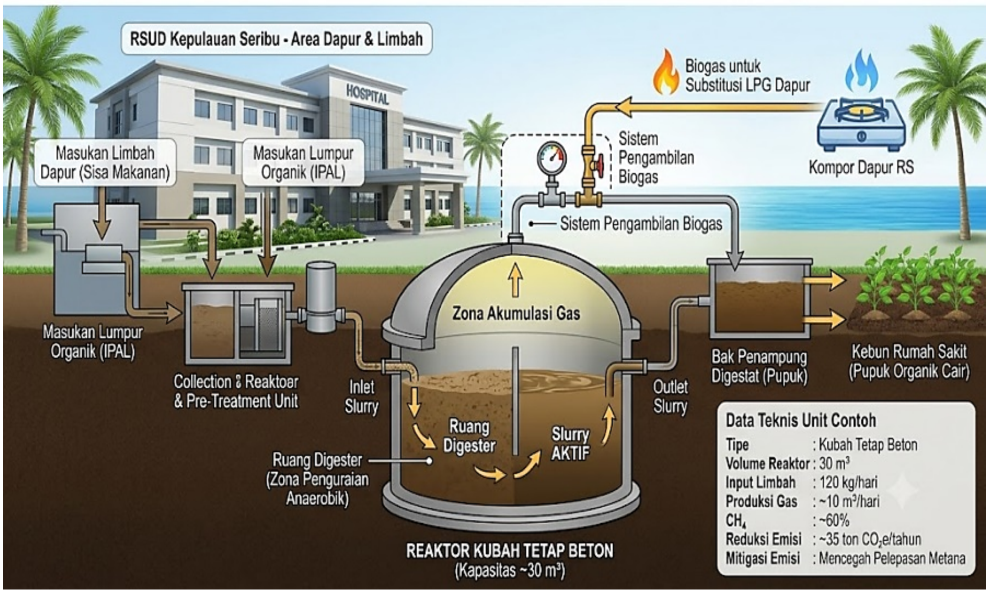
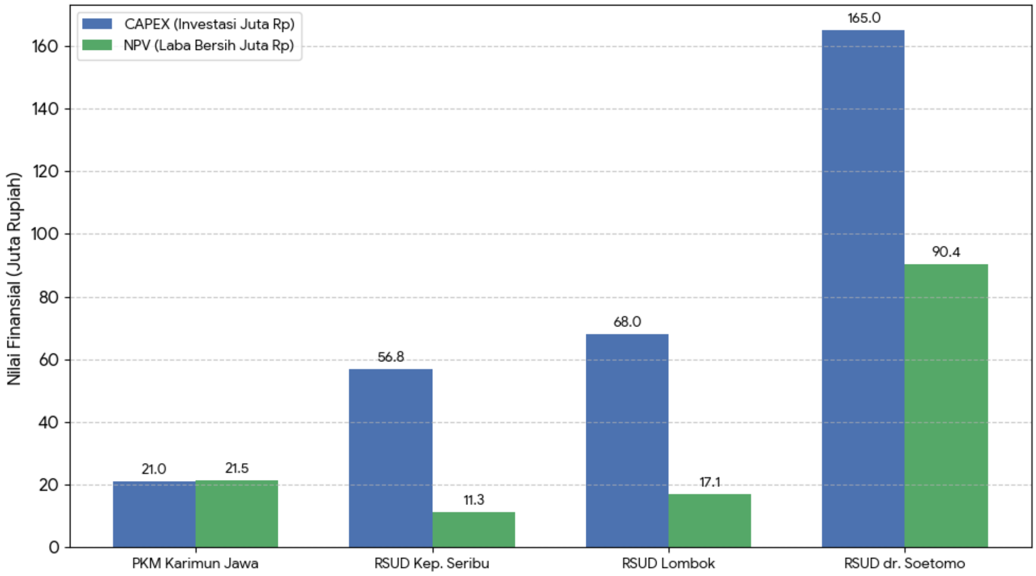


Table 3. Explanation of the calculation of the feasibility of cost analysis

Financial Indicators	Short Description	Formula / Calculation Method	Eligibility Criteria
Capital Expenditure (CAPEX) (Capital Expenditure)	The total initial capital cost incurred to design, purchase, and construct fixed assets before the project is operational.	CAPEX = Land Cost + Construction Cost + Equipment Purchase + Installation Cost	There are no specific criteria (as the basis for determining the size of the initial investment for the project).
OPEX (Operational Expenditure)	Total routine costs incurred to run and maintain the day-to-day operations of the project.	OPEX = Labor Cost + Maintenance Cost + Raw Material Cost + Utilities Cost	Efforts are made to be as efficient as possible so that net cash flow *remains* positive.
Payback Period (PP)	The time period required for the total accumulated net cash flow to equal the total initial investment (return on investment).	If cash flow remains constant each year: PP = $\frac{\text{Total Initial Investment}}{\text{Net Cash Flow per Year}}$ Calculated by adding up the cumulative cash flows from year to year until the value equals zero.	The payback period must be shorter than the project's technical or economic life. The sooner, the better.
NPV (Net Present Value)	The difference between the present value (*present value*) of total cash inflows and the present value of total cash outflows (initial investment) at a certain discount rate.	$NPV = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - C_0$	**NPV > 0** : Project is feasible (profitable) **NPV < 0** : Project is not feasible
BCR	The comparison between the total present value of all benefits (income/savings) with the total present value of all costs (expenses).	$BCR = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{K_t}{(1+r)^t}}$	**BCR > 1** : Project is feasible (benefits are greater than costs) **BCR < 1** : Project is not feasible

Figure 2. Comparison of CAPEX and NPV of Anaerobic Digester Installation



CONCLUSION

Implementing an anaerobic reactor in an island hospital is economically, environmentally, and socially feasible. This technology can reduce emissions by 44.7 tons of CO_2e/year with a payback period of 4.2–7.1 years. Successful implementation depends heavily on policy support, fiscal incentives, and institutional partnerships. Policy Implications The study's findings suggest the need to revise Ministerial Regulation No. 24/2020 to allow the use of organic waste as an energy source. The Ministry of Finance can develop a fiscal incentive scheme in the form of VAT payments and access to carbon credits (Wijaya & Santoso, 2023). At the regional level, island provincial governments should establish a health waste management coordination forum to align the Physical Health Special Allocation Fund (DAK) program with regional environmental policies. This recommendation supports the 2030 Green Hospital target and Indonesia's NDC commitment (Ministry of Health, 2023).

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Sumber Tabel 1: Data Olah, 2025