Effectiveness Analysis of Biogas Power Plant at PT. Gree Energy Hamparan

M. Marbun[1], D. Despa[2,3*], T. Septiana[4], and M. Martinus[5]

[1]PT Gree Energy Hamparan, Jl. Lintas Sumatera km. 257 Desa Terbanggi Ilir Kec. Bandar mataram Kab. Lampung Tengah, Lampung, Indonesia. 34149
[2]Departement electrical engineering, Faculty of Engineering, Lampung University, Gedong Meneng, Rajabasa, Bandar Lampung, Indonesia. 35141
[3]Departement of Profesional Engineering Program, Faculty of Engineering, Lampung University, Gedong Meneng, Rajabasa, Bandar Lampung, Indonesia. 35141
[4]Departement Informatics engineering, Faculty of Engineering, Lampung University, Gedong Meneng, Rajabasa, Bandar Lampung, Indonesia. 35141
[5]Departement Mechanical engineering, Faculty of Engineering, Lampung University, Gedong Meneng, Rajabasa, Bandar Lampung, Indonesia. 35141
*despa@eng.unila.ac.id

Abstract. PT. Gree Energy Hamparan has revolutionized the use of tapioca wastewater, transforming it into biogas, which is then converted into fuel for power generation. Collaborating with PT. Hamparan Bumi Mas Abadi, the tapioca factory that produces the wastewater, and PT. PLN as the recipient of electrical energy, the company has encountered factors hindering the operation of the biogas power plant, resulting in its low effectiveness in meeting the installed and contract capacity with PT. PLN. This case study identifies the key factors contributing to the inefficiency which are limited availability of biogas fuel, customer unpreparedness to receive energy, human resources, and power plant reliability. The analysis reveals that the two most critical factors are the limited availability of biogas fuel and customer unpreparedness. To address these issues, the tapioca factory must process wastewater routinely to produce the necessary biodigester reactor wastewater required by the power plant. Additionally, PT. PLN must improve its medium-voltage network service to minimize energy loss. Urgent action is needed to address these issues and improve the effectiveness of the biogas power plant at PT. Gree Energy Hamparan. The study showed that the lack of biogas raw materials and translated to lack of biogas power plant energy output (only 70% of contract to PT. PLN) and also the unpreparedness of PT. PLN as the energy recipient.

Keywords: Biogas Power Plant, Ineffectiveness, Energy, Tapioca wastewater.

1. Introduction

Indonesia has long relied on non-renewable fossil fuels as its primary source of energy [1]. However, fluctuating international oil prices have caused the government to increase domestic fuel prices, burdening the people and private sectors. To overcome this, the government and private sectors must seek alternative or renewable energy sources. While Indonesia has various alternative or renewable energy sources, their utilization is not yet optimal [2]. Biogas is one such source, which can be produced from agricultural and livestock manure. The technology for biogas production has been

A. Zakaria et al. (eds.), *Proceedings of the 1st International Conference on Industry Science Technology and Sustainability (IConISTS 2023)*, Advances in Engineering Research 235,
https://doi.org/10.2991/978-94-6463-475-4_31

available for decades but has not been widely adopted due to the convenience and low cost of fossil fuel energy [3].

Lampung Province, located in the southern part of Sumatra, is one of Indonesia's largest agricultural industrial areas, with cassava factories producing large amounts of solid and liquid waste [4]. The solid waste is used as animal feed and fertilizer, while the liquid waste is an excellent feedstock for biogas production. PT. Gree Energy Hamparan is a company that has taken advantage of tapioca wastewater to produce biogas for power generation. They work in collaboration with PT. Hamparan Bumi Mas Abadi, a cassava factory that has a production capacity of 200 tons per day and produces 3,000 tons of wastewater per day. According to studies, this cassava wastewater can generate 2500 kW of electricity if processed into biogas for power generation [5]. Since 2016, PT. Gree Energy Hamparan has collaborated with PT. Hamparan Bumi Mas Abadi and PT. PLN (Perusahaan Listrik Negara) to supply energy to the medium-voltage grid. The biogas power plant project began in February 2018 and was commissioned in December 2020. Effective operation began in January 2021, and the amount of kWh generated from January to December 2021 is shown in Table 1 [5].

Increasing energy demands in Indonesia necessitate the exploration and utilization of renewable energy sources. Biogas production from cassava wastewater is one such source that can be used for power generation. PT. Gree Energy Hamparan has already put this technology into practice, collaborating with PT. Hamparan Bumi Mas Abadi and PT. PLN, to supply energy to the grid, and the project's successful operation from January to December 2021 shown the potential of this renewable energy source.

Table 1. Energy Export of PT. Gree Energy Hamparan Power Plant to PT. PLN in 2021.

Month	Target (kWh)	Actual (kWh)	Deviation (kWh)	%(Act/Target)
January	823.814	825.366	1.552	100.20%
February	1124.724	1110.962	-13.762	98.8%
March	1054.004	822.753	-231.251	78.1%
April	1371.375	754.745	-616.630	55.0%
May	1263.930	357.307	-906.623	28.3%
June	1371.375	415.644	-955.731	30.3%
July	1371.375	910.036	-461.339	66.4%
August	1054.004	1315.914	261.910	124.8%
September	1401.278	1077.663	-323.615	76.9%
October	1371.375	824.672	-546.703	60.1%
November	1371.375	693.765	-677.610	50.6%
December	1421.375	573.293	-848.082	40.3%
Yearly	15000	9682.120	-5317.884	64,5%

The main issue in this case study is the low effectiveness of the biogas power plant in meeting the installed capacity and contract capacity with PT. PLN. To tackle this issue,

there is a need to analyze the factors that cause low energy production from the plant and the necessary policies to improve its effectiveness. Based on the problem description, the primary objective of this study is to provide a strategic plan for improving the effectiveness of the biogas power plant at PT. Gree Energy Hamparan. The study aims to identify the factors affecting the power plant's energy production and recommend feasible solutions to address these issues.

Generally, effectiveness refers to a condition that indicates the level of success or achievement of a goal measured by quality, quantity, and time in accordance with the previously planned objectives. Effectiveness is the relationship between the output of the operation and the target that must be achieved. The greater the contribution of the output to the achievement of the target, the more effective the unit can be considered to be [6].

The primary measuring tool for assessing the effectiveness of a task is its results. The achievement of the final outcome of an activity can be seen by adjusting the results obtained with the objectives that have been set before the work is carried out. Therefore, before the activity is carried out, the expected goals must be determined. If these objectives do not meet expectations, it means that the activity is ineffective.

Table 2. Criteria for Effectiveness [6].

Percentage	Criteria
100% and above	Very Effective
90%-100%	Effective
80%-90%	Adequate
60%-80%	Inadequate
Below 60%	Ineffective

The reliability of a power generation system is defined as the probability of successful operation of the power generation system to serve the system load during certain periods and conditions. In this case, one day per year is taken as a benchmark for the reliability level. The reliability of the power plant is influenced by the installed capacity, maintenance methods, and availability of spare parts [7].

2. Methodology

This research was conducted with a conceptual framework of analyzing various factors that affect the low effectiveness of the power plant. The conceptual model framework, also known as the theoretical framework, is a model presented in the form of a diagram that shows the structure and logical relationships between the identified research variables from the theory and findings of the article review, which will be used to analyze the case study [8]. In this case study, the author analyzed several factors that

contribute to the low effectiveness of the biogas power plant at PT. Gree Energy Hamparan by collecting operational data in 2021 as shown in Fig. 1 as below:

1. Data on biogas raw materials, namely cassava production, tapioca wastewater, COD of tapioca wastewater, calculating biogas potential, and calculating potential energy production. This calculation was then compiled in a monthly table. From the data collected in 2021, the availability of biogas and the potential energy production in 2021 were calculated and compared to the kWh target in 2021.
2. Installed capacity, maintenance method, and spare part readiness. This data will be examined to see whether it has a positive or negative impact on kWh production.
3. Human resources, including the reliability and professionalism of human resources, and their impact on energy production.
4. Data on the number of hours of disruptions that occurred on the customer's side (PT. PLN) in one year, resulting in the customer being unable to receive energy from PT. Gree Energy Hamparan. The number of disruption hours will be calculated, and the potential loss of kWh during 2021 will be determined.

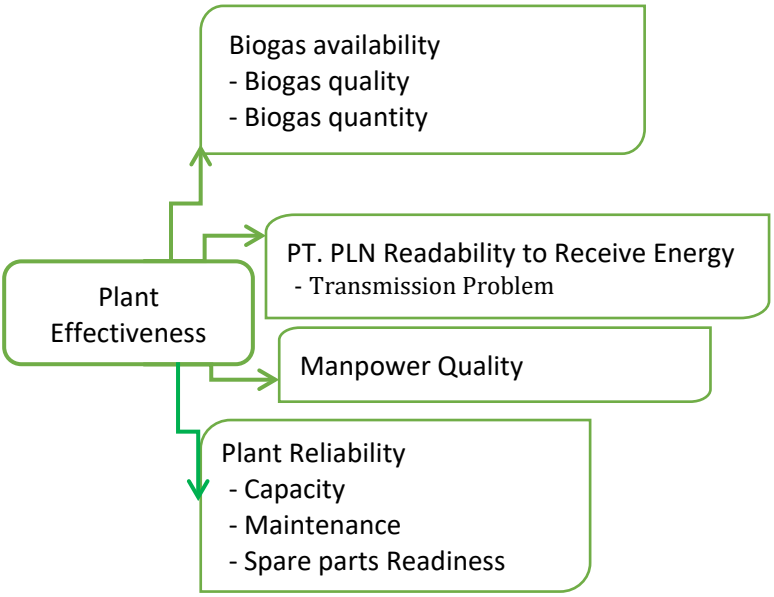

Fig 1. Conceptual Frameworks.

3. Result and Discussion

Table 4 showed data on the production of raw materials and wastewater received by PT. Gree Energy Hamparan from PT. Hamparan Bumi Mas Abadi in 2021. The latter is the partner company of PT. Gree Energy Hamparan and is a cassava factory that

generates wastewater as a byproduct. The table provides information on the quantity of raw materials, i.e., cassava production, and the volume of wastewater generated by the factory. PT. Gree Energy Hamparan utilizes this wastewater as a raw material to produce biogas which is then processed into fuel for power generation. Therefore, the data in Table 4 is important for PT. Gree Energy Hamparan to determine the availability of raw materials needed to achieve the energy export target of 15000 MWh in one year. The company needs at least 2100 m^3 of wastewater per day or 739000 m^3 per year, with wastewater quality of COD reduction ±14.5 kg/m^3 to reach the production target. However, the actual waste water obtained from PT. Hamparan Bumi Mas Abadi is only an average of 1428 m^3 per day with COD ±14.5 kg/m^3, which can only produce maximal of 2856 kWh per day, while the annual production target is 15000 MWh. Therefore, the data in Table 4 is crucial for PT. Gree Energy Hamparan to evaluate the number of raw materials available to produce biogas and achieve the energy export target as contract to PT. PLN.

Table 3. Production Data of Raw Materials and Wastewater Received by PT. Gree Energy Hamparan in 2021.

2021 Data	Cassava Production (Ton)	Starch Production (Ton)	Cassava Waste Water (m^3)	Average CODin (kg/m^3)	Average CODout (kg/m^3)	Average COD Reduction (kg/m^3)
January	14636	3207	49840	12.7	0.6	12.1
February	19702	4130	52713	15.6	0.5	15.1
March	22500	4889	44158	14.1	0.6	13.5
April	11515	2671	34462	18.3	0.6	17.7
May	4011	943	12730	20.5	0.5	20
June	5965	1365	18841	16.4	0.6	15.8
July	18529	4035	40272	16.4	0.6	15.8
August	20945	4726	72578	13.8	9.7	13.1
September	19370	4203	59276	13.5	0.5	13
October	15560	3180	47290	12.9	0.5	12.4
November	15005	3248	47091	11.7	0.7	11
December	14957	2981	41826	15.4	0.7	14.7
Yearly	182695	39460	521077			
Daily Average	501	0.108	1428			14.5

From the data, the potential biogas and energy can be calculated using the formula as follows:

$$V_{bg} = \frac{COD_{re} \; x \; V_{al}}{0.5} x \; 0.35$$

[5], [9]

Where:
V_{bg} = Biogas volume (m^3)
COD_{re} = COD reduction (kg/m^3)
V_{al} = Wastewater volume (m^3)
0.35 = Biogas production in m^3 per 1kg COD reduction
0.5 = Methane content factor
The conversion of biogas to energy is 1 m^3 at a methane content of 50%-70% produces around 2 kWh. With the equation in hand, we can calculate the equivalent estimated electrical energy that can be exported to PT. PLN, as shown in Tabel 6. It is shown that the power output from the biogas power plant is well below the plant maximum capacity. The plant output yearly is 10128 MWh again well below the contract 15000 MWh.

Table 4. Equivalent Estimated Electrical Output from Biogas Powerplant.

2021 Data	Biogas Volume (m3)	Estimated Equivalent Electric Energy (kWh)
January	42214.48	84428.96
February	55717.64	111435.3
March	41729.31	83458.62
April	42698.42	85396.84
May	17822	35644
June	20838.15	41676.29
July	44540.83	89081.66
August	66554.03	133108.1
September	53941.16	107882.3
October	41047.72	82095.44
November	36260.07	72520.14
December	43038.95	86077.91
Yearly	506402.8	1012806
Daily	1428	2856

Customer (PLN) Readiness to Receive Energy. Table 5 illustrates that the PT. PLN grid transmission experienced numerous downtimes, resulting in a loss of energy transferred from the power plant to the PT. PLN Grid.

Table 5. PT. PLN Grid Disturbance Data and Potential Export Loss of PT. Gree Energy Hamparan Power Plant in 2021.

Electric Power Contract to PT. PLN (kW)		**2500**
Month	Downtime (hour)	Potential Electric Energy Loss (MWh)
January	7.0	17.50
February	18.0	45
March	4.0	10
April	50.0	125
May	0.0	0
June	0.0	0
July	4.0	10
August	24.0	60
September	9.0	22.50
October	3.5	8.75
November	15.0	37.50
December	122.0	305
Yearly	256.5	641.25

From the calculation in Table 7, the loss of energy export to the grid network of PT. PLN is 641 MWh or 4.3% of the target production in one year just due to grid down time.

Power Plant Reliability. The installed capacity of this power plant is 3000 kW, so it is very capable of producing 2500 kW. The maintenance of this power plant is carried out through preventive maintenance in accordance with standard operating procedures, and spare parts are always available in the warehouse in case of maintenance. In general, this power plant is very reliable according to the reliability test conducted during commissioning.

4. Conclusion

This case study has concluded that the main factors contributing to the low effectiveness of the biogas power plant at PT. Gree Energy Hamparan are the insufficient supply of biogas feedstock and the unpreparedness of PT. PLN to receive energy.One of the main factors contributing to the low effectiveness of the biogas power plant at PT. Gree Energy Hamparan is the insufficient supply of biogas feedstock. The required amount of feedstock to achieve the energy production target of 15000 MWh per year is at least 739000 m^3 or 2.1 m^3 per day, with a wastewater

quality of approximately ±14.5 kg/m^3 COD reduction. However, the actual amount of wastewater received from the cassava factory partner, PT. Hamparan Bumi Mas Abadi, is only an average of around 1428 m^3 per day with a COD of ±14.5 kg/m^3. Under these conditions, only about 10128 MWh or approximately 70% of the energy production target can be achieved. This indicates a missed opportunity to export energy by 30%.

Another factor affecting the effectiveness of the biogas power plant at PT. Gree Energy Hamparan is the unpreparedness of PT. PLN to receive energy. There is a loss of energy export to the PT. PLN grid of 641 MWh or about 4.3% of the production target in one year.

Acknowledgments. The Authors would like to thank the university of Lampung, especially Professional Engineer Program and LP2M Universitas of Lampung for providing this research grant.

Disclosure of Interests. The authors have no competing interests.

References

1. N. A. Pambudi *et al.*, "Renewable Energy in Indonesia: Current Status, Potential, and Future Development," *Sustainability*, vol. 15, no. 3, p. 2342, Jan. 2023, doi: 10.3390/su15032342.
2. Asian Development Bank, "Renewable Energy Tariffs and and Incentives in Indonesia: Review and Recommendations," Asian Development Bank, Manila, Philippines, Sep. 2020. doi: 10.22617/TCS200254.
3. R. F. T. Tagne, X. Dong, S. G. Anagho, S. Kaiser, and S. Ulgiati, "Technologies, challenges and perspectives of biogas production within an agricultural context. The case of China and Africa," *Environ. Dev. Sustain.*, vol. 23, no. 10, pp. 14799–14826, Oct. 2021, doi: 10.1007/s10668-021-01272-9.
4. W. A. Zakaria, T. Endaryanto, L. S. M. Indah, and D. Hermawan, "The Development of Cassava Agribusiness in Lampung Province (The Implications for The Cassava Agribusiness Partnership Model)," *J. Manaj. Dan Agribisnis*, Nov. 2021, doi: 10.17358/jma.18.3.330.
5. Jenbacher, "Biogas Engine Operation And Maintenance Manual PT. Gree Energi Hamparan, Jenbach, Austria." 2020.
6. R. L. Jacobs, "Performance Rating Scales," in *Work Analysis in the Knowledge Economy: Documenting What People Do in the Workplace for Human Resource Development*, R. L. Jacobs, Ed., Cham: Springer International Publishing, 2019, pp. 223–233. doi: 10.1007/978-3-319-94448-7_16.
7. A. Kolawole, O. O. Agboola, P. P. Ikubanni, O. G. Raji, and C. Okechukwu Osueke, "Reliability and power loss analysis: A case study of a power plant in Nigeria," *Cogent Eng.*, vol. 6, no. 1, p. 1579426, Jan. 2019, doi: 10.1080/23311916.2019.1579426.
8. R. Salawu, A. O. Shamsuddin, S. Bolatitio, and S. Masibo, "Theoretical And Conceptual Frameworks In Research: Conceptual Clarification," *Eur. Chem. Bull.*, vol. 12, pp. 2103–2117, Sep. 2023, doi: 10.48047/ecb/2023.12.12.139.

9. Filox Biotech, *Start Up And Operation Manual Biogas Plant PT. Gree Energi Hamparan*, A-6200. Jenbach, Austria, 2020.