PAPER • OPEN ACCESS

# Bio-failure or Bio-fuel? Economic Feasibility of Converting Palm Oil Waste to Biogas

To cite this article: D. S. I Prihatiningtyas *et al* 2023 *IOP Conf. Ser.: Earth Environ. Sci.* **1242** 012034

View the article online for updates and enhancements.

You may also like

- Simulation investigation of the baffle overlapping rate on three-phase separation efficiency in a typical UASB reactor
Feilin Hao and Mingwei Shen

- Treatment of landfill leachate using an up-flow anaerobic sludge semi-fixed filter
J Hua, S Y Bai, Z Y Li et al.

- Treatment and Energy Valorisation of an Agro-Industrial Effluent in Upflow Anaerobic Sludge Reactor (UASB)
Ramiro Martins, Rui Boaventura and Larissa Paulista

245th ECS Meeting • May 26-30, 2024 • San Francisco, CA

Learn more & submit!

Present your work at the leading electrochemistry & solid-state science conference.

Network with academic, government, and industry influencers!

Submit abstracts by December 1, 2023


This content was downloaded from IP address 114.10.139.48 on 29/10/2023 at 08:08

# Bio-failure or Bio-fuel? Economic Feasibility of Converting Palm Oil Waste to Biogas

**I Prihatiningtyas D.S [1,*], E Heryadi [2] , G Arimbi [3] , Hermanto [4]**

[1,2,3]Department of Chemical Engineering, Mulawarman University, Indonesia
[4] Samarinda Industrial Standardization and Services Center, Indonesia

*Corresponding author email: indah.ft@ft.unmul.ac.id;

**Abstract.** This study aimed to investigate the economic feasibility of using an Up-Flow Anaerobic Sludge Blanket (UASB) reactor to convert liquid waste from palm oil processing plants into biogas containing methane. The study examined total capital investment (TCI), working capital investment (WCI), and production costs at different capacities (3, 30, and 300 liters per day) to determine if the process could generate a profit. The results showed that the biogas production from palm oil industrial liquid waste using the UASB reactor did not result in a profit due to the large capital costs and low biogas production. The implication of this study is that further research is needed to find ways to reduce the capital costs of the process and increase biogas production to make it economically feasible.
**Keywords:** techno-economic assessment, biogas, Up-Flow Anaerobik Sludge Blanket reactor

## 1 Introduction

It was reported that in 2021 Indonesia has around 14,663.6 hectares of oil palm plantations [1]. Palm oil is a strength industrial plant for the Indonesian economy and is one of the plantation commodities that contributes a large foreign exchange. Refinitiv Agricultural Research reported that in 2021 global palm oil demand increased around 6.5%, from 47.6 to 50.6 million tonnes[2]. The increase in demand of palm oil triggers an increase in the area of oil palm plantations and encourages the growth of palm oil plants that produce CPO. Palm oil plant produces around 20-23% of Crude Palm Oil (CPO), 5-7% of kernel and the remaining around 70-75% is a waste [3]. To date, the processing of palm oil waste has only been based on the fulfillment of waste quality standards without further utilization of the economic values that can be generated from the waste.

Fossil energy sources are limited, hence biogas as a renewable energy source has potential to be produced. Liquid waste from palm oil processing plants contains organic and inorganic compounds, with the help of microbes in the anaerobic process it can be converted into biogas. In biogas production, the process of decomposition of organic substances by bacteria follows 2 stages i.e acetogenesis and methanogenesis [3].

There are many types of anaerobic reactors that can be used for wastewater treatment, UASB is an anaerobic digester that is widely used to treat various types of industrial wastewater due to its capacity is greater than others. UASB reactor has the ability to treat wastewater with a high organic matter load, addition it can produce biogas. High concentration of anaerobic microorganisms because

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

microorganisms are combined into solid granules then produce higher methane [4]. $CH_4$ or methane is the main component of biogas which has a fairly high heating value.

In this work, a techno-economic assessment (TEA) at the early stage of biogas production from palm oil industrial liquid waste using up-flow anaerobik sludge blanket reactor is made by estimating total production cost and profit. The experimentally determined UASB reactor performance, different scenarios as capacity, the CAPCOST program, and cost data available in the literature were used to estimate the cost of the equipments.

The upflow anaerobic sludge blanket (UASB) reactor is one of the anaerobic continuous reactors which was developed in the 1970s by Lettinga and his coworkers [5]. The UASB reactor is a widely used for treating high-strength industrial wastewater. Many efforts have also been made to improve the "gas solid liquid" separation inside the bioreactor in order to avoid the loss of fine biomass particles, addition anaerobic reactors could be used to produce biogas by treating wastewaters [6]. In the UASB reactor, at the bottom of the reactor is an anaerobic sludge in the form of suspended granules and wastewater flows upward through the mud blanket. In the UASB reactor, the processes of acidogenesis and methanogenesis are separated so as to improve reactor performance and assist in biomass retention, further enabling the recovery of biomass during hydraulic and organic shocks [7]. UASB reactor has a low cost, operational simplicity, low sludge production , besides the cost for operation and maintenance of a UASB reactor requires less than 1% of its capital cost per year [8],[9].

## 2 Methodology

The TEA model is developed using expererimental data in order to perform the TEA of UASB reactor in converting liquid waste of palm oil processing plant into biogas [3]. Fig. 3.1 presents the working process of UASB reactor. TEA analysis to assess the economic feasibility using the following assumptions and equations. Total capital investment (TCI) is the cost acquired to set up and operate the plant which is calculated from fixed and working capital investment (FCI and WCI). FCI is the total cost of installing process equipment, buildings and tools while WCI consists of raw material, in-process, product, extended credit and available cash inventories. WCI also can be calculated around 10–15% of the TCI or 25% of the annual production selling values [10]. Total production cost (TPC) is the amount of Direct, Indirect, Fixed Manufacturing Costs and General Expenses (GE) [10],[11]. There are three scenarios of reactor capacity i.e a reactor capacity of 3.3 liter/day, 30 liter/day and 300 liter/day with incubation period of 10-12 days. The factory is estimated at 10 years with an annual depreciation of 10%, operated for 330 days per year [11], labor costs is estimated 10% of total sales.

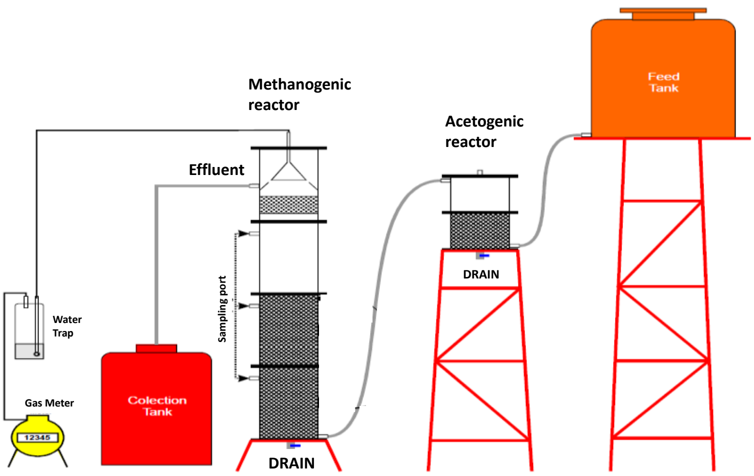


**Fig.1**. The working process of UASB reactor.

**3 Result and Discussion**

Total capital investment and production cost [11] at different capacities are shown in Table 1 and Table 2. The price of biomethane is assumed of 1.23 USD or Rp 18,163per litre [12].

**Table 1**. Total capital Investment at different biogas productions.

| Description | Production capacity of biogas | | |
|---|---|---|---|
| | **3 L/day** | **30 L/day** | **300 L/day** |
| Support from iron; cast concentrate for 30 and 300 L/day | 10,000,000 | | |
| Feed tank 1200 L from plastic, cast concentrate for 30 and 300 L/day | 2,000,000 | 8,352,000 | 43,772,000 |
| Circulation tank 600 L from plastic, cast concentrate for 30 and 300 L/day | 1,000,000 | 6,057,000 | 20,799,000 |
| Acedogenic reactor | 5,000,000 | 45,000,000 | 450,000,000 |
| Methanogenic reactor | 2,000,000 | 18,000,000 | 180,000,000 |
| Perilstatic pump | 15,000,000 | 135,000,000 | 1,215,000,000 |
| Water scrubber | 2,000,000 | 18,000,000 | 180,000,000 |
| Gas measurement | 2,000,000 | 2,000,000 | 2,000,000 |
| Purchasing cost | | | 34,500,000 |
| Installing process | 8,625,000 | 44,375,000 | 405,500,000 |
| Fixed Capital Investment (FCI) | 43,125,000 | 414,384,000 | 3,715,671,000 |
| Working Capital Investment (WCI = 10% TCI) | 4,791,666 | 46,042,667 | 412,852,333 |
| **Total cost investment (TCI)** | **47,916,667** | **460,426,667** | **4,128,523,333** |

Table 1 describes that fixed capital cost (FCI) contributes around 90% of total cost invesment (TCI). This is due to several reactors and huge feed tank needed for producing biogas using UASB reactor. Table 2 shows that the production of biogas from liquid waste of palm oil plant using UASB reactor does not provide financial benefits. This is because the liquid waste processed is quite large so it requires a large investment but the production of biogas is still low (see Table 1).

**Table 2**. Total production cost at different biogas productions.

| Description | Production capacity of biogas | | |
|---|---|---|---|
| | **3 L/day** | **30 L/day** | **300 L/day** |
| Labor (L) | 1,798,178 | 17,981,776 | 179,817,759 |
| Maintenance (1% FCI) | 431,250 | 4,143,840 | 37,156,710 |
| Utilitas | 17,820,000 | 178,200,000 | 1,782.000,000 |
| Direct Manufacturing Cost (DMC) | 20,049,428 | 200,325,615 | 1,998,974,469 |
| Laboratory (10% L) | 179,817 | 1,798,177 | 17,981,775 |
| Indirect Manufacturing Cost (IMC) | 179,817 | 1,798,177 | 17,981,775 |
| Depreciacion (10%FCI) | 4,312,000 | 41,438,400 | 371,567,100 |
| Fixed manufacturing cost (FMC) | 4,312,000 | 41.438,400 | 371,567,100 |
| Manufacturing cost (MC) | 24,541,745 | 243,562,193 | 2,388,523,345 |
| Administration (3%MC) | 736,252 | 7,306,865 | 71,655,700 |
| R&D Cost (3,5% MC) | 858,961 | 8,524,676 | 83,598,317 |
| General expense (GE) | 1,595,213 | 15,831,542 | 155,254,017 |
| **Total production cost (TPC) = MC + GE)** | **26,136,959** | **259,393,736** | **2,543,777,362** |
| **Sales (Rp 18,163 / L)** | **17,981,775** | **179,817,759** | **1,798,177,590** |
| **Profit** | **-8,155,184** | **-79,575,977** | **-745,599,772** |

In the processing of liquid waste, it will reduce environmental pollution, both water and soil. In the operation of industrial wastewater treatment plants produce direct emissions due to biological processes, greenhouse gases (GHG) such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), in addition to indirect emissions resulting from energy generation [13]. Treatment of wastewater into biogas is one possible way to reduce these emissions. By processing palm oil effluent, the quality of the environment is getting better, such as a reduction in greenhouse gas emissions that is causing a global warming. Hence, for further TEA studies, it is necessary to study the environmental, health and social impacts of waste treatment which are converted into economic values.

## 4 Conclusion

Biogas can be produced by treating the palm oil industrial liquid waste using up-flow anaerobik sludge blanket reactor (UASB reactor). In this study, TEA analysis showed that the production of biogas for capacities of 3.3, 30 and 300 liters per day using UASB reactor did not provide a profit. However, with this waste treatment, the quality of the environment and public health is getting better. Therefore, in TEA assesment, analysis of environmental impacts, social and public health should be considered in the economic calculation. This comprehensive analysis will be interesting if the process of converting liquid waste into biogas is integrated with a Crude Pal Oil plant where the energy produced is used for plant operations.

## References

[1] Badan Pusat Statistik, "Luas Tanaman Perkebunan Menurut Provinsi," 2022. [Online]. Available: https://www.bps.go.id/indicator/54/131/1/luas-tanaman-perkebunan-menurut-provinsi.html.
[2] Council of Palm Oil Producing Countries, "Palm Oil Supply and Demand Outlook Report 2022," 2022. [Online]. Available: https://www.cpopc.org/wp-content/uploads/2021/12/CPOPC-OUTLOOK-2022.pdf.
[3] Hermanto and A. Susanti, "Produksi Biogas dari Limbah Kelapa Sawit Menggunakan Bioreaktor Up-Flow Anaerobik Sludge Blanket (UASB)," Jurnal Riset Teknologi Industri, vol. 9, pp. 56-63, 2015.
[4] E. I. España-Gamboa, J. O. Mijangos-Cortés, G. Hernández-Zárate, J. A. Domínguez Maldonado, and L. M. Alzate-Gaviria, "Biotechnology for Fuels," Biotechnology and Bioengineering, vol. 82, no. 5, 2012.
[5] G. Lettinga, A. F. M. van Velsen, S. W. Hobma, W. De Zeeuw, and A. Klapwijk, "Use of Upflow Sludge Blanket (USB) Reactor Concept for Biological Wastewater Treatment, Especially for Anaerobic Treatment," Biotechnology and Bioengineering, vol. 22, pp. 699-734, 1980.
[6] P. Mullai, S. Vishali, M. K. Yogeswari, M. E. Lopez, and E. R. Rene, "Current Developments in Biotechnology and Bioengineering," Current Developments in Biotechnology and Bioengineering, pp. 17-36, 2020.
[7] B. Tiwari, P. Drogui, and R. D. Tyagi, "Current Developments in Biotechnology and Bioengineering," Current Developments in Biotechnology and Bioengineering, pp. 457-480, 2020.
[8] A. Azimi and M. Zamanzadeh, "Determination of Design Criteria for UASB Reactors as a Wastewater Pretreatment System in Tropical Small Communities," Int. J. Environ. Sci. Technol., vol. 1, pp. 51–57, 2004.
[9] N. Khalil, R. Sinhab, K. Raghava, and K. Mittal, "UASB Technology for Sewage Treatment in India: Experience, Economic Evaluation and Its Potential in Other Developing Countries," in Proceedings of the Twelfth International Water Technology Conference, IWCT 12, Alexandria, 2008, pp. 1411–1427.
[10] R. S. Aries and R. D. Newton, Chemical Engineering Cost Estimation, New York, NY, USA: McGraw-Hill Book Co, 1955.

[11] L. Ifa, T. Syarif, Sartia, Juliani, Nurdjannah, and H. S. Kusuma, "Techno-Economics of Coconut Coir Bioadsorbent Utilization on Free Fatty Acid Level Reduction in Crude Palm Oil," Heliyon, vol. 8, 2020.
[12] "Methane Prices, Litre, 13 June 2022," 2022. [Online]. Available: https://www.globalpetrolprices.com/methane_prices/.
[13] J. L. Campos, D. Valenzuela-Heredia, A. Pedrouso, A. Val del Río, M. Belmonte, and A. Mosquera-Corral, "Greenhouse Gases Emissions from Wastewater Treatment Plants: Minimization, Treatment, and Prevention," Journal of Chemistry, 2016. [Online]. Available: https://www.hindawi.com/journals/jchem/2016/3796352/.