ECONOMIC FEASIBILITY AND PERFORMANCE OF BIOGAS PRODUCTION FROM CACAO WASTE

Kelayakan Ekonomi dan Performa Produksi Biogas dari Limbah Kakao

Bernardia Vitri Arumsari[1*], Mohd Razif Harun[2]

[1]Department of Agricultural Socio-Economics, Universitas Gadjah Mada
Bulaksumur, Caturtunggal, Depok, Sleman, Indonesia 55281
[2]Department of Chemical and Environmental Engineering, Universiti Putra Malaysia
Jalan Universiti 1 Serdang, Seri Kembangan, Selangor, Malaysia 43400
Author correspondence. Email: bernardia.vitri@gmail.com

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ABSTRAK

Dalam mencapai target konsumsi energi terbarukan, Indonesia dapat memanfaatkan bioenergi. Biogas adalah bentuk energi terbarukan dan sektor bisnis berkelanjutan yang dapat menyediakan alternatif energi untuk aktivitas konsumsi. Penelitian ini bertujuan untuk: (1) memahami hasil dan mengukur kelayakan ekonomi produksi biogas eksperimental dari kulit cangkang buah kakao (CPH); dan (2) mengukur kelayakan ekonominya. Sampel CPH dikumpulkan dari kelompok petani di Kecamatan Patuk, Kabupaten Gunungkidul, Daerah Istimewa Yogyakarta, Indonesia. Sampel tersebut dianalisis di laboratorium untuk mendapatkan hasil eksperimental potensi produksi biogas. Kemudian, hasil eksperimental dikategorikan ke dalam 6 skenario berdasarkan jumlah CPH dan ukuran reaktor biogas. Pada penelitian ini, *Net Present Value* dan *Internal Rate of Return* digunakan untuk menentukan kelayakan ekonomi dari skenario produksi biogas. Hasil penelitian menunjukkan bahwa biogas dari limbah kakao di Dusun Gambiran saat ini tidak layak, tetapi skenario VI layak karena CPH tambahan dan limbah kakao lainnya dapat dikumpulkan dari kecamatan sekitarnya. Oleh karena itu, kelayakan ekonomi biogas dari CPH juga dapat bervariasi tergantung pada bahan organik, lokasi, dan ukuran reaktor.

Kata kunci: *biogas, hasil eksperimental, kelayakan ekonomi, kulit cangkang buah kakao*

ABSTRACT

To achieve the renewable energy consumption target, Indonesia can utilize bioenergy. Biogas is a form of renewable energy and a sustainable business sector that can provide energy alternative for consumption activities. This study aims to understand the yield economic feasibility of the experimental biogas production from cacao pod husk (CPH). The CPH sample was collected from a farmer group in Patuk Sub-district, Gunungkidul Regency, Yogyakarta Special Region, Indonesia. The sample was analyzed in the laboratory to obtain the experimental results of potential biogas production. Then, the experimental results are categorized into 6 scenarios according to the amount of CPH and biogas reactor size. Meanwhile, Net Present Value and Internal Rate of Return were used to determine the economic feasibility of biogas production scenarios. Results showed that biogas from cacao waste in Gambiran Hamlet is currently not feasible, but scenario VI is feasible as additional CPH and other cacao waste can be gathered from nearby sub-districts. Hence, the economic feasibility of biogas from CPH may also vary according to organic materials, locations, and reactor size.

Keywords: *biogas, cacao pod husk, economic feasibility, experimental result*

INTRODUCTION

Renewable energy is energy taken from natural resources in the form of sunlight, wind, water, sea temperature, waves and tides, biomass, and geothermal energy, which is naturally renewable (Spellman 2016). According to World bank data (2020), in 2015, renewable energy consumption in the world was 18% of total final energy consumption. Meanwhile, the number did not change much in 2019, which amounted to 17.7%. Moreover, renewable energy accounts for 15.9% of Asia's final energy consumption. At the same time, Africa has the highest percentage of 54.5%. In Oceania, renewable energy only accounts for 11.9% of gross final energy consumption.

Meanwhile, the energy mix in Indonesia are as follows: coal 17.4%, briquettes 0.003%, natural gas 12.2%, crude oil 47%, biogas 0.02%, LPG 6.7%, and electricity 16.7% (Usman 2020). Renewable energy accounts for 9.15% in 2019 of total energy (DEN 2020). According to government regulation No. 79 of 2014 concerning National

Energy Policy (KEN), by 2025, Indonesia's renewable energy consumption needs to achieve the target of 23% of total energy supply. To achieve the target, we could as well increase bioenergy use, which can be done by utilizing biogas. Hence, measuring the economic feasibility of biogas from different raw materials is needed. In this paper, the economic feasibility of biogas from cacao waste is measured.

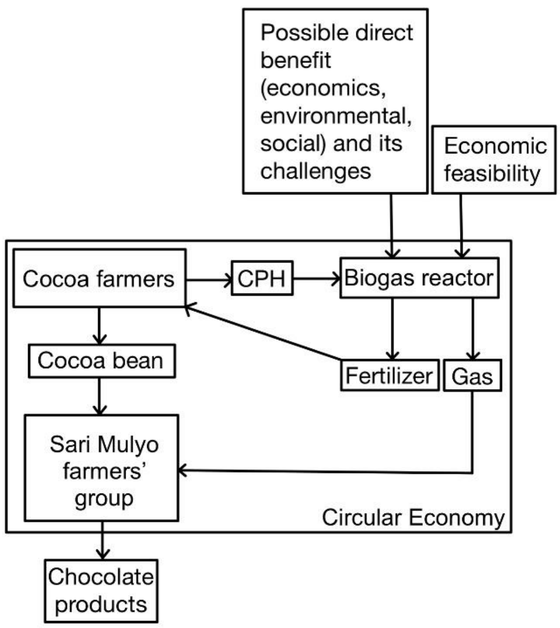
Indonesia's key theme is to merge local resource capacity with competitive technological options to provide modern and reliable energy services while encouraging sustainable growth (Silveira et al. 2018). One of the local resources that can be used to produce energy is cacao waste, especially its pod husk. On average, cacao pod husk makes up 70-75% of the cacao harvest, making it an important and economically viable resource in developing countries. It is a rich source of minerals (particularly potassium), fiber (including lignin, cellulose, hemicellulose, and pectin), and antioxidants (e.g., phenolic acids) (Lu et al., 2018). It is very rich in nutrients, making it suitable biomass for anaerobic digestion (Dahunsi et al., 2019).

Let us now consider that some farmers in Patuk Sub-district, Gunungkidul Regency, grow cacao on their lands. In Gambiran Hamlet, Bunder Village, Sari Mulyo Farmers' Group processes the cacao bean into various chocolate products: cacao mass, cacao butter, cacao nib, and cacao powder. Generally, they could process about 10-20 kg of dry cacao beans in a day. The availability of CPH itself is about 735 kg a year. The cacao pod husk (CPH) produced from the plantation has not been optimally utilized yet. As for this research being conducted, the CPH is utilized as a biofertilizer, but it is found to increase soil pH which caused yellow leaves. This situation allows for an idea to utilize the CPH in biogas production.

According to Abbasi et al. (2012), biogas is organic matter which decomposes in the absence of free oxygen, giving rise to a gas consisting of 40-70% methane. If ignited, this gas will burn cleanly, just like LPG gas. The process happens at anaerobic digester or bioreactor. When operating a wet digester in continuous mode, materials can be continuously fed into and removed from the system. Alternatively, the digester can be fed and harvested in batches (Valijanian et al., 2018). The main product of AD, i.e., biogas, can be stored before it is used to provide heat, electricity, injected into a natural gas grid, and/or utilized in the chemical industry. It produce a by-product that can be used as biofertilizers to provide nutrients to plants and increase the organic fraction of the soil (Langeveld & Peterson 2018).

Maleka (2016), investigated the feasibility of CPH-based direct combustion, gasification, pyrolysis, anaerobic digestion, and hydrothermal carbonization. Total investment costs, operating costs, revenues, and other economic indicators were obtained and calculated for economic analysis and technology comparison. Anaerobic digestion and hydrothermal carbonization were found to be the best conversion processes because they produce the highest NPV.

Moreover, various researchers have studied the economic feasibility of biogas-each with different method and diverse raw materials. The methods for determining the profitability of the biogas include sensitivity analysis, net present value (NPV), payback period (PBP), total investment, rate of return on investment (IRR), production costs, benefit-cost ratio, and the profitability index (Amir et al. 2016; Ankamah et al. 2017; Gabisa & Gheewala 2019; Maleka, 2016; Sarker et al. 2020; Walekhwa et al. 2014). Meanwhile, some of the raw materials for biogas that have already been researched were CPH (Maleka 2016), cow dung (Walekhwa et al. 2014), and even human waste, which was feasible (Ankamah et al. 2017).



Source: Authors

Figure 1. Framework of the study

A circular economy describes an economic system based on business models that replace the 'end-of-life' concept with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes. By these definitions, biogas could take part in the circular economy by refashioning cacao pod husk into gas that could be useful for chocolate production. There was no research about the economic feasibility of CPH as biogas input in Indonesia. Therefore, this paper would be the first paper that measures the economic feasibility of biogas with the cacao pod husk as its primary input in Indonesia.

METHODS

Obtaining Data

Data were obtained from a biogas technician who built an already-running, small-scale biogas reactor, and it was included in the investment cost section. Additional data was gathered from institutions and books. For the experimental calculations, results were collected from laboratory research at Universiti Putra Malaysia. It is assumed that biogas reactor inputs will be only cacao pod husk, which is not mixed with other materials, such as manure and other agricultural waste.

Study Location

The study location is in Bunder Village, Patuk Sub-district, Gunungkidul Regency, Yogyakarta Special Region (Figure 2), where there are currently 30 farmers cultivating cacao plantations. There are, on average, 61.3 kg of CPH produced per month. The variables used to count the revenue of biogas in this cacao waste study are gas and bioslurry as fertilizer. Meanwhile, the total investment cost includes basic material, appliances, labor, management, contingency, land cost, and transportation cost, as seen in Table 1. Annual operating cost uses 5% of the total investment, covering the maintenance cost and annual tax, as seen in Table 2.

Source: Gunungkidul Regency in Figures (2021)

Figure 2. Map of Gunungkidul Regency

A techno-economic analysis aims to boost technology commercialization. This analysis enables evaluating and comparing the newly developed research findings performed in the lab and pilot scales. The biofuel manufacturing cost can be estimated and compared with conventional biofuels, gasoline, and natural gas (Tabatabaei and Ghanavati 2018).

Techno-Analysis

In the techno-analysis, six batch reactors and 1 L Scotch bottles were used in the research at Universiti Putra Malaysia. The bottles were submerged in a water bath heated to 35°C. The exocarp, mesocarp, and a coating of endocarp from the newly harvested cocoa fruit make up the cocoa pod husk (CPH). The CPH were dried in the oven at 65°C for a night before being subjected to a period of one month in room temperature for the purpose of shipment from the plantation area to the laboratory. The samples were then stored at 4°C until it was time to be fed into the reactor. Prior to feeding, the particle size was reduced using a kitchen blender and mixed with water at a sample-to-water ratio of 1:5 for CPH until the texture was slurry-like.

The treatments were: C1 (CPH + inoculum) and blank (only inoculum). A total of 450 mL of seed sludge from a running biogas digester treating food waste was fed into the reactor, along with another 450 mL of substrate, leaving 100 mL for biogas space. The cocoa processing waste was introduced with OLR at a rate of 1.15 g/L/day, resulting in 2.3 g COD/L. Chemical Oxygen Demand (COD) is utilized for determining the quantity of organic substances present in waste streams and to estimate the possibility of generating biogas. Whilst Organic Loading Rate (OLR) is characterized as the quantity of organic waste provided in relation to the volume of the digester, per day (Gautam et al. 2022). Taking the COD of the samples into account, the volume of CPH was 15.68 mL. To remove oxygen, the bottles were flushed with 100% nitrogen gas for 1 to 2 minutes before being sealed with air tight rubber stoppers containing a gas tube connected to the gas displacement cylinder. The biogas production was measured daily for 22 days using the water displacement method, where the volume of water displaced in the container equals the volume of gas. The biogas production from CPH reached 735 mL within 22 days of hydraulic retention time (HRT). CPH has 88% organic content removal

Table 1. Total capital investment in USD

No.	Materials	Reactor size (m^3)				Percentage (%)
		1	4	6	8	
1	Basic materials	314	287	331	377	31-74
2	Appliances		122	153	153	
3	Labor	8	304	362	421	2-27
4	Management	0	132	150	167	0-12
5	Contingency	20	53	67	80	5
6	Land cost	73	220	342	488	17-29
7	Transportation	7	0	0	0	0-2
	Total	422	1,118	1,404	1,687	100

Source: Biogas technician (modified by authors)

Table 2. Experimental economic feasibility of CPH biogas plant

No.	Measurement	Scenario					
		I	II	III	IV	V	VI
1	Bioreactor size (m^3)	1	1	1	4	6	8
2	CPH production per year (kg)	735.20	2,679.60	3,255.20	14,752.80	22,140.00	29,520.00
3	CPH production per day (kg)	2.04	7.44	9.04	40.98	61.5	82
4	Total volume of bioreactor needed (m^3)	0.20	0.73	0.88	4	6	8
5	Volume of biogas produced (m^3 biogas/year)	16.19	59.15	72.04	326.5	489.99	653.32
6	Volume of biogas Produced/HRT cycle (m^3 biogas/20 days)	0.99	3.59	4.36	19.79	29.7	39.6
7	Total capital investment (USD)	421.69	421.69	421.69	1,118.17	1,404.48	1,686.65
8	Revenue per year (USD)	5.39	19.63	23.84	108.06	162.17	216.23
9	Annual operating cost (USD)	21.08	21.08	21.08	55.91	70.22	84.33
10	Annual Profit (USD)	-15.70	-1.46	2.76	52.15	91.95	131.90
11	Return on Investment, ROI	-0.04	0.00	0.01	0.05	0.07	0.08
12	Net Present Value, NPV (USD)	-680.25	-445.69	-376.25	-259.08	110.14	486.03
13	Internal rate of return, IRR	-10%	-10%	-16%	-1%	2%	4.3%
14	Feasibility	not feasible	not feasible	not feasible	not feasible	not feasible	feasible
15	Cooking gas (kg/year)	7.49	27.28	33.14	150.19	225.39	300.53

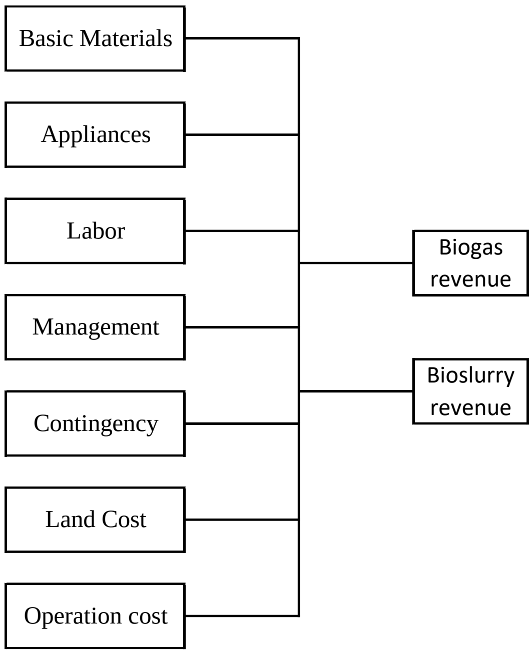
Source: Authors calculation

percentage, methane percentage 48.9%, and 0.19 L methane/g COD methane production.

Economic Analysis

In the economic perspective on technology, there must be information about the prices of each input to calculate the total cost of all inputs together, and then the values of outputs and by-products should be calculated. The costs are categorized into the cost to create, cost of possession (fixed cost per year), and cost of operation (variable cost per unit of output) (Herriot 2015).

The economic feasibility study is conducted by computing the Net Present Value (NPV) and Internal Rate of Return (IRR). The experimental calculation follows the laboratory experiment which previously conducted. NPV is the present value of the cash flows at the required rate of the project's return compared to the initial investment (Gallo 2014). The NPV rule accepts the investment if NPV is positive (Myers 2020).



Source: Herriot (2015) with authors modification

Figure 3. The economic perspective on biogas technology

$$NPV = -Co + \sum_{t=1}^{T} \frac{Nt}{(1+R)^t}$$

Where t denotes the year of investment, with Co shows the initial investment; Nt is the estimated net revenue of year t, and R is the discount rate. The discount rate used was 1.47%, which was obtained from the formula (Werner et al. 1989):

$$R = ((100 + P) / 100 + a) * 100 - 100$$

Where P denotes the market rate of interest, which is 3.5% (BI 2021), and a is the rate of inflation, which is 2% (Knoema 2021).

Next, IRR is related to NPV. IRR is the discount rate that sets the NPV to zero.

$$IRR = R$$

where

$$NPV = -Co + \sum_{t=1}^{T} \frac{Ct}{(1+R)^t} = 0$$

There are at least two ways to obtain IRR. The first is through trial and error, i.e., by computing NPV with a range of discount rates, such as between 7% and 18%. The second is by graphical method, i.e., by drawing two estimates of NPV (on Y-axis), preferably positive and negative NPV, to improve accuracy, based on different discount rates (on X-axis). The two dots are then connected, and the line will pass through the X-axis, which shows the discount rate that makes NPV zero (Olson 2011).

The first three scenarios use balloon digester with 1 m^3 maximum capacity. While the rest use fixed-dome plant. The first scenario is when the CPH produced per year amounts to 735.2 kilograms, which follows the actual amount of cacao of Gambiran Hamlet members which are delivered to Pak Paryanto. The second scenario uses the surveyed amount of CPH produced in Gambiran Hamlet for a year. Meanwhile, the third scenario uses (SIC), estimates of biodiesel production costs (BPC), internal rate of return (IRR), and sensitivity analysis of the actual amount of CPH produced from cacao which was delivered to Pak Paryanto in the scenario I, with the addition of the amount of CPH from cacao from the Plosokerep, a nearby area of Gambiran Hamlet, which is delivered to Pak Bani to be fermented.

The next scenario, scenario IV is when the 4 m^3 biogas plant capacity is maxed out with 14,752.8 kg CPH needed as the input. Then, the fifth and sixth scenario maxed out 6 m^3 and 8 m^3 capacity, where the additional waste is assumed to be collected from the surrounding areas.

These 4 m^3, 6 m^3, and 8 m^3 capacities were chosen as those are the available reactor capacity in the biogas reactor provider which can accommodate the projected amount of CPH in Sari Mulyo farmers' group and nearby smallholders plantations. Therefore, small-scale biogas feasibility in these scenarios is mostly determined by the amount of CPH produced and the total capital investment.

Feasibility Criteria

Furthermore, the criteria to determine the economic feasibility of the project are as follows:

1. NPV > 0
2. IRR > guaranteed interest rate by Indonesia Deposit Insurance Corporation (currently 3.5% according to Kontan (2021), this risk-free rate is chosen instead of loan interest rate as the project is intended to provide societal benefit. Loan interest rate to evaluate private projects has little to do with social discount rates (Fields & Slomka 2020).

The breakdown of cost and revenue structure of biogas that uses cacao pod husk as the feedstocks with anaerobic digestion is as follows. Total capital investment (TCI) consists of basic material, appliance, labor cost, management fee, contingency, transportation, and land cost, as shown in Table 1. This cost structure is based on the estimation from local biogas technician and the authors' own calculation. Meanwhile, Sorapipatana and Yoosin's (2011), study used an estimate of the production process cost, including raw materials cost, operation and maintenance costs, capital costs, and byproduct benefits.

Moreover, in a study conducted by Skarlis et al. (2012), technical and economic analysis of projects used estimates of specific investment costs (SIC), estimates of biodiesel production costs (BPC), internal rate of return (IRR), and sensitivity analysis. Capital investment cost (CIC) represents the capital required for the equipment installation process. Expenditures for site preparation, piping, instruments, insulation, foundations, and ancillary facilities are examples.

CIC also includes capital for construction overhead costs and all reactor components indirectly related to operational processes, such as field office costs, other supervision expenses/ contractor costs/ technical costs, contingency costs, and land acquisition.

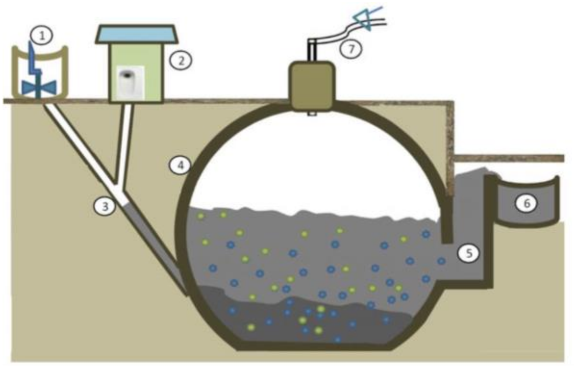
Furthermore, revenue per year is calculated by adding the revenue from heating gas and the fertilizer produced. The heating gas revenue is derived from LPG gas price as available in the local market, which first, the biogas produced converted to LPG equivalen.

RESULTS AND DISCUSSION

From 51 respondents in this study, there are 30 farmers who plant cacao trees. From those 30, only 15 farmers sell the cacao to Mr. Paryanto, as he is the chocolate processer in Gambiran hamlet. The farmers collect the cacao from their own yard and then transfer it to Mr. Paryanto by walking or by using motorcyle. Usually, Mr. Paryanto will give 8,000 rupiahs per kilogram of cacao fruit sold to him. This pandemic year, he got a profit of around 20% a year of the total 10,000,000 rupiahs revenue. In this study, we computed 6 scenarios, all with 20 years period of investment (as the lifetime of a biogas plant is 20 years), for the economic feasibility of the CPH biogas plant (Table 2).

Economic Feasibility

In this study, both NPV and IRR are used. Net present value is the present value of the benefits minus the required investment. The internal rate of return is analogous to the interest rate if a bank accepted a deposit of the investment amount and paid back according to the schedule of the project's expected cash flow (Herriot 2015). With the criteria described in the method section (IRR>3.5% and NPV>0), all scenarios in the experimental calculation are not feasible, as seen in Table 2, except for scenario VI. In scenario I, II, III, and IV, the NPVs are negative coupled with low IRR. Scenario V has positive NPV but still with low IRR.

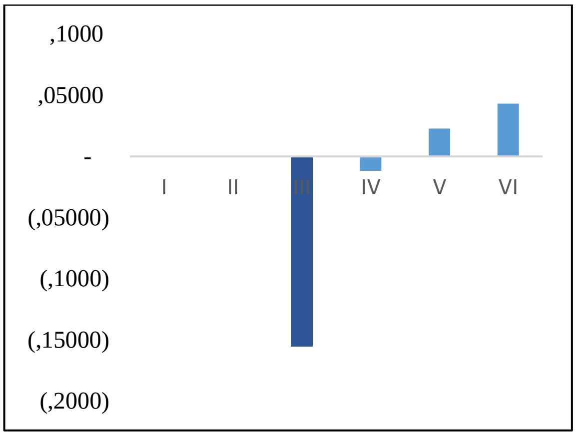


Source: Tabatabaei and Ghanavati (2018)

Figure 4. Fixed-dome digester

From the cost structure in Table 1., the percentage of the land acquisition cost is 17-29% of the total cost. If this cost structure can be minimized by utilizing the available area in the farmer's yard, the feasibility of this biogas project would be improved. Moreover, the biogas project's cost structure may vary depending on the locations, organic compounds, and project size. Since CPH as biogas has varying economic feasibility, the conclusions of this research may not be applicable to other projects or scenarios.

For example, in Uganda, biogas is economically viable for small-scale biogas plants with a volume of 8 m^3, 12 m^3, 16 m^3. The analysis was conducted by calculating NPV, IRR, and payback period. Those three decision criteria can improve the analysis's robustness and increase confidence in investment opportunities' viability (Walekhwa et al. 2014). However, a study assessed the socio-economic feasibility of four bio-digesters projects in an urban area in Bandung. This research used NPV to determine the project's feasibility. The results revealed that the conversion of food waste to biogas is economically not feasible, primarily caused by the low penetration of bio-slurry—a by-product regularly used for fertilizer—into local fertilizer supply chains (Amir et al. 2016). While in Africa, Ali et al. (2020), found that the earnings generated from selling electricity generated by biogas and the fertilizing digested slurry could cover the initial investment without any subsidies in roughly 6.5 years.



Source: Authors calculation

Figure 5. IRR

Direct and Indirect Benefit

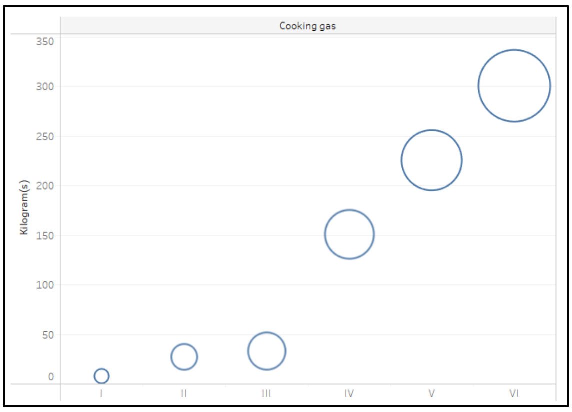
Other than economic feasibility, there are benefits that come from utilizing CPH as input for the biogas reactor. These benefits are household expenditure saving, reduction of plant disease incidence, reduction of waste, space-saving, and additional income. Even though biogas is not economically feasible, assuming that the initial investment is not coming from the household itself, then the household user can utilize the output of biogas to cook which will reduce the usage of LPG (Liquid Petroleum Gas) which the household usually need to buy.

Meanwhile, reduction of plant disease incidence, reduction of waste, space-saving, and additional income can happen as the CPH collected can save farmers' yard space and reduce waste by delivering it to the CPH collector. Plant disease incidence can be reduced by not directly using the fermented CPH as fertilizer, as the previous direct use brought yellow leaves. As stated by Doungous et al. (2018), that indeed compost application increased soil pH.

Moreover, CPH can also be profitable to farmers if the revenue from CPH delivered can be subtracted from the annual operating cost of biogas production. It is assumed that 80% of the annual operating cost are attributed to the CPH collected. As a result, every kilogram delivered can be priced at 0.23-2.29 cents. If a farmer delivers 20 kg CPH per month, he can earn 0.55 - 5.51 USD per year from the CPH collectors or biogas users, this amount could buy 4 to 40 soap bars in Indonesia.

From Figure 5., it is known that the cooking gas produced per year amounts to 7.49 kg in the scenario I. It means that the actual CPH that existed in the Sari Mulyo group can give about 0.62 kg LPG substitution each month. In other words, a typical Gambiran household with 6 kg LPG consumption per month can save more than 10% expenditure on cooking gas just by using the actual production. With cooking gas per year amounts to 300.53 kg or 25.04 kg per month, scenario VI can provide enough gas for four households in Gambiran per month.

That amount of cooking gas will also benefit the chocolate production conducted by Sari Mulyo farmers' group. Along with the expenditure saving, it can also reduce air pollution that comes from burning the firewood and save time that was previously used to find the firewood in the yard. This is in line with the benefit of the biogas captured in a Pakistan study by Yasar et al. (2017)which found that biogas installations have resulted in economic, social, and health improvements by reducing fuel and fertilizer expenditure, saving time, and reducing disease cases. In detail, biogas can reduce 53.3% of energy expenditure and save as much as half of 43% of women's time, previously used for wood collection. Biogas plants also reduce 25% respiratory disease and cardiovascular disease due to reduced air pollution. These are positive externalities of biogas in its contribution to global benefits. As stated by Srinivasan (2008), that biogas may give immediately recognized global benefits especially in mitigating green house gas emissions.



Source: Authors calculation

Figure 6. Cooking gas (biogas equivalent to LPG) produced (kg) per year

Feasible Biogas

As the formula of profit would be revenue reduced by cost, there are two main solutions to make the investment feasible: to make the revenue higher or make the cost even lower. Unfortunately, for biogas, in which the price follows the price of current LPG gas, it is hard to increase revenue without using a different approach. This results mean that the small scale plant is not feasible. Therefore, to increase profit, we have to increase the scale or the capacity of the plant. Scenario VI IRR, which consists of 8 m^3 bioreactor volume, could reach 4.3% which satisfies the requisite feasibility status (3.5% as the interest rate). The exact daily CPH input to get to IRR 3.5% is 79 kg. Thus, this IRR and positive NPV contribute to better feasibility in 8 m^3 bioreactor. The challenge in applying this calculation would be to arrange more input. This input could be derived from the neighboring villages cacao waste. In scenario III, some of the neighboring villages cacao waste already be the input, but there are actually more nearby places which have not been recorded, namely Playen, Ponjong, and Nglipar Sub-District.

Lastly, it is known that cacao pods weigh an average of 400 g (14 oz), and each one yields 35 to 40 g (1.2 to 1.4 oz) dried beans (Abenyega & Gockowski, 2003). With the experimental calculation above, Indonesia's cacao bean production is 722,572 MT/year, and 80% of the fruit is CPH; the volume of biogas produced per year by assuming 50% of CPH is processed into biogas could be as significant as 76,759,015.5 m^3. With the conversion rate of biogas to LPG (standard cooking gas used by Indonesian households) is 0.46 (Wahyuni, 2013) and with the price of LPG gas is 0.51 USD per kilogram, the potential of biogas made from CPH in Indonesia amounts to 18,047,936.55 USD per year.

Again, with the varying cost structure and plantation location, the potential biogas projects may be feasible. This is in line with Tabatabaei & Ghanavati (2018), who explained variables that affect economic assessment outcomes can be raw material costs, tax rates and contingencies; product prices; plant location and capacity; and interest rates. Moreover, Purwanta et al. (2022), stated that differing policies among countries can either stimulate or discourage stakeholders from converting industrial waste into biogas which influenced the feasibility. Furthermore, unfavorable placement, expensive raw materials, problems with the supply chain and logistics, limited availability of raw materials, lengthy tender processes, and insufficient financial backing from bank may hinders the involvement of private investors (Cardoso et al. 2019).

CONCLUSION AND SUGGESTION

This paper has measured the economic feasibility of biogas production from cacao waste, Gambiran hamlet members' perception regarding biogas and factors which affect the perception towards biogas. It is found that biogas from CPH in Gambiran Hamlet is economically not feasible in the actual scenario and in all scenarios, which maximize the capacity of the reactor sized 4 m^3 and 6 m^3. However, assuming a CPH input of 29,520 kg per year, scenario VI with the reactor sized 8 m^3 provides the highest NPV, and 4,3% IRR. Furthermore, possible direct benefits include reduced household expenditures, reduced plant disease incidence, reduced waste, space savings, additional revenue, and reduced air pollution caused by firewood burning. These are positive externalities of biogas in its contribution to global benefits. These could also be incorporated in the revenue calculation so that the biogas produced may be feasible. Nevertheless, biogas from CPH can provide enough cooking gas from 10% up to four times the household's daily cooking gas needs, as well as an extra source of income for smallholder cocoa producers. For this case, it is recommended to cooperate with either government, NGO, or any other entities that can provide biogas plant incentives as it is still considered expensive for Sari Mulyo farmers group to spend the money to build the biogas plant.

Location, organic material, reactor size, interest rates, and material costs can all have an impact on the feasibility of biogas production. Hence, there remains plenty of room for improvement in the experimental settings. It is suggested to mix other organic waste with CPH to maximize the capacity of biogas and to get better methane production. These organic wastes can be manure, other fruit waste, household waste, human dung, as well as other crops waste. The research on the mix of those wastes along with biogas potential in different locations has not been done in this study. Therefore it can be, hopefully, the suggestion for further research which may beneficial for the nationwide biogas roadmap preparation.

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