Reduce GHGs by Utilizing Biogas in Starch Industry

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Abstract. This paper includes findings from biogas as a renewable energy source and an important component in sustainable research and climate change mitigation efforts. It is created by the anaerobic digestion of organic materials in agricultural effluent. The method involves microorganisms breaking down organic material in the absence of oxygen, creating biogas. Biogas is largely composed of methane (CH_4) and carbon dioxide (CO_2), with trace amounts of nitrogen, hydrogen sulfide, and trace elements. Mitigation action attempts to reduce greenhouse gas emissions caused by methane gas delivered during the decaying of organic materials in starch wastewater. We can limit the release of methane into the atmosphere by capturing and utilizing biogas, thereby reducing greenhouse gas emissions and mitigating climate change. The purpose of this article is to fully utilize the potential of biogas as a component of sustainable research and climate change mitigation, especially in Indonesia's cassava and Metroxylon starch industries. Investing in a covered lagoon anaerobic gas collecting system and a 1.5 MW modular electricity generation facility, with a total power generation of 0.9 MW per day, then lowering greenhouse gas emissions based on Tier 1 IPCC around 15.100 tCO2e per year.

Keywords: renewable energy, sustainable, climate change, biogas, greenhouse gas

INTRODUCTION

Waste is described as the by-products of a business or human activity. Waterborne waste is produced by a range of industrial activities, including manufacturing, mineral extraction, power generation, and water and wastewater treatment.[1]. It can also be categorized as waste from gaseous, liquid, and solid objects. Many countries are also facing an energy crisis as a result of depleted fuel reserves, especially in non-renewable fossil fuels [2]. The significance of this efficient, sustainable, and renewable approach cannot be overstated in light of the risks of global warming, the greenhouse effect, and climate change. The usage of fossil-fuel-derived energy creates greenhouse gases in the form of CO2, which contribute to climate change.[3].

Aside from the benefits of nearly no CO2 emissions, the use of renewable energy should be promoted due to the depletion of fossil fuel reserves and the unpredictability of fossil fuel costs. Concerning sustainable development, the development and deployment of ecologically acceptable renewable energy sources require careful consideration.[4]. Renewable energy provides benefits over other energy sources provided if it is promoted. Renewable energy has several advantages, including the fact that it is derived from natural resources that will never run out, is ecologically beneficial, not dependent on fossil fuel prices, may create new employment, and has cheap operating costs for power plants. It may be developed at different scales and in different locations, from construction to quick operation.[5].

Currently, Indonesia needs answers to numerous challenges arising from economic, social, and environmental concerns. Support for NRE development may be a solution for Indonesia at this time, such as strengthening the economy, generating employment, supplying renewable energy (non-consumable), ecologically friendly, and other benefits for Indonesia in social, economic, and environmental aspects.[6].

Sago flour is typically processed near water sources, such as the sides of rivers or streams. Typically, garbage is disposed of into nearby rivers, particularly liquid waste, which is regarded to contaminate river water. Wastewater entering the aquatic environment has the potential to degrade water quality and harm the ecosystem[7]. The impact of this waste may be seen as a breakdown on the water's surface, and at certain intervals it will solidify and blanket the water's surface.[8]. River water pollution caused by sago factory processing waste may be avoided by using this waste as a substrate for creating biogas.

Material and Method

To determine the estimated reduction in greenhouse gas from tapioca and sago industrial effluent, this study employs a quantitative descriptive methodology. The sample consists of biogas used to produce electricity and wastewater from tapioca and sago. The Indonesian National Standard (SNI) for surface water is followed when sampling wastewater. Additionally, composite sampling and a flow-indicating totalizer instrument unit (FIT) were used to collect gas samples. In-depth literature research on the issues and goals was combined with the collection of primary and secondary data throughout three months of factory operation. Data was obtained at the PT Bangka Asindo Agri starch mill on the West Ring Road, Kenanga Village, Sungailiat District, Bangka Regency, Bangka Belitung Province, Indonesia. For a quarterly year of plant operation, real production capacity and wastewater flow rate were measured. Meanwhile, wastewater sampling and laboratory analysis were carried out by the regulation stipulated by the Government of Indonesia. Samples were taken after approximately six hours since the tapioca plant began operating. Table 1 illustrates monitoring systems that use measurement methods and measurement parameters, whereas Figure 1 depicts the schematic diagram of the sample location.

Tabel 1 Wastewater Flowrate & Production from observed starch factory

Period	Wastewater Generated (m3/day)	Inlet COD (mg/L)	Outlet COD (mg/L)	Processed Starch (ton/day)
1st Month	-	-	-	-
2nd Month	-	-	-	-
3rd Month	-	-	-	-
Average	-	-	-	-

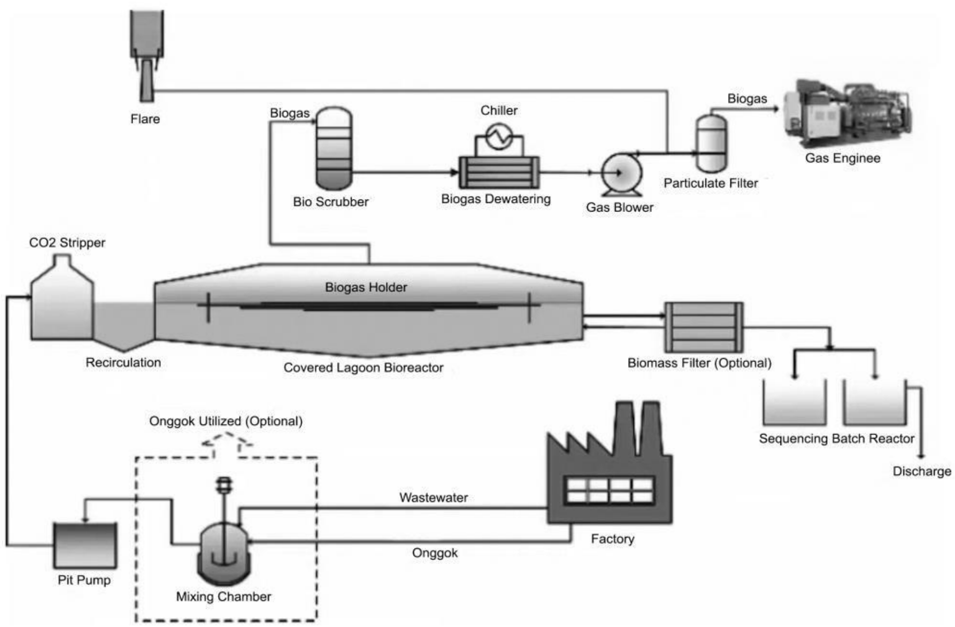

FIGURE 1. Wastewater treatment process and GHG reduction plant

The graphic (Figure 1) depicts the biogas production process at the research site, which uses covered lagoon technology to create power and reduce greenhouse gas emissions. The effluent from starch is sent to the sump pit, a temporary reservoir before being transferred to the stirring tank. The admixture then flows to the feed pond before entering the digester. A covered lagoon anaerobic bioreactor was employed as the digester.

As depicted in Figure 1, organic degradation occurs in the anaerobic biodigester, culminating in the conversion of organic pollutants into biogas through hydrolysis, acidogenesis, acetogenesis, and methanogenesis phase. In the digester, the HRT is 25-35 days typically. To prevent the disturbance of sediment of solid deposits at the bottom of the

digester, the return flow is used to be added in the digester. To regulate the bacterial performance and pH value in the digester, recirculation is performed using a return sludge pump.
The sedimented sludge in the bottom of the digester is flowing to the settling pond and then flows into anaerobic ponds. Left for around one month before being applied for planting in the land. The biogas product is sent to the scrubber to be removed from hydrogen sulfide gas (H_2S) by water absorption. The settling pond water is employed as an absorbent. The scrubber water flows to the circulation tank and then is pumped to the anaerobic ponds, where the scrubber water will be mixed with the treated effluent for applications on the land. Biogas from the H_2S scrubber is blowered to the dry filter, where it is cleaned of any leftover contaminants.
From the dry filter, the biogas is then dehumidified to the heat exchanger (HE), where its heat is cooled via the transfer process. The dry & cooled biogas is sent to a 1.5 MW generator, where it has function as fuel and is turned into electricity. During engine repair, biogas is sent to the other stand by the engine or being flared.

Biogas gas generated from the biogas plant was estimated using equation 1[9]

$$\mathrm{CH4} = \frac{COD\ in - COD\ out\ x\ Q\ x\ 0.35}{1000} \tag{1}$$

Where:

CH4ww	= Tapioca wastewater that produces methane gas (Nm3/day)
COD in	= Concentration of chemical oxygen demand at the inlet in the biogas reactor (mg/l)
COD out	= Concentration of Chemical oxygen demand at the outlet in the biogas reactor (mg/l)
Q	= The rate of a wastewater flow (m3/day)
0.35	= Methane potential from being produced (Nm3/kg COD removal)

Methods calculation is explained in Equation 1, while the system boundary can be found in Figure 2.

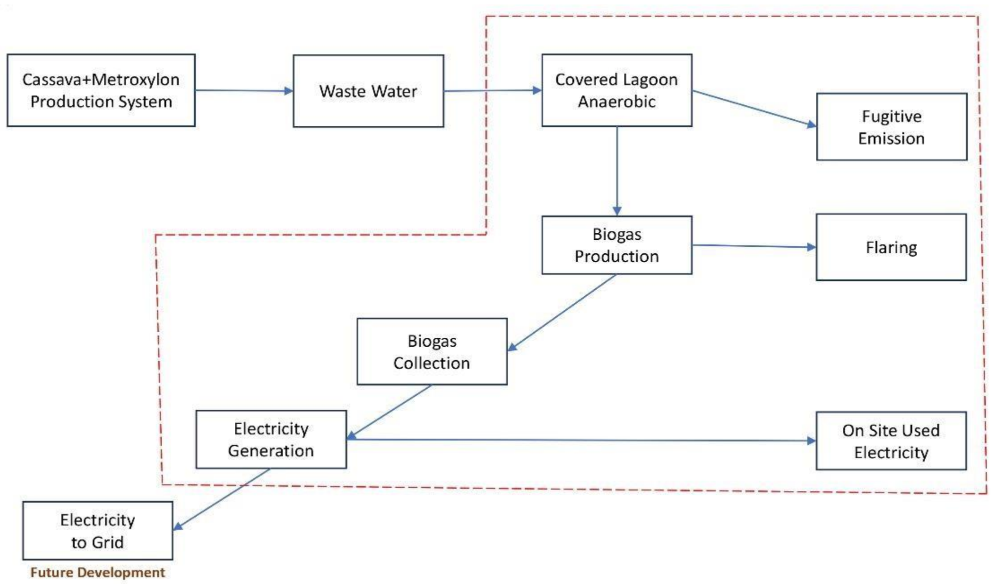

FIGURE 2. The system boundary of the greenhouse gas reduction program[10]

Emission Calculation was estimated using equation 2[11]

$$E_{CO_2}^{Eq} = CH_4 \times GWP_{CH_4} \quad (2)$$

Where:

$E_{CO_2}^{Eq}$ DA = Emission CO_2 Equivalent (gCO_2^e /day)

CH_4 = Methane Potential (g/day)

GWP_{CH_4} = 21 (IPCC 2006)

RESULTS AND DISCUSSION

Electricity Generation

Based on the method detailed above (Figure 1), it is clear that this mill, like most other starch or palm oil mills in Indonesia, uses a typical biogas generating system. As a modified variation of the pond system, a closed lagoon is utilized to absorb methane gas. This anaerobic biodigester with large capacity requires also a large amount of space, is easier to operate than any other kind of digester, and needs only not highly skilled personnel. This plant handled wastewater with a tank system comprised of anaerobic and aerobic processes before deploying methane capture technology. The tank system employed at the plant site has been modified in numerous ways, the use of mixing by regularly flowing a return sludge.

These mixing tank roles is reducing the accumulation of sediments at the tank's bottom. Tank systems typically have less operational control, monitoring, and mechanical agitation. Anaerobic pond systems produce more methane than open tank systems in traditional systems. A covered anaerobic biodigester allows anaerobic bacteria to be active more efficiently. This explains why covered tank systems emit less methane than open tank systems into the air.

The typical production capacity observed by starch factories was approximately 105 -135 tons of starch and can be triggered to 250 tons per day, designed effluent per day is 10.000 m3. As primary treatment, the plant effluent was treated in an anaerobic bioreactor to minimize the environmental pollution in emissions while also producing biogas. Sample were taken by composite sample which is a collection of various individual samples separately taken regularly over a period specific time, usually within 24 hours. The samples collected in one 24 hours are then mixed in one container for analysis. The composite sample will produce an analysis that represents average performance. The average COD in and out is 13.300 mg/L and 645 mg/L, respectively (Table 2), thus the efficiency of the biogas plant in reducing pollutant load is around 95%.

Tabel 2 Starch Factory Production and Wastewater Flowrate

Period	Inlet COD (mg/L)	Outlet COD CLAR (mg/L)	Starch Production (Ton/Day)	Wastewater Flowrate (m3/day)
1st Month	13.500	675	135	2.970
2nd Month	13.600	748	105	2.520
3rd Month	12.800	512	127	2.667
Average	**13.300**	**645**	**122**	**2.719**

Methane gas produced from the anaerobic biodigester was calculated using Equation 1 above :

The cost of electricity is the second greatest component of the expenditures of starch-processing factories. Several solutions exist for businesses to boost their electricity consumption efficiency and lower their heat and power costs. Using motor load control (MLC) can help to increase motor performance while running because starch production uses many kinds of machines that use motors as prime movers. Equation (3) is used for calculating the estimated methane potential per day in the starch factory observation. Thus, from a methane potential, the results of plant waste that produces energy can be calculated by the amount of 12,043 Nm^3 of biogas per day.

The power generation value was calculated using the following equation [12]:

$$Po = \frac{CH4ww * LHv * 0.40}{24\ x\ 60\ x\ 60} \tag{3}$$

Where:
Po (MW) = Power generation (MW)
L.Hv = Low Heating Value of methane (35.7 MJ/Nm^3)
0.40 = Conversion efficiency from biogas objects to electrical objects

The sum of biogas converted into electricity depends on the performance of the generating set unit. According to equation (3) above, the performance of conversion from biogas energy into electrical can be stipulated, which is 0,40. The potential for electricity and biogas generated from tapioca and sago starch effluent during the 3 (three) months of study according to equation (3) is 1.99 MW of electrical power. This will be a crucial opportunity for prospective expansion. Through observation, the average effluent inlet flow is 2.719 m3/day, while flour powder output is 122 tons/day. The amount of effluent is 22.28 m3/ton of starch below the legal limit of 30 m3/ton of starch production. The remaining 73% of the capacity is unused, the idle effluent load is 7.281 m3/day. The measurement results show that the ready-to-use produced biogas is 12.403 Nm3 of biogas per day. Nevertheless, only 5,600 Nm3 is used to generate 0.9 MW of electricity from the installed 1.2 MW generating set. As a result, biogas production and installed electricity capacity with unused capacity are 6.803 m3 and 300 kW of power generation, respectively. Biogas produced from anaerobic bioreactors will be used for electric heating and power generation through drying and internal combustion engines. The idle gas can be processed furthermore as raw material of BioCNG (See Figure 4).

Emission Reduction

Degradable waste does contribute to the emission of greenhouse gases (GHG) into the air, mainly methane. When starch wastewater is processed in an anaerobic digester, methane gas (CH_4) is produced, which is a source of greenhouse gas (GHG) emissions that contribute to global warming (See Figure 3). Capturing methane and converting it into energy is one option for lowering environmental impact while providing renewable energy. Venting greenhouse gases into the air may hurt climate change. However, good waste management, particularly energy recovery, and recycling, could offset this effect. Global trash creation is predicted to be 0.26 tons per capita, with a 70% rise projected by 2050[13]. Baseline emissions are GHG emissions caused by the absence of PLTBg or the use of biogas as a fuel source. The following results (Table 3) show the GHG emissions from the biogas plant at the study location. Methane gas is the result of calculations of GHG emissions. This has a potential global warming value of 21 times that of carbon dioxide [14] with CH4 (methane) density around 0,657 kg/m3 and CH4 (methane) content around average 50%. The data was gathered from the starch factory where the observation was conducted. The data is collected to calculate the emissions after biogas power plant construction, including daily raw materials, daily liquid waste stream, COD load, on-site emission source, and generation of greenhouse gas.

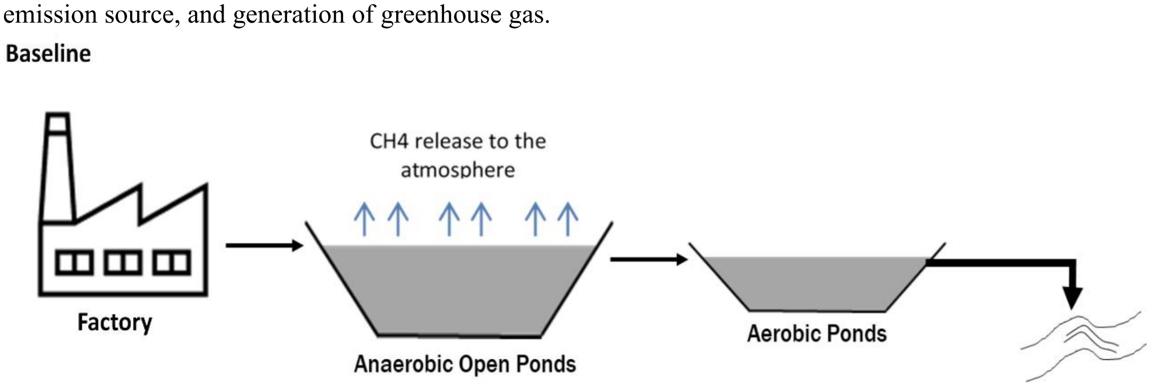

FIGURE 3. The system boundary before mitigation of green house gas (GHG)

Emission data after the installation of the biogas power plant is compared with the emission source data before the installation of the biogas power plant. Emission reductions can be determined using baseline emissions, which are greenhouse gas emissions under current conditions in the absence of the project, and project emissions, which are greenhouse gas emissions after methane recovery facilities are erected and electricity is used for production.

The following equation obtains reduced emissions [15]:

$$\textit{Emission Reduction } \boldsymbol{(ER)} = \textit{Baseline Emission } \boldsymbol{(BE)} - \textit{Project Emission } \boldsymbol{(PE)} \quad (4)$$

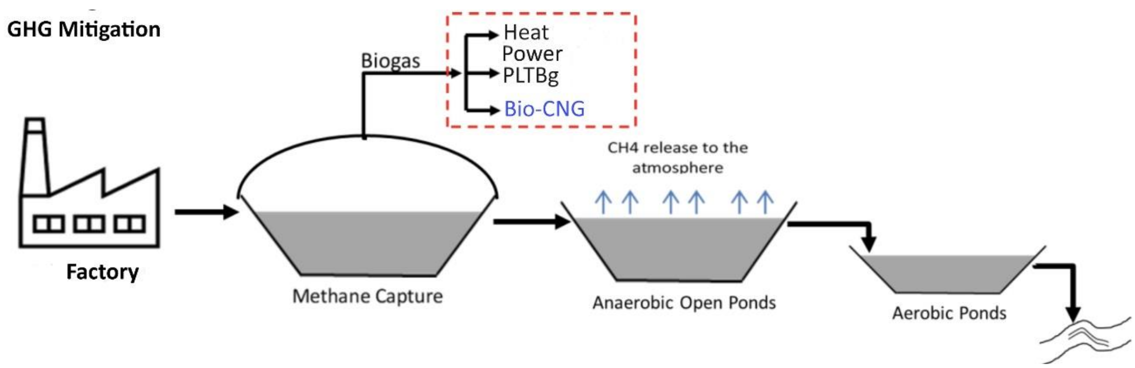

FIGURE 4. The system boundary after mitigation of green house gas (GHG)

Table 3 The Advantages of Using a Biogas Plant to Reduce GHG Emissions

Baseline Emission Without Biogas Plant	**30.000 tCO2-eq/Years**
Wastewater Emission	5.100 tCO2-eq/years
Emissions from Combustion	4.500 tCO2-eq/years
Electricity Generation Emission	1.400 tCO2-eq/years
Fugitive Emission	2.700 tCO2-eq/years
Biogas Plant Project Emission	1.200 tCO2-eq/years
Emission Reduction	**15.100 tCO2-eq/years**

Values were input based on averages based on operational conditions from January until March 2023. According to the table above, running an anaerobic biodigester plant can increasingly degrade GHG emissions, in this case by around 15.100 tCO_2-eq/year. As a result, it benefits environmental sustainability.

CONCLUSION

The production of starches (e.g. tapioca and sago) involves peeling, washing, grinding, extraction, settling, drying, and packaging. These different processes aim to produce up to 250 tons of starch per day while treating 10,000 cubic meters of designed wastewater. Alternatively, wastewater from the biogas process can be used throughout the production process as primary treatment. With a CoLAR efficiency of approximately 95.0%, the liquid waste contained an average of 13.300 mg/L COD, which converted to 12.043 Nm3 of methane (CH4) and a potential of 1.99 MW. In case of a gas shortage, additional gas (approximately 6.803 m3 per day) can be made available to the public in the form of BioCNG feedstock.

According to an environmental impact study, starch wastewater in the study area has the potential to emit around 30.000 tons of CO2-eq/year. However, the biogas plant at the study site has reduced greenhouse gas emissions from starch wastewater by around 15,100 tons CO2 equivalent/year. This benefits environmental sustainability; Therefore, biogas production from starch effluent should be widely used in other starch plants.

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