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# *Environmental Critical Aspects of The Conversion of Biomass to Biogas for Sustainable Energy in Indonesia*

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**ABSTRACT**

Renewable energy will become the foundation for meeting the world's energy needs in the future. However, Indonesia has not done much research on the development and application of technology for sustainable energy. Indonesia has potential energy sources. However, biomass conversion into other forms of energy, such as biogas, will hurt the environment. The development of biomass-based bioenergy is one of the best solution for meeting Indonesia's current and future energy needs. Biogas is biomass-based bioenergy, which is the potential for future energy sources. Minimizing the environment's degradation is a significant aspect of preparing the biomass to biogas conversion model. Furthermore, the production of biogas with automatic monitoring and control will minimize new waste formation. Indonesian government regulatory support and total community participation will increase converting biomass into biogas as renewable energy into electrical energy. The paper analyzes the environmental impact of biomass conversion into biogas and proposed an environmentally friendly conversion model.

## 1. INTRODUCTION

The development has a noble goal in the form of economic growth and welfare improvement. Energy is a significant component to drive development success. Energy comes from renewable energy sources and non-renewable energy sources that can produce energy either directly or through a conversion or transformation process(Mayer, Bhandari, & Gäth, 2019). Energy can be heat, light, mechanical, chemical, or electromagnetic(Zabek & Morini, 2019). Development also causes undesired side effects, namely environmental pollution, global warming, social inequality, and lack of natural resources.

Solar cells and bioenergy will become the foundation for meeting the world's energy needs in the future (Kumari & Singh, 2018; Prabakar et al., 2018; Roy & Dias, 2017; Zabaniotou, 2018). However, Indonesia has not researched developing and applying solar cells and bioenergy (Suryaningsih and Irhas, 2014; Papilo et al., 2018; Simangunsong et al., 2017). This condition is a challenge for researchers in Indonesia to prepare and implement renewable energy as an energy source immediately. It is crucial to start the development to not depend on foreign countries to provide solar cells and bioenergy facilities and infrastructure.

Indonesia is lagging compared to several countries in Asia, such as China, India, Singapore, South Korea, and Japan. These countries are very active in researching the

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development and application of solar cells and bioenergy (Huang et al., 2018; A. Kumar et al., 2018; S. Kumar et al., 2017; Yadav, Pandey, Bhatt, Kumar, & Kim, 2017). The high demand for solar cells related to fossil energy reduction has pushed some countries to be very active in research into solar cells' development. Singapore, South Korea, and Japan are very intensive in researching manufacturing new materials related explicitly to increasing solar cells' efficiency.

In the last decade, total energy consumption in Indonesia multiplied. Dependence on fossil energy, especially petroleum, in meeting domestic energy needs is still very high. On the other hand, efforts to develop and use renewable energy to reduce greenhouse gas emissions have challenging to proceed as planned. The use of energy tends to be very wasteful in various fields, especially industry, agriculture, households, and transportation. Besides the decline in fossil energy reserves such as petroleum, coal, and gas, discovering new energy reserves cannot be matched. The limited energy infrastructure available in Indonesia also limits people's access to energy. This condition makes Indonesia vulnerable to disruptions in the global energy market because most energy consumption, especially oil production such as Premium, Pertamax, and Avtur, is still met from imports. The development of biomass-based bioenergy is the best solution for meeting Indonesia's current and future energy needs. Bioethanol, biogas, and biodiesel are biomass-based bioenergy, which is the potential for future energy sources.

Indonesia can use renewable energy resources in hydro, geothermal, biomass, solar, wind, ocean, uranium, and biodiesel energy sources. (Azam, Khan, Bakhtyar, & Emirullah, 2015; Erahman, Purwanto, Sudibandriyo, & Hidayatno, 2016; Kurniawan, Sugiawan, & Managi, 2018; Liu, Zhang, & Bae, 2017; Purwanto, Sušnik, Suryadi, & de Fraiture, 2018; Sarrica, Richter, Thomas, Graham, & Mazzara, 2018) However, to date, only three types of renewable energy resources have been utilized by Indonesia, namely hydro, geothermal, and energy from biomass. Indonesia is still very dependent on non-renewable energy sources, namely oil, natural gas, and coal. Although Indonesia also has other non-renewable energy sources, namely coal, methane gas, and shale gas. Several countries have also developed new energy sources from nuclear, hydrogen, methane gas, liquefied coal, and confirmed coal. (Mirzoyan, Vassilian, Trchounian, & Trchounian, 2018; Ren, Zhao, Chen, Guo, & Cao, 2016; Sainati, Locatelli, & Smith, 2019; Sikder, Inekwe, & Bhattacharya, 2019) Nevertheless, Indonesia has not yet carried out development and research to keep abreast of global energy developments.

Another impact of development is the increase in energy needs derived from economic growth, population growth, industrial growth, office growth, hotels, and human welfare, and changes in daily human activities. (Bilgili, Koçak, Bulut, & Kuloğlu, 2017; Hidayatno, Destyanto, & Hulu, 2019; Vieira et al., 2019) Indonesia is in a condition of dependence on fossil energy sources, especially petroleum, in meeting domestic energy consumption, where most of the consumption is from imports. Other conditions include energy consumption that tends to be wasteful, a decline in fossil energy reserves, and the absence of new reserves. This condition has led to efforts to utilize renewable energy, which has not proceeded as planned until now. Besides, the limited available energy also limits people's access to renewable energy.

The utilization of renewable energy sources and non-renewable energy sources to produce energy, both directly and indirectly, such as conversion or transformation, must be managed appropriately not to cause adverse impacts on the environment. Energy management will prevent environmental pollution and environmental degradation and how many other negative impacts such as the meaning of acid rain, depletion of the ozone layer in the stratosphere, global warming due to the effects of greenhouse gases, and several other adverse effects.(Lee, 2017; Mishra, Roy, & Mohanty, 2019; Prabakar et al., 2018; Roy & Dias, 2017; Singh, Varanasi, Banerjee, & Das, 2019; Thi, Lin, & Kumar, 2016; Zabaniotou, 2018). In summary, a comparison of the various sources of renewable energy that can be applied in Indonesia is shown in Table 1.

The need for electrical energy in the industrial sector in Indonesia is increasing. The application of industrial technology 4.0 encourages industrial growth as well as the consumption of electrical energy. In addition, the high public interest in using electric vehicles is the driving force for increased consumption of electrical energy in the transportation industry sector. Data from the Ministry of Energy and Mineral Resources of the Republic of Indonesia in 2020 shows that 85.79% of electrical energy comes from non-renewable sources. Renewable energy production only reached 14.21%. Hydroelectric power (PLTA) contributed 5.84%, geothermal power plants (PLTPB) by 8.17%, and other renewable energies (Wind Power-PLTB, Solar Power-PLTS, Biomass Power Plants -PLTBm, Biogas power plant-PLTBg) by 0.20%. Indonesia's target in 2025 for the renewable energy mix of 23% (Direktur Jenderal EBTKE, 2020).

Indonesia has a potential biomass energy source and may become a source of energy in the future. However, biomass conversion into other forms of energy, such as biogas, bioethanol, and biodiesel, will hurt the environment. Indonesia has built many biogas production units (Bedi, Sparrow, & Tasciotti, 2017).

Biogas production can use pulp and paper waste, bagasse, grass and leaves, leftover food, wood, and fanfare. The hybrid, physical, chemical, and biological methods vary according to the type of media used. Most of the biogas production in Indonesia uses biological processes because of the low production costs is shown in Figure 1. Biogas from biomass can have several negative impacts, namely an increase in $CO_2$ emissions, odors, wastewater, and sludge that requires further processing (Hashemi, Sarker, Lamb, & Lien, 2021). Very few industries carry out advanced processing. If the waste is disposed of in the environment without treatment, it can cause increased greenhouse gas effects, water and air pollution, and soil contamination. It is necessary to analyze the environmental impact of converting biomass into biogas and developing an environmentally friendly conversion model.

**Table 1.** Comparison of different renewable energy sources in Indonesia

| Source | Advantages | Ref. |
|---|---|---|
| Solar | Environmentally friendly | (Huang et al., 2018) |
| Hydropower | Environmentally friendly | (Tasri & Susilawati, 2014) (Tang et al., 2019) |
| Geothermal | Approximately 28.91 GW of 312 locations on different islands | (Pambudi, 2018) |
| Wind energy | The cheapest form of electricity generation with LCOE of 0.13 US$/kWh (±0.01 US$/kWh) | (Rogers, Ashtine, Koon Koon, & Atherley-Ikechi, 2019) |
| Biomass | Low investment | (Sgroi, Donia, & Alesi, 2018) |
| Biohydrogen | Source and prevent the organic wastewater contamination | (Chu, Hastuti, Dewi, Purwanto, & Priyanto, 2016) |
| Biogas | Potential source and conversion to electrical energy | (Harihastuti et al., 2021) (Steinhauser & Deublein, 2011) |

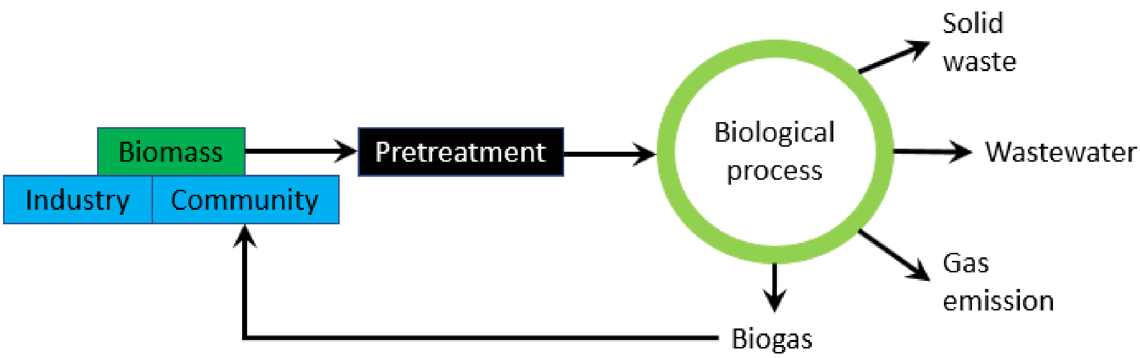


**Figure 1.** Conversion biomass into biogas production in Indonesia (Adapted from (Bharathiraja, Sudharsanaa, Bharghavi, Jayamuthunagai, & Praveenkumar, 2016; Guebitz, Bauer, Bochmann, Gronauer, & Weiss, 2015)

## 2. METHOD

This study was conducted systematically reviewed the available articles in ScienceDirect and Google Scholar up to 2021. The search terms we used are renewable energy and Biomass, and Biogas and treatment and sustainable energy. A manual search was also performed. The study selection based on biogas as a product resulted in biomass conversions. We selected literature based on the environmental impacts and their potential sustainable energy. Two proposed models developed scenarios based on the existing scenario and environmental scenario of converting biomass to biogas.

## 3. RESULT AND DISCUSSION

### *3.1. Renewable Energy Based Biomass*

Indonesia's strategic position on the equator raises several advantages, such as sunlight throughout the year so that various plants thrive. This condition increases the potential of Indonesia's biological resources, several types of energy plants that can potentially produce energy in Indonesia (Hasan, Mahlia, & Nur, 2012). Including sugar cane, sugar palm, sunflower, candlenut Sunan, sago, corn, sesame, sweet potato, cassava, avocado seeds, palm oil, and algae (Direktur Jenderal EBTKE, 2015).

Currently, Indonesia has still used biomass as a source of food and industrial raw materials. If the biomass is converted into an energy source, the techno-economic value could not match conventional energy conversion's economic value, although biomass has a relatively high biodegradable carbon component compared to biomass waste (Harihastuti et al., 2021). So that biomass waste is still the leading source for conversion to biogas in Indonesia.

### *3.2. Biomass Waste*

Based on data from the National Waste Management Information System (Sistem Informasi Pengelolaan Sampah Nasional-SIPSN) in 2020, Indonesia's waste generation is 36.54 million tons. In 2020, there was an additional 5.47 million tons. Managed waste reaches 53.61%, and there is a potential for unmanaged waste of 16.95 million tons. This type of biomass waste is the most significant contributor to waste based on waste composition, namely 30.80% food scraps, 12% wood/twigs/leaves, 11.20% is paper/cardboard. The biomass waste sources are 32.40% households, 21.70% traditional markets, and 13.90% commercial centers (SIPSN, 2021).

The availability of biological resources in Indonesia encourages an increase in the agro-industry rate. However, on the other hand, the agro-industry operational processes also produce undesirable side effects, namely solid waste, liquid waste, and emissions. Some potential biomass waste to be converted into biogas are waste from the sugar cane industry and waste from the cassava flour industry (Rame, 2018).

Some other industries also produce biomass waste that is the potential to be converted into biogas. Namely the leather tanning industry, the palm oil industry, the rubber industry, tapioca, the milk processing industry. Including the soft drink industry, the vegetable oil product industry, the fruit and or vegetable processing industry. Also, fishery product processing industry, seaweed product processing industry, coconut processing industry, meat processing industry, soybean processing industry, cattle and pig farming industry, and wet process cooking oil industry (Direktur Jenderal EBTKE, 2015). There is also the potential for biomass waste originating from health service facilities, slaughterhouses, and domestic waste such as residential areas, office areas, commercial areas, apartments, restaurants, and dormitories (Zuli Pratiwi, Hadiyanto, Purwanto, & Nur Fadlilah, 2020).

### *3.3. Bioenergy from Biomass*

Indonesia has enormous potential for developing bioenergy from biomass due to the potential of extensive land areas, the large number and types of plants available, and the abundant amount of biomass waste. However, current research in the world focuses on the field of solar cell development. However, bioenergy from biomass is still the majority of research focus, namely developing the biomass to hydrogen convention, especially in Taiwan and South Korea. (Eker & Erkul, 2018; Maaroff et al., 2019; Preethi, Usman, Rajesh Banu, Gunasekaran, & Kumar, 2019; Rambabu et al., 2019; Sinharoy & Pakshirajan, 2020). Development of biogas energy production not chosen to be developed by developed countries because the potential of methane gas emissions is more damaging to the ozone layer as a protector of the Earth than the destructive power of carbon dioxide gas (Dyominov & Zadorozhny, 2005; Sarkodie & Strezov, 2019; Sharifzadeh, Hien, & Shah, 2019).

World researchers are competing to research biohydrogen, which is believed to be the energy of the future. Nanotechnology supports the development of hydrogen energy by the rapid development that will produce enormous energy efficiency. Using nanotechnology, the energy produced from a hydrogen source in the form of a pen can move a motorized vehicle such as a car because even though the outer dimensions look small, the surface area inside is very high. One gram of nanomaterial will have a contact surface area similar to that of a soccer field. Nanomaterials support world energy development (Sinharoy and Pakshirajan, 2020; Srivastava et al., 2018, 2019).

Indonesia has the potential to develop nanomaterial basis biohydrogen energy if it is seriously developing. Hydrogen energy converted from biomass or bio solar in the future. Although hydrogen energy efficiency is lower when compared with nuclear energy efficiency. On the other hand, nuclear energy production has a considerable potential disaster risk.

Besides that, Indonesia's advantage is that it has an extensive sea area, an extensive land area that produces a very high potential for renewable energy sources. Indonesia's biomass waste is also very high as an alternative source of bio-energy, including in the form of residential or industrial waste. Biomass convert to biofuels. The utilization of biomass can be directly or indirectly. Biomass can be directly burned as a source of boiler energy to drive generators. Indirectly biomass can be converted into several energy sources such as biogas, bioethanol, biodiesel, biohydrogen, or fuel cells. In the short term, biohydrogen or fuel cell has not been used as a bioenergy source because investment costs are still relatively expensive.

Based on the Ministry of Energy and Mineral Resources data in 2109, biogas' supply is 166 thousand Barrel Oil Equivalent (BOE). Meanwhile, the supply of biofuel is 45.92 million BOE, and biomass is 61.39 million BOE (Adi et al., 2020), according to Figure 2. The National Waste Management Information System data provides information that there is a potential for unmanaged waste of 16.95 million tons (SIPSN, 2021). About 10 million tonnes is biomass can be converted into biogas.

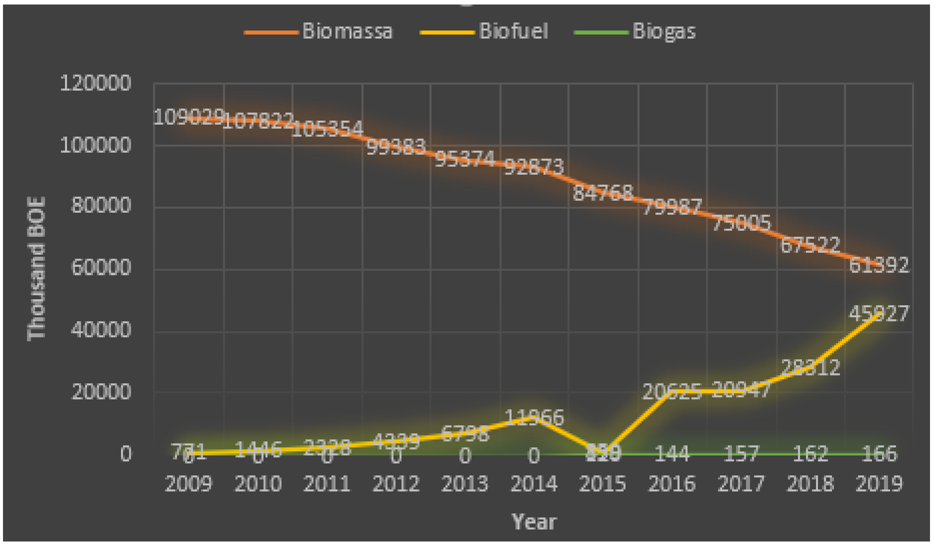


**Figure 2.** Bioenergy supply in Indonesia (Adi et al., 2020)

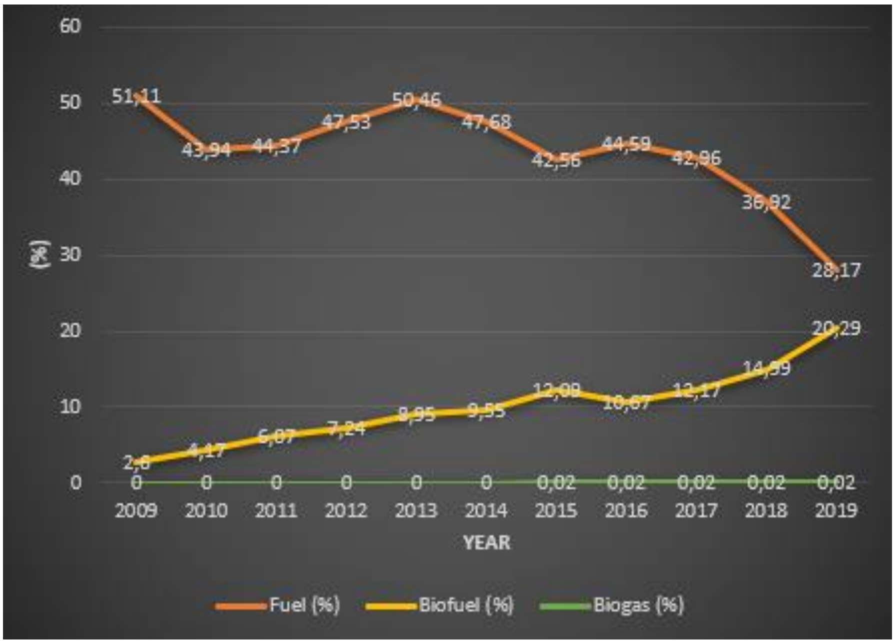


**Figure 3.** Share of bioenergy consumption in Indonesia (Adi et al., 2020)

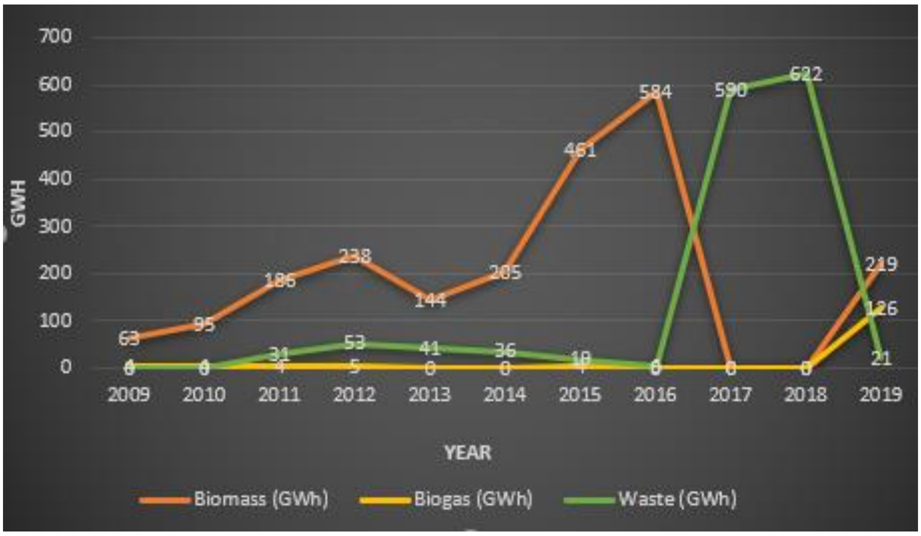


**Figure 4.** Bioenergy power plant production in Indonesia (Adi et al., 2020)

Although there is an increase in biofuel consumption by 20.29% in 2019, the actual percentage of energy consumption from biogas is only about 0.02% of Indonesia's total energy consumption, as shown in Figure 3. Bioenergy used in power plant production in Indonesia has decreased gradually, as shown in Figure 4. Although in 2019, the power plant production of biogas increased to 126 GigaWatt Hour (GWh) and biomass to 219 Gwh. On the other hand, power plant production from biomass has decreased drastically from 622 GWh to 21 GWh. In total, the contribution of bioenergy is still below 1%, with the 2019 PLN Power Plant Production of 278,942 GWh (Adi et al., 2020).

### *3.4. Biogas*

Biogas is a product of the fermentation of biomass or organic material waste. A few years ago, there was a boom in converting coal into liquid fuels (Xiang, Yang, & Qian,

2016) and natural gas into liquid fuels, namely in various countries such as South Africa, Thailand, and Malaysia, and several other countries. Indonesia has developed biogas to liquid fuel, but only to the pilot plant stage and not yet to the industrial-scale production stage. Finally, Indonesia returned to the use of coal directly, which resulted in environmental pollution.

The Indonesian government must fully support the development of renewable energy. Although it cannot be denied, at this time, Indonesia is still very dependent on fossil energy sources, namely oil, coal, and natural gas. Indonesia is still very far behind in technology and the development of biogas fuels. On the other hand, methane gas is hazardous for the environment if not managed correctly. Indonesia still has not shown seriousness in developing biogas potential related to methane gas storage or methane gas production. Therefore, purification research and research on the storage and distribution of methane gas are the most urgent thing to support the development of energy directed towards reducing greenhouse gas emissions. The use of biomass for bioenergy is the right choice for Indonesia. Because when choosing solar cell development, Indonesia is still far behind related to solar cell material technology. Indonesia will be challenging to catch up with the rapid development of solar cell technology in the world today. South Korea, Taiwan, Europe, and America are currently very focused on developing semiconductor materials to support solar cells' efficiency.

Some countries have implemented biogas energy sources as transportation modes, such as Thailand, Malaysia, and several other countries. In the development of biogas, it is crucial to study the biogas composition before scale-up for industrial. Because each biogas raw material will produce different biogas characteristics, for example, tofu industry waste or livestock industry waste, or agro-industry waste will produce different biogas compositions. Different. For purification efficiency, comprehensive testing is needed to determine the composition of the gas and its fluctuations in a sufficient period. Then continue setting the purification conditions, the process of storage, and distribution. The latest development related to biogas is that converting methane to hydrogen has been successfully carried out. However, it has not been implemented on an industrial scale because the conversion process requires a relatively expensive investment and operational costs, making it challenging to implement in Indonesia. Also, the development of biogas conversion into biohydrogen is often constrained by hydrogen analysis, which requires unique accessories that are relatively expensive. Several research articles show the efficiency of various types of substrates to produce biogas.

### *3.5. Environmental impacts from conversion biomass to biogas*

The characteristics of biomass wastes fluctuate with different organic and inorganic contamination levels at different input time ranges. This condition will indirectly change the input process parameters so that sometimes the biogas biodigester unit will experience interference. The occurrence of this disturbance can hamper biodigester operations, which is to inhibit the fermentation process. This condition has the potential to dispose of water in biodigesters that have not been appropriately treated to environmental bodies. The impact is in the form of water or soil pollution.

The current biogas production system from biomass still allows toxic gas release into the biodigester unit environment. At certain concentration levels, these gases will pose a risk of shortness of breath and poisoning. This condition will also occur if there is a gas leak. The danger of poisoning and shortness of breath is mainly due to the content of hydrogen sulfide in biogas, which is toxic even in low concentrations due to the potential for inhalation will produce these symptoms to cause fatal poisoning. (Barbusinski, Kalemba, Kasperczyk, Urbaniec, & Kozik, 2017; Indrawan, Thapa, Wijaya, Ridwan, & Park, 2018)

The combination of atmospheric air with specific concentrations of biogas under certain conditions can form explosive gases. (Bharathiraja, Sudharsanaa, Bharghavi, Jayamuthunagai, & Praveenkumar, 2016; Guebitz, Bauer, Bochmann, Gronauer, & Weiss, 2015; Monlau, Kaparaju, Trably, Steyer, & Carrere, 2015; Rosato, 2017) In addition to the potential for explosions due to the formation of explosive gas mixtures, there is a risk of fires surrounding biogas tanks and biodigesters. In areas that are far from the biodigester unit, although there is minimal risk of an explosion due to deficient biogas levels, there is the possibility of a fire due to sparks arising, sources of ignition, electrical short circuits, or natural lightning.

In addition to producing hydrogen sulfide gas, which can cause shortness of breath and poisoning, converting biomass into biogas also produces methane gas and carbon dioxide as a greenhouse gas emission that causes global warming. (Mayer et al., 2019; Vieira et al., 2019; Winter, Agarwal, Hrdlicka, & Varjani, 2019; Wu et al., 2017; Zhang, Bauer, Mutel, & Volkart, 2017) Methanogenic bacteria produced methane as a metabolic byproduct in anaerobic conditions, while the methane formation phase formed carbon dioxide during the hydrolysis phase.

The conversion of biomass into biogas also creates new problems in wastewater and sludge (Amirta, Herawati, Suwinarti, & Watanabe, 2016). The fermentation residue composition in the form of wastewater has different characteristics depending on the substrate used. The fermentation residue still contains some organic acids, ammonia, and several other intermediate compounds (Rahayu, Budiyono, & Purwanto, 2018). Fermented residual water is directly discharged to environmental bodies at the current conversion process without further processing (Harihastuti et al., 2021). Further processing is needed, but most of the biogas units in Indonesia have not yet carried out the processing. Biogas units that dispose of the fermented residual water can cause environmental pollution and environmental degradation.

### 3.6. *Renewable energy regulation in Indonesia*

The current position of the renewable energy mix in Indonesia requires a regulatory approach and community support to meet the energy mix target of 25% by 2025 (Suharyati, Pambudi, Wibowo, & Pratiwi, 2019). Increasing renewable energy consumption will reduce carbon emissions and reduce greenhouse gas emissions to reduce the greenhouse effect.

Several regulations have been made in developing new renewable energy and energy conservation, among others, regulations concerning the national energy policy, presidential regulation, national energy general plan, and utilization of renewable energy sources for electricity supply (Direktur Jenderal EBTKE, 2020). However, with these regulations, renewable energy development in Indonesia is still far from the renewable energy mix target.

Additional regulations are needed to support infrastructure development in the production and distribution of renewable energy in Indonesia based on the principle of equitable energy so that the energy independence of the Indonesian nation can be realized. Therefore, it is necessary to add government regulations to attract investors and the public to develop renewable energy. In addition, regulations related to community support in managing biomass waste into renewable energy, especially biogas, may accelerate the renewable energy mix.

The world's most formidable challenge in developing renewable energy is the significant investment required to produce and distribute this type of renewable energy. The Indonesian government needs to commit and realize developing renewable and sustainable energy as an alternative to sustainable and environmentally energy management. Currently, the level of the renewable energy mix is still around 14.21%. By increasing the conversion of biogas from biomass in the Biogas power plant, the achievement of the renewable energy mix is expected to reach 23%.

### 3.7. *Biogas Conversion Existing Scenario in Indonesia*

Converting biomass into biogas is an anaerobic fermentation process that converts biomass into biogas and several other byproducts. Biogas fermented from biomass is a mixture of methane gas (up to 70%), carbon dioxide gas (up to 50%), hydrogen sulfide gas, and other gases such as carbon monoxide and hydrogen gas (Harihastuti et al., 2021). The conversion process generally uses a doom reactor and a little use of a stirred tank reactor (Direktur Jenderal EBTKE, 2015).

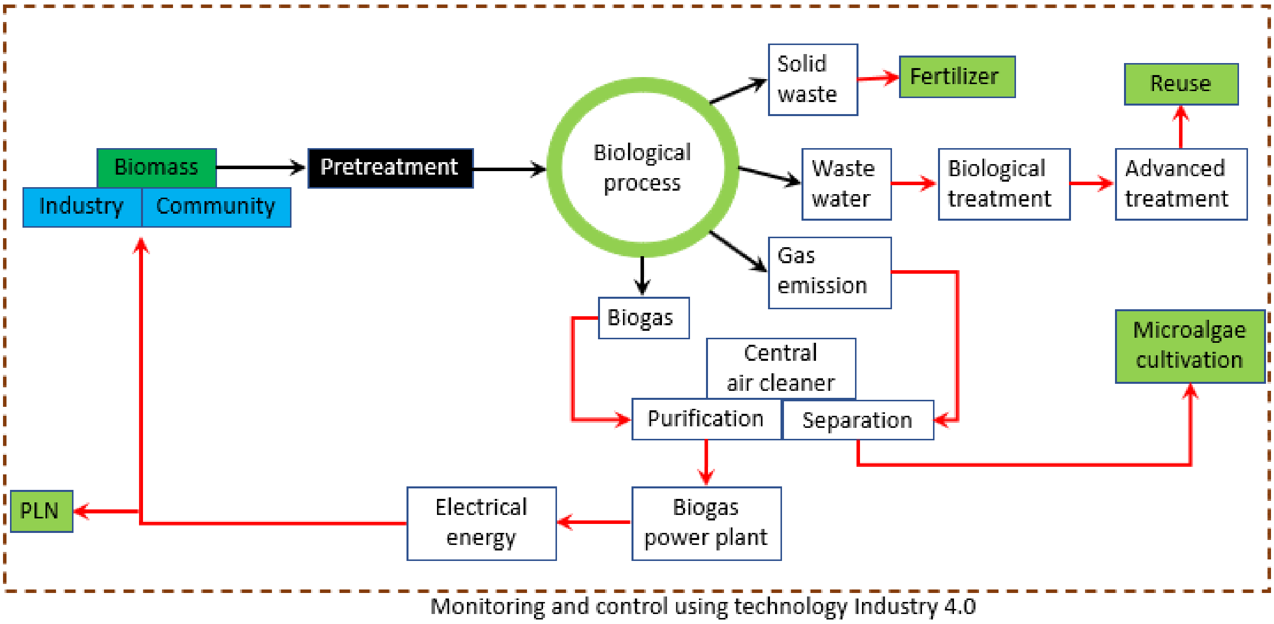


**Figure 5.** Proposed scenario new eco-friendly conversion biomass into biogas

The conversion of biomass into biogas generally consists of 5 stage components and the first is the equalization bath, the second is a mixing bath, the third is a hydrolysis tank, the fourth is a methane gas formation tank, and the last is a runoff bath. This conversion model makes it challenging to manage the optimization of conversion variables such as the rate of waste loading, fermentation time, the level of degradation, the quality of gas production, and the homogenization of the substrate (Direktur Jenderal EBTKE, 2015).

### 3.8. *Proposed new eco-friendly Scenario Biogas Conversion in Indonesia*

Minimizing negative impacts on the environment is a significant aspect of preparing the biomass to biogas conversion model. This model aims to protect the environment by minimizing the negative impacts of converting biomass into biogas to the surrounding environment to prevent contamination into the air environment and the water and soil environment.

The model proposed in this review is shown in Figure 5, namely, the stage to deactivate germs and pathogens present in the water output of the conversion process. Air pollution's prevention stage protects the environment from the harmful effects of odor, pollutants, and dust emissions. The prevention phase of water pollution, to prevent the spread of contaminants in surface water or groundwater. The water treatment stage continues because the output water still contains high organic contamination. Phase Conversion on-site biogas to electricity /thermal/liquid fuel/biohydrogen prevents emissions from methane leakage.

This review finally recommends a proposed model for converting biomass to biogas shown in Figure 5. The biogas conversion process is monitored and controlled in real-time using sensors. After further processing in the central air cleaner, the output of $CO_2$ will be used as nutrients in microalgae cultivation. Biogas conversion wastewater can be treated using catalytic processes such as catalytic or electrocatalytic ozonation. Furthermore, treated water is used in microalgae cultivation or other processes. Convert biogas output into several products, namely biohydrogen, liquid fuel, thermal, or electricity.

## 4. CONCLUSION

Indonesia has an extensive sea area, an extensive land area that produces a very high potential for renewable energy sources. To develop and apply bioenergy, Indonesia still needs a transfer of technology developed rapidly from abroad. Indonesia needs to develop biomass-based bioenergy, such as biogas, to meet Indonesia's current and future energy needs. Environmental protection by minimizing biomass conversion to biogas in the environment is done by preventing contamination into the air environment, water, and soil environment. The pollution prevention model is carried out through wastewater treatment plants, Central air cleaner, utilization of $CO_2$ gas residues for microalgae cultivation, control and monitoring of sensor-based conversion and emission processes, and on-site conversion of biogas to electricity.

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