Chapter 6

Renewable Energy of Biogas Through Integrated Organic Cycle System in Tropical System

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Additional information is available at the end of the chapter

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Abstract

Energy is a critical requirement for economic development and specifically to improve the conditions that influence all aspects of human welfare. However, the majority of people in developing countries have no access to reliable and affordable domestic energy sources. Development of organic material as sources of renewable energy through biomass, biogas, biofuel, bioreactor, algae fuel, biohydrogen, and so on, with better biotechnology by genetic improvement, environmental manipulation, purification, packing, compressing, are important for sustainable development. Biogas becomes one of the solutions to meet the energy need in rural areas of developing countries. However, the implementation of biogas has many challenges. Biogas produced from different biosources may contain pollutants that should be removed. The quality of biogas, represented by methane enrichment, can be improved with biogas purification technology. Removing the pollutants is recommended to avoid severe downstream damage and to increase the calorific value. This chapter discusses biogas purification.

Keywords: biogas purification, methane enrichment, organic cycles, renewable energy, sustainable development

1. Integrated organic cycle system

Tropical bio-geo-resource has high biomass productivity but still less economical values [1]. Integrated Bio-cycle Farming System (IBFS) is an alternative system of agriculture which harmoniously combines agricultural sectors such as agriculture, horticulture, plantation, animal husbandry, fisheries, forestry with nonagricultural aspects, such as settlements, agro-industry, tourism, industry which are managed based on landscape ecological management under one integrated area [2, 3]. The cycles of energy, organic matter and carbon, water, nutrient, production, crop, money was managed through 9R (reuse, reduce, recycle, refill, replace, repair, replant, rebuild, reward) to get optimal benefits for the farmer, community, agriculture, and global environment. The system has multifunction and multiproduct (food, feed, fuel, fiber, fertilizer, pharmacy, edutainment, ecotourism) [2, 3]. They will meet with the expected basic need for daily-, monthly-, yearly- and decade's income at short-, medium- and long- term periods. IBFS was expected to provide additional benefits for farmers with small, medium and big capital, through the recycling of organic waste into renewable resources to produce high-value production, such as organic fertilizer (liquid and solid), animal feed, and sources of biogas energy [2–4].

IBFS was developed by UGM through Integrated Crop Management (ICM), Integrated Nutrient Management (INM), Integrated Soil Moisture Management (IMM) and Integrated Pest Management (IPM). The system should collaborate and develop networking system between Academic, Business, Community and Government (ABCG) with economic, environmental and sociocultural approach as a characteristic of Education for Sustainable Development [2–4]. This model facilitates the learning needed to maintain and improve our quality of life and the quality of life for generations. It is about equipping individuals, communities, groups, businesses and government to live and act sustainably as well as giving them an understanding of the environmental, social and economic issues involved. Integrated farming could support for better sustainable life and environment.

The key characteristics of IBFS developed in UGM University Farm are (1) an integration of agriculture and non-agriculture sector, (2) value of environment, esthetics and economics, (3) rotation and diversity of plants, (4) artificial and functional biotechnology, nanotechnology, pro-biotic, (5) management of closed organic cycle and integration in an integrated area among ICM, IPM, IMM, INM, IVM, (6) management of integrated bioprotection and ecosystem health management, (7) landscape ecological management, agro-politan concept, (8) specific management of plant and (9) holistic and integrated system [2–4]. The IBFS has more advantages compared to the other various types of sustainable agricultural system such as: low input agricultural, integrated farming, organic farming, biodynamic, or agroforestry system.

IBFS is expected to be one alternative solution for improving land productivity, program development and environmental conservation and rural development in an integrated management [5–7]. They will meet with the expected basic need at short-, medium- and long-term for food, clothing and shelter. Thus, IBFS could provide income at daily-, monthly-, yearly- and decade's term for farmers. The role of micro-, meso- and macro-organisms on biogeochemical and nutrient cycling in increasing of land productivity is very important. Microorganisms are able to provide essential nutrients to plants through both mutualistic symbiotic and nonsymbiotic.

IBFS was expected to provide additional benefits for farmers with small, medium and big capital through the recycling of organic waste into renewable resources to produce high-value production, such as organic fertilizer (liquid and solid), animal feed, and sources of bio-gas energy [2–4]. That will be a good prospect that organic farming can provide sustainable economic, environment and sociocultural aspect. IBFS can produce "gold of life," such as yellow gold (food, rice, corn), green gold (vegetables), brown gold (plantation wood), red gold (meat), white gold (milk, fish), black gold (organic fertilizer), transparent gold (water), gas gold (oxygen), blue gold (biogas, biomass energy, biofuel), king gold (herbal medicine), prosperity gold (tourism) and inner gold (mystic) [2, 3].

2. Renewable energy of biogas

Biogas is a combustible gas mixture which has methane as its main composition. It is formed by anaerobic decomposition process of organic compounds. Naturally, biogas is produced in swamps, bogs, rice paddies and in the sediment at the bottom of the lakes or ocean in anaerobic condition. Van Helmont recorded that the decaying organic compounds produced flammable gases so that biogas construction could be engineered. Biogas construction had been known in several centuries. In 10th century BC, biogas was used for heating bath water in Assyria [8]. The combustible gas, methane, was produced by John Dalton and Humphrey Davy's works during 1804–1808 [9]. In the 1890s, biogas was used to power street lamps in the UK and China. Since then, biogas technology began to be commercialized.

Methane production pathways by anaerobic decomposition consist of four stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis [10]. At hydrolysis stage, the long-chain molecules of biomass such as carbohydrate, protein and fat are broken down into monomers. These monomers (monosaccharides, amino acids, and long-chain fatty acids) are then broken down into long-chain acids at acidogenesis stage and converted to acetic acid by acetogenic microorganism at acetogenesis stage. Lastly, the acetic acid is converted to methane by methanogens at methanogenesis stage (see **Figure 1**).

Biogas composed of methane (CH_4), carbon dioxide (CO_2), and other gases in very small amount, such as nitrogen (N_2), hydrogen sulfide (H_2S), hydrogen (H_2), and water vapor. Biogas composition is presented in **Table 1**.

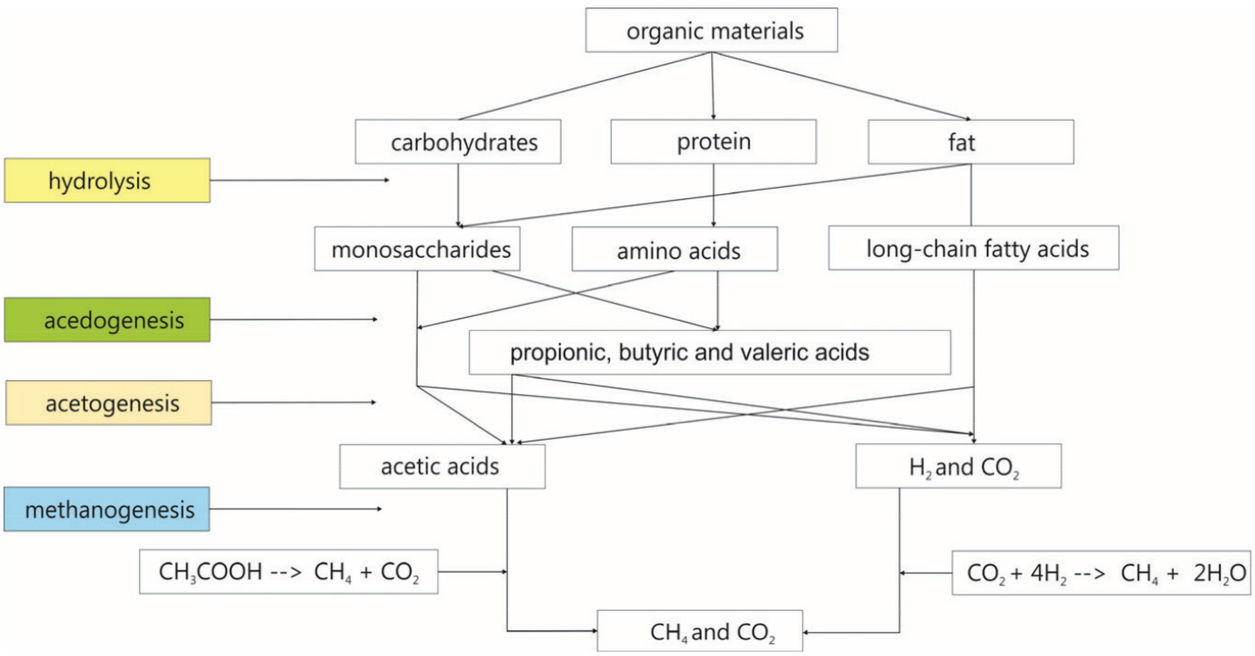

Figure 1. Conversion pathways of biogas production from biomass [10].

Gases	% composition	
	A	B
Methane (CH_4)	55–70	50–70
Carbon dioxide (CO_2)	30–45	30–40
Hydrogen sulfide (H_2S)	1–2	small amount
Hydrogen (H_2)		5–10
Ammonia (NH_3)		—
Carbon monoxide (CO)	Small amount	—
Nitrogen (N_2)	Small amount	1–2
Oxygen	Small amount	—
Water (H_2O)	—	0.3

Table 1. Biogas composition [11, 12].

The spread of biogas technology gained momentum in the 1970s, when oil price became higher. It became the motivation for finding alternative energy sources such as biogas. The intensive effort in developing biogas began in the 1900s. The fastest growth of biogas was found in developing countries such as Asian, Latin American and African countries. In developing countries, where energy was in short supply and expensive, anaerobic decomposition had a far relevance to meet energy needs. Stoves, refrigerators and engines were appliances commonly fuelled by biogas. India and China became the role model countries of biogas development in Southeast Asia. India had built their first anaerobic digester in 1897, utilized human waste to generate biogas to meet the lighting needs. China had the largest biogas progam in the world. Until 2006, there were more than 18 million biogas plants built in China [13]. By the end of 2011, the number of domestic biogas installations grew to 41.68 million [14].

When fossil fuel-based energy is abundant and inexpensive, people are not enthusiastic about the use of biogas as energy source. The higher installation and maintenance cost of biogas make people choose fossil fuel energy. Some people prefer to use fossil fuel-based energy than biogas because fossil fuel-based energy is inexpensive, ready to use, and has high calorific value. However, in several years, biogas exists along with the increase of energy needs in the world every year, and fossil fuel energy is expected to be depleted. In addition, global warming that was caused by the emissions in the use of fossil fuel-based energy also becomes the driving force behind the implementation of biogas technology as clean energy. Microbially controlled production of biogas is an important part of the global carbon cycle [13]. This is one of the efforts in mitigating the global warming disaster. Methane, the main component of biogas, is greenhouse gases (GHGs) with a much higher global warming potential than carbon dioxide. Biogas is able to isolate methane and convert it into clean energy. According to Cuellar and Webber [15], biogas from livestock waste was able to reduce GHGs emissions at 3.9% of the total emission from electricity production by fossil fuel with the same capacity. A researcher said that biogas from cow manure was able to reduce carbon dioxide emissions and replace the consumption of kerosene and firewood for cooking [16]. Based on the study conducted by National Electricity Company of Indonesia, around one million units of biogas plant were able to save 900 million liters of kerosene or 700,000 tons of LPG per year [17].

Biogas also has benefits in mitigating and overcoming organic waste issue [18]. Anaerobic decomposition of biogas is a suitable and efficient technology for organic waste management [3]. Organic wastes that are commonly used as substrate to produce biogas are from livestock manure, agricultural waste, sewage sludge, human waste, and so on [19]. If these wastes are not handled properly, they will decompose naturally and emit GHGs. Moreover, the untreated organic waste will cause bad smell and potentially contaminate the aquatic life [15]. On the other hand, the organic waste has the potential to generate energy. Therefore, many researchers investigated the best way to convert organic waste into energy. Moreover, biogas implementation can be integrated with agriculture and livestock development. It means that no waste is generated from the life cycles of agriculture and livestock sectors (close loop). Organic waste is directly used as substrate in biogas production, and the waste from biogas production can be used as organic fertilizer (see **Figure 2**).

Benefits of biogas system for users, society and environment in general are as follows [20]:

- Production of energy (heat, light and electricity)
- Transformation of organic waste into high-quality fertilizer
- Improvement of hygienic conditions through reduction of pathogens, worm egg and flies
- Reduction of workload, mainly for women in firewood collecting and cooking
- Positive environmental externalities through protection of soil, water, air and woody vegetation
- Economic benefits through energy and fertilizer substitution as income sources

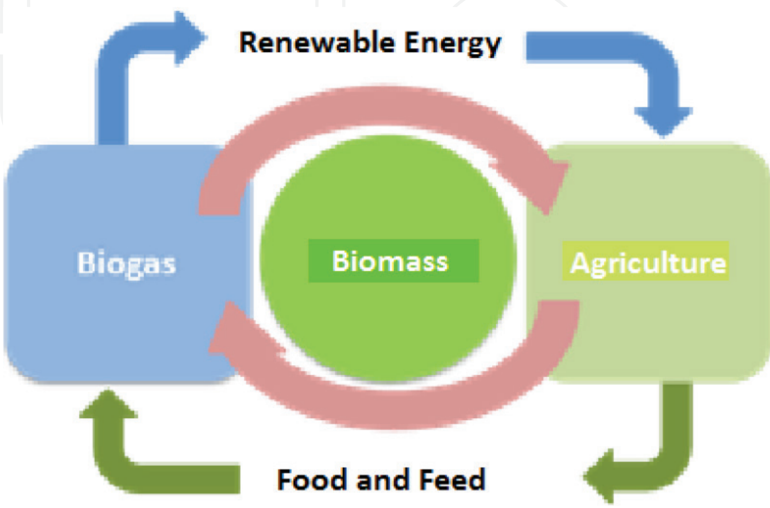

Figure 2. Integrated biogas installation [17].

Biogas can substantially contribute to the conservation and development in developing countries. However, the required high-level investment of capital and other limitations of biogas technology should also be considered.

Energy-cost-effective production and utilizing bioenergy is the key to improve the living standard of developing countries. Biogas can effectively reduce fuel consumption per capita in rural community by partly replacing coal, oil and fuelwood with straw and livestock manure-based energy [21]. Besides meeting the energy supply, biogas is expected to be integrated with biowaste management such as biogas installation in Germany (see **Figure 3**). Many programs had been done to promote the implementation of biogas technology in developing countries. In India, the Ministry of Non-Conventional Energy Sources (MNES) continues to implement the National Biogas and Manure Management Programme. Nepal, through Alternate Energy Promotion Centre (AEPC) with donor support from the Netherlands and Germany, promotes the use of biogas to rural community [20]. Ethiopia was able to disseminate 57.6% of total 14,000 domestic biogas plants planned in period 2009–2013 [14].

With the issues of global warming and the depletion of fossil fuel, the development of biogas has larger portion to disseminate, especially in developing countries. Many reports informed that biogas installations had been developed. However, the amount in many developing countries was still low. Moreover, biogas implementation is not sustainable. In Uganda, a large number of biogas installations were installed, but 29% of them had been dis-adopted, and this was within the average time period of 1.8 years after the installation [22]. Total number of biogas digesters is low in Indonesia compared to other developing countries [23]. Many people

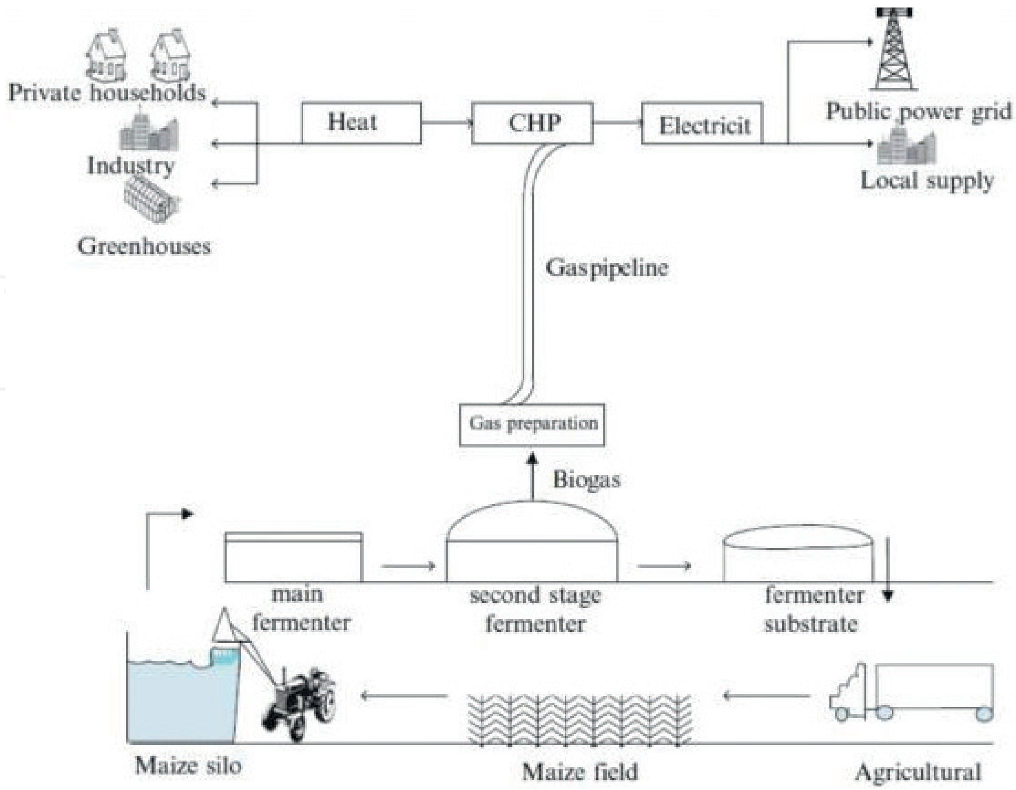

Figure 3. A typical maize-based biogas plant in Germany [20].

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prefer to consume fuelwood, gas and/or oil as their household energy supply because they do not think that the price of biogas is lower than fossil fuel-based energy.

The dissemination of renewable energy technologies in general and biogas technology is constrained by a number of factors including policies, institutions, financial constraints, subsidies, availability of input and awareness about the technology [14]. For example, financial constraint is one of most frequently cited challenges limiting the expansion of biogas technology. Thus, financial incentives are needed such as soft loans and subsides for renewable energy. Government subsidies are able to enhance the speed of biogas adoption. The low price and practicality in using fossil fuel-based energy are the reasons why people are not interested in using biogas.

In fact, subsidies are not enough to encourage the expansion of biogas technology. Another factor that influences biogas implementation is technical factor. Biogas did not meet the cooking and electricity needs of household [22]. His report informed that the use of biogas could not fully replace the use of fossil fuel. In addition, there was also a lack of motivation among the community to operate and repair the installation. Biogas cannot fully replace fossil fuel because it has low calorific value. The average calorific value of biogas is about 21–24 MJ/m^3, lower than the calorific value of fossil fuel (see **Table 2**). The lower energy of biogas is caused by the presence of impure gases in biogas [24], for example carbon dioxide, hydrogen sulfide, nitrogen, and so on. The negative effects of impurities gases were explained by the authors mentioned in refs. [8, 25, 26], as shown in **Table 3**.

Fuels	**Biogas**		**Fossil fuel**		
Gases	Biomethane	Purified biomethane (90%)	Propane	Butane	Methane
Calor (MJ/m^3)	21.5	32.3	90.9	118.5	35.9
	21–24				31–40[c]
	23				

Table 2. Comparison of calorific value between biogas and fossil fuel [8, 25, 26].

Gases	**Effects**
Carbon dioxide (CO_2)	• Inflammable gas, decreasing calorific value
	• Corrosion (contain carbon acid) if biogas is in wet condition
Hydrogen sulfide	• Inflammable gas, decreasing calorific value
(H_2S)	• Corrosion
	• Poison
Ammonia	• Emits NO_x emission after combustion
(NH_3)	• Anti-knock properties of engines
Water vapor	• Corrosion
Nitrogen	• Decreasing calorific value
N_2	• Antiknock properties of engines

Table 3. Effects of impurities in biogas [2, 25, 26].

The presence of impurities in biogas can be minimized through biogas purification. This method has also been a highlighted topic in recent years [24]. Biogas purification focuses on the removal of contaminants in biogas. Biogas purification methods used for biogas cleaning are discussed in Section 3.

3. Biogas purification

3.1. Biogas purification methods

Biogas purification is a process of removing the impure gases in biogas that affects the gas transmission grid, appliances or end user, and the increasing calorific value [27]. The impure gases are carbon dioxide, hydrogen sulfide, nitrogen and trace elements. The increase of calorific value affects the increase of biogas energy efficiency so it is able to compete with fossil fuel-based energy. In developing countries, biogas purification technology has been a site-specific and case-sensitive one, depending on local circumstances [24]. There are many methods of biogas purification that have been developed and investigated: physico-chemical methods and biological methods. Physico-chemical methods are consisted of absorption (water and chemical scrubbing), cryogenic separation, adsorption and membrane technology (see **Figure 4**).

3.1.1. Absorption

In the absorption technique of biogas purification, the raw biogas is brought into contact with nonvolatile liquid phase. The purpose is the mass transfer of contaminant from the gas phase to liquid phase [18]. The main idea in cleaning biogas using absorption is to transfer carbon dioxide to stationary liquid phase. There are two types of techniques depending on the types of the absorbent:

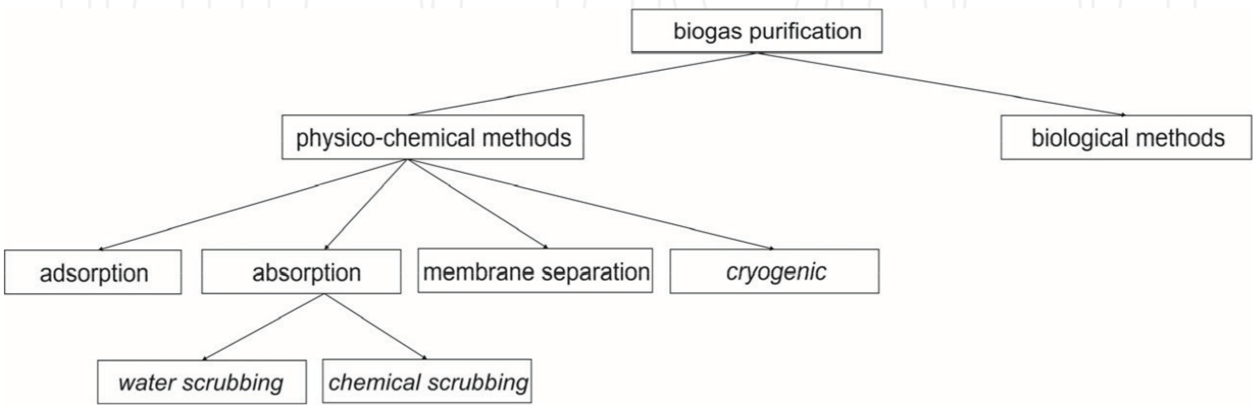

Figure 4. Biogas purification methods [27].

a. Water scrubbing

Water is used as solvent in scrubbing. The solubility of methane in water is much lower than that of carbon dioxide and hydrogen sulfide. In principle, carbon dioxide and hydrogen sulfide can be removed. However, because hydrogen sulfide is poisonous and dissolved hydrogen sulfide can cause corrosion, the pre-treatment of waste is required.

The disadvantage of this method is the large amount of water needed so it must be treated in wastewater to minimize the water consumption. Water scrubbing is the most commonly used method to clean biogas, and plants are commercially available in a broad range of capacities.

b. Chemical scrubbing

It is very similar to water scrubbing. The difference is that the carbon dioxide is absorbed in chemical solvent. Chemical scrubbing involves the formation of reversible chemical bonds between the pollutants and the solvent. The chemical solvents used in biogas cleaning are alkaline solutions such as potassium hydroxide (KOH), sodium hydroxide (NaOH) and alkanolamine solutions such as mono ethanol amine (MEA), di-methyl ethanol amine (DMEA) or tertiary amines [18, 27]. In carbon dioxide absorption by chemical solvent, the following reactions take place as given in Eqs (1)–(3):

$$CO_2 + 2\,OH^- \rightarrow CO_3^{2-} + H_2O \tag{1}$$

$$CO_2 + CO_3^{2-} \rightarrow H_2O \rightarrow 2\,HCO_3^- \tag{2}$$

$$CO_2 + R - NH_2 + H_2O \rightarrow R - NH_3 + HCO_3^- \tag{3}$$

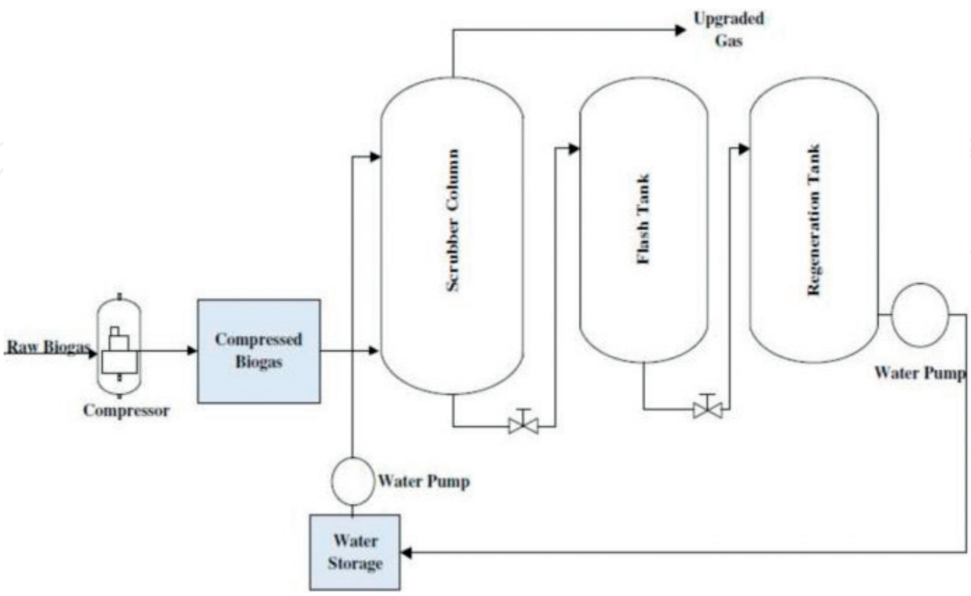

Figure 5. Schematic of chemical scrubber [28].

The advantage of this method is that the solvent can be regenerated. However, the downside of this technology relates to the energy consumption to regenerate the chemical solvent (see **Figure 5**).

3.1.2. Membrane technology

Membrane technology is a separation method at molecular scale. In biogas cleaning, carbon dioxide and hydrogen sulfide can be removed selectively through membrane column so it is able to enrich methane component in biogas.

Membrane used in this technique is made of materials that are permeable to carbon dioxide, water, ammonia and other contaminants.

3.1.3. Adsorption

Adsorption is a method to separate certain gas from gas mixtures based on the affinity to a solid adsorbent. In biogas purification, the adsorptive materials are zeolite, active carbon, silica gel for carbon dioxide and hydrogen sulfide adsorption. The adsorption process relied on the fact that at low pressure, gases tend to be attracted to adsorbent and at higher pressure, more gas was adsorbed (see **Figure 6**) [28].

The advantage of adsorption method is that when solid adsorbents are saturated, it can be replaced by regenerated adsorbent by washing with water or heating at high temperature [18].

Physical-chemical biogas purification is the most commonly and frequently implemented method. **Table 4** shows the results of evaluation of biogas purification method by many researchers. Regarding the technology adoption, biogas purification technology that requires a lot of operations is always not sustainable in rural areas or developing countries. Therefore, a cheap and easy biogas purification method needs to be operated independently by the communities. From the summary of **Table 4**, we can conclude that the adsorption method is a

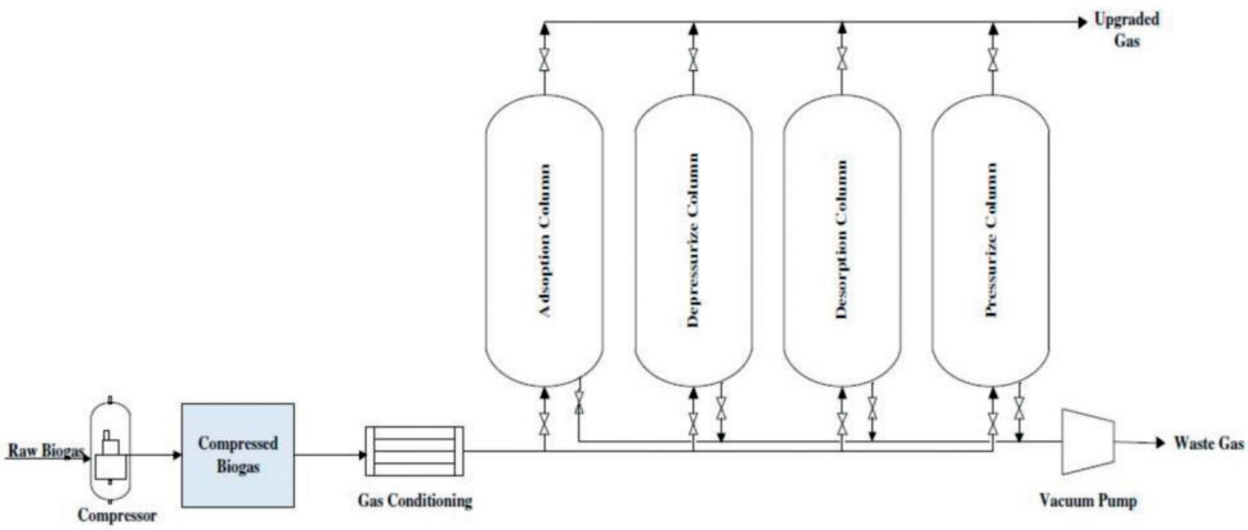

Figure 6. Schematic of adsorption in biogas purification [28].

good candidate for the technology implementation in rural areas because of the low cost and easy operation of the installation.

3.2. Methane enrichment through adsorption method

Adsorption is a separation method involving the transfer mechanism of soluble molecules in a fluid to the surface of solid material. Adsorption occurs on porous solid material that has a

Methods	Principles	Advantages	Disadvantages
Water scrubbing	Separation based on solubility	• Methane recovery at 80–99% • Methane loses 3–5% • No chemical solvent • Lower operational cost	• High energy consumption to regenerate solvent • High water consumption • Dissolved H_2S causes corrosion • Clogging due to bacterial growth • Corrosion
Chemical scrubbing	Separation based on solubility	• Methane recovery up to 95% • Methane loses 0.1–0.2% • Higher absorption capacity than *water scrubbing* • Operational time is shorter than water scrubbing	• Energy intensive • Corrosion • Large amount of solvent • Chemical waste may require treatment • Solvent is expensive
Cryogenic Separation	Separation based on condensation temperature	• Methane recovery up to 98% • Methane loses <1% • Side product is pure carbon dioxide for *drying ice*	• High energy consumption • Need more pre-treatment to remove H_2O and H_2S • Uses lots of process equipment • High operational and maintenance cost
Membrane technology	Separation based on molecule selectivity on membrane	• Methane recovery up to >96% • Simple operation • Low energy required • Membrane is able to be generated	• Some membrane has low selectivity • Often yields lower methane • High-cost membrane
Adsorption	Separation based on the different selectivity of gases on adsorbent	• Methane recovery between 96 and 98% • Methane loses at 2–4% • Can use common and cheap adsorbent • Simple installation and operation • Adsorbent can be generated	• Some adsorbents are expensive, for example *metal organic materials* (MOMs) • Methane loses in malfunctioning of valves

Table 4. Advantages and disadvantages of biogas purification methods.

partial attraction force on soluble molecule. In adsorption, there are adsorbate, adsorptive and adsorbent. Adsorbate is soluble molecule, which has been adsorbed by the surface of solid material; adsorptive is a molecule that is capable of being adsorbed on solid material [29]; and adsorbent is a solid material on which the soluble molecules accumulate.

Related to biogas purification, adsorption becomes a technology that may be suitable to adopt in developing countries. Adsorption is an easily handled technique. In rural areas, a cheap, simple and viable method becomes more attractive, and the implementation can be made sustainable. An adsorption process can be done in a variety of equipment, namely, fixed bed, moving bed, rotary bed and fluidized bed reactors. Each device has advantages and disadvantages. The main advantages of fixed bed system are the simplicity and inexpensive equipment needed, and the adsorbent is only reordered because of its position in the column. There are many related studies discussing the ways to enrich the methane level in biogas by removing carbon dioxide, hydrogen sulfide and other compounds that decrease the calorific value of biogas using zeolite, fly ash, biochar, and so on.

Saputri and Pertiwiningrum [30] have been evaluated bagasse fly ash (BFA) to adsorb H_2S in biogas from tofu waste. The preparation of BFA was conducted by its activation in 3% H_2O_2 for 5 h. The experiment was conducted in cylindrical adsorption column. The result showed that activated BFA was able to adsorb H_2S with the capacity between 1.28 and 2.42 mg/g. From this study, we saw that the difference of particle size and flow rate influenced the adsorption capacity of H_2S. The smaller the particle size was, the greater the H_2S adsorption capacity became, and the optimum capacity of the particle size was 200 meshes at 1.81 mg/g. Recycled BFA was also reusable as adsorbent although it had slightly lower adsorption capacity. Yuniarti and Pertiwiningrum [31] also used recycled BFA derived from the residue of sugarcane.

The utilization of zeolite as an adsorbent has been widely applied in oil industry for CO_2 adsorption [32]. It means that zeolite can also be used as CO_2 adsorbent in biogas purification. Mofarahi and Gholipour [33] have investigated the use of zeolite as CO_2 adsorbent in simulated biogas. This study reported that the adsorption capacity increased with the decreasing temperature and increasing pressure. **Figure 7** shows that at low pressure, the slopes of the isotherms for CO_2 are very high but then decrease very fast with the increasing pressure as the adsorbent approaches saturation.

Carbon dioxide adsorption on zeolite has been reported by Alonso-Vicaro et al. [34] at 173.9 mg/g. Zeolite is also able to adsorb H_2S with the capacity at 1.4 mg/g. Additionally, zeolite is completely regenerable and stable through several adsorptions. Bezzera et al. [28] tried to use zeolite and activated carbon to uptake CO_2 gases. They confirmed that zeolite had higher adsorption capacity than AC at 1 bar (206 mg/g and 83 mg/g, respectively). The different performance types of adsorbents are shown in **Table 5**.

From **Table 5**, we can conclude that zeolite has the best performance in carbon dioxide adsorption in biogas. However, the drawback is that not every rural area has natural resource of zeolite. As a consequence, the cost for adsorbent becomes expensive because of the packaging and distribution process.

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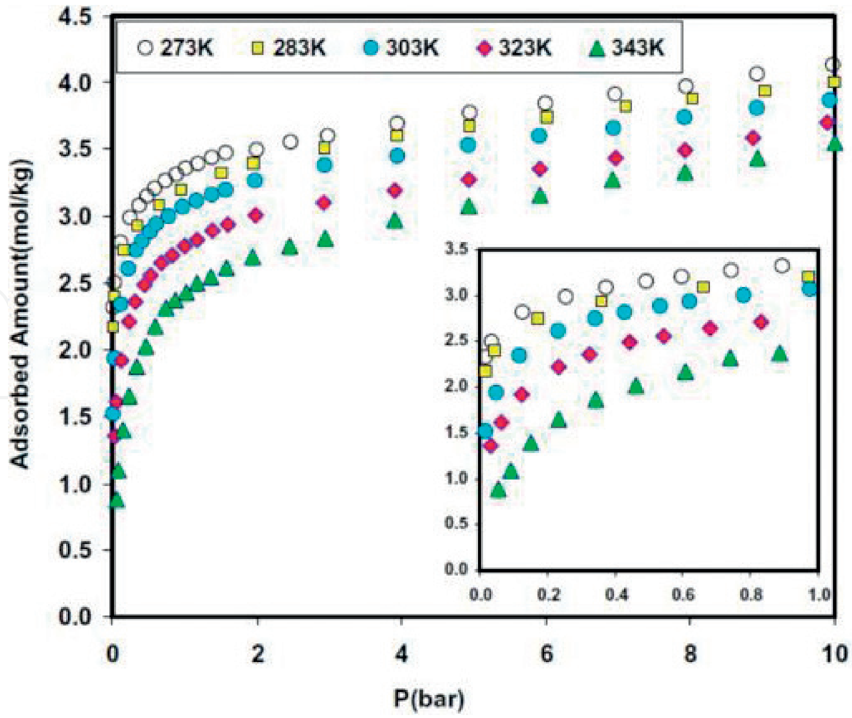

Figure 7. Carbon dioxide adsorption by zeolite [33].

Researchers	Solid materials (mg/g)				
	Zeolite	Activated carbon	Biochar	Kaolin	Silica
Bezzera et al. [35]	205.9	83.16			
Kacem et al. [32]	176	66			
Hauchhum [36]	187	124			
Bkour et al. [37]				79.6	
Mofarahi and Gholipour [33]	145.2				
Huang et al. [38]			77		
Creamer et al. [39]			73.48		
Minelli et al. [40]					26.4

Table 5. Carbon dioxide adsorption capacity of solid materials.

Biochar has been proposed as one of the substitute adsorbents for natural zeolite due to its low cost, and it is more environmental friendly. According to some researchers, biochar is proved to be capable of adsorbing carbon dioxide. Therefore, biochar is a potential adsorbent to capture CO_2 in biogas application. Huang et al. [38] investigated rice straw-based biochar to capture CO_2. The rice straw had been processed by microwave pyrolysis and conventional pyrolysis. The biochar produced by microwave pyrolysis at the power level of 300 W and maximum temperature of 300°C could adsorb CO_2 with the capacity up to 80 mg/g, higher than the biochar produced by conventional pyrolysis. Biochar produced from sugarcane bagasse was able to adsorb 73.55 mg/g of CO_2. In addition to agricultural waste, biochar can also be produced from livestock waste such as cow manure, pig manure and chicken manure.

4. Future of biogas energy

Biogas is an alternative and clean energy that replaces fossil fuels and enhance energy security. Biogas is one of the most promising and plentiful resources and is easily found in developing countries [41] especially in countries with abundant biomass resources. Biogas utilization was reported to be very important in mitigating GHGs from economic activities in rural areas, for example, fuelwood and agriculture sector. Moreover, crude oil stock decrease and cannot fulfill energy demand of countries, so there is a need to find new alternative energy for example biogas. In the future, biogas will be one of the most important alternative energy in developing countries as self-sufficient energy [42]. Biogas has developed opportunities as the demand of fossil fuel increases but the fuel stock decreases.

Biogas performance can also be compared with fossil fuel and the other renewable energy. Wahyuni [43] reported comparative study between kerosene and biogas, a case in Indonesia. By using comparison data of biogas production from livestock waste and energy from kerosene, we got comparison of cost needed to get biogas and kerosene energy in **Tables 6** and **7**.

Number of animals	Biogas production (m^3)	Conversion to kerosene (liter)
1 cow	2	1.24
2 horses	2	1.24
8 pigs	2	1.24
20 goats	2	1.24
620 chickens	2	1.24

Table 6. Conversion biogas energy to kerosene [43].

Fuel	Amount	Unit	Cost/unit (Rupiah)	Cost (Rupiah)
Biogas	1	m^3	1,620	1,620
Kerosene	0.62	liter	8,000	4,960
LPG	0.46	12 kg	75,000	2,872
Gasoline	0.8	liter	4,500	3,600
Fuel wood	3.5	kg	3,000	10,500

Table 7. Comparison of cost that is needed to get biogas and the other energy source in Indonesia [43].

5. Conclusion

Renewable energy generally gets cheaper, while fossil fuels generally get more expensive. Integrated Bio-cycle System (IBS) is a close-to-nature ecosystem on landscape ecological management to manage land resource (soil, mineral, water, air, microclimate), biological resources (flora, fauna, human) and their interaction to have more high added value in environment, economic, socioculture and health. The biocycles chain should be managed through 9A (agro-production, technology, industry, business, distribution, marketing, infrastructure, management, tourism) with 9R (reuse, reduce, recycle, refill, replace, repair, replant, rebuild, reward). IBFS could produce food, feed, fuel, fiber, fertilizer, water, oxygen, pharmacy, edutainment, ecotourism for sustainable life and environment. Development of organic material as sources of renewable energy through biomass, biogas, biofuel, bioreactor, algae fuel, bio-hydrogen, and so on with better biotechnology by genetic improvement, environmental manipulation, purification, packing, compressing, are important for sustainable development. In rural areas, the reliable and affordable technology in biogas purification should produce less waste, has less energy requirements, low cost and simple in operation and maintenance. Adsorption becomes a recommended technology in biogas purification. Adsorption is easy to operate and less expensive because it uses alternative low-cost biomass waste-based adsorbents, such as fly ash and biochar.

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Conflict of interest

The authors have declared that no conflict of interest exists.

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