IOP Conf. Series: Materials Science and Engineering 1143 (2021) 012031 doi:10.1088/1757-899X/1143/1/012031

The potential of Biogas in Energy Transition in Indonesia

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Abstract. Indonesia is an agrarian country that has a rich bioenergy potency in liquid (biodiesel, bioethanol). The Government of Indonesia (GoI) has set the target to achieve 23% of renewable energy utilization into the national energy mix by 2025. In addition, the GoI also aims to increase the production of biofuel to 7.21 million kilolitres by 2019. Theoretically, biogas technology will be a strategic measure in achieving the target, however, at the moment the biogas technology market in Indonesia is still in a nascent state, especially for the direct utilization of biogas for electricity production. Alternatively, biogas provides Indonesia with a promising source of energy, which can be injected directly into natural gas grids and hitchhike existing distribution infrastructure, resulting in reduced costs along the production-distribution pipeline. For this reason, biomethane has been the focus of some developing countries (e.g Argentina, Republic of South Africa) in moving toward energy transition. This paper examines the state of the biogas market in Indonesia using literature review. The status of natural gas is mapped out through its available potential and the existing initiation of national programs related to biogas. Finally, the study provides recommendations on how biogas technology could accelerate the energy transition in Indonesia.
Keywords: Energy Transition, Biogas, Indonesia

1. Introduction

Since 1978, Indonesia has been included in the list of the largest natural gas producing countries with a total production of 11.2 million m^3, after which the figure has increased following the opening of several oil and gas block points. At its peak in 2000, Indonesia became the highest ranking (ranked 6^{th}) Asian country in the world in producing natural gas. Total production at that time reached 70.5 million m^3/year. However, in the last 10 years, Indonesia's natural gas production has decreased by 5% each year. In 2018, Indonesia's natural gas production reached 73.7 million m^3. If natural gas is produced at the same rate as in 2016, the natural gas will only last for up to 47 years in the future. Eventually, Indonesia will become a net importer of gas in 2028. Natural gas production is predicted to be unable to meet the national gas demand in the future, so it is necessary to import gas in the form of LNG [1]. On the other hand, the use of LPG for household and commercial use faces many obstacles, as more than 65% of the current LPG supply comes from imports. Since this program was implemented in 2007, the price of 3 kg LPG is Rp. 4,250/kg and has never been increased ever since, even though the import price of LPG has reached Rp. 10,000 per kg. This can cause the amount of LPG subsidies to increase and be burdensome to the national economy as it will increase the trade balance deficit [2]. Therefore, the use of LPG should be gradually reduced to as small as possible [3].

Due to economic and population growth, it is predicted that the need of energy will continuously grow, reaching up to 450×10^9 kWh by 2026. The irresponsible use of energy, especially fossil fuels, is producing emissions that pollute the environment and increase the earth's temperature. The use of fossil fuels contributes to greenhouse gas (CO_2) emissions by 76%, which reached through usage in industrial processes (65%) and other land uses (11%). Regarding the energy problem and the greenhouse gas effect, bioenergy development can be an alternative solution. Biogas is biomass-derived fuels produced by anaerobic digestion of organic feedstock through a process through a four-step process that is mediated microbially: hydrolysis, acidogenesis, acetogenesis, and methanogenesis [33]. Biogas is one of the alternative energies that can be used to fulfill some of the domestic gas needs. The use of biogas is an effort to increase economic value from liquid waste to renewable energy and simultaneously reduce greenhouse gas (GHG) emissions [4, 5].

Globally, there are various forms of feedstocks for biogas production, these can be obtained from animal farms, municipal solid waste, agricultural residues, sludges from many industries, and wastewater treatment units [34]. Biogas from POME is composed of 50-75% methane (CH4), around 24-25% carbon dioxide (CO2) and H2O, H2S, and other gases [6]. Biogas can be upgraded by removing the CO2 content using technologies such as water or organic physical scrubbing, chemical scrubbings, pressure swing adsorption, membrane separation, and cryogenic technology [35]. The upgrading process yields biomethane with methane content up to 90-95% [36]. This methane in biogas or biomethane then could be used for several purposes, such as producing heat, electricity, and vehicle fuel, after being cleaned of any impurities to satisfy certain limits or natural gas specifications. The mentioned impurities that must be removed are water vapor and H2S. Water vapor should be extracted as it causes corrosion, accumulation of water in pipes, and freezing at high pressure. On the other hand, H2S is toxic, causes corrosion, and would produce SO2 and SO3 compounds that are more toxic than H2S while in combustion [7, 8]. One of the technologies that can be used to purify biogas into biomethane is a water scrubber.

While Indonesia’s power generation still comes primarily from fossil fuel, the Indonesian government is targeting to achieve a total of 23% renewable energy in the energy mix by 2025 [37]. Currently, most biogas production case studies in Indonesia are done in small scale using animal waste as its potential feedstock. This is due to the increasing number of cattle population in Indonesia [38]. By 2015, 16,000 biogas plants had been disseminated in mostly rural areas covering ten provinces: Bali, Banten, Central Java, D.I. Yogyakarta, East Java, East Nusa Tenggara, Lampung, South Sulawesi, West Java, and West Nusa Tenggara [39]. Other case studies have also been conducted to assess the feasibility of biogas production in Indonesia using other feedstocks, e.g. Arabica coffee pulp [40], green seaweeds [41], human excreta [42], and municipal solid waste (MSW) [43]. Since most biogas plants are disseminated in rural areas, the biogas produced are focused to be used directly for household purposes

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e.g. cooking, water heating, etc. However, there are attempts to increase the quality of the biogas produced from these plants through purification methods, namely pressurized gas scrubbing [44].

2. Literature Review

2.1. Biogas upgrading

CO2 gas from biogas and purify it to increase the heating value and reach the expected standard specifications. In general, commercial upgrading technologies are membranes, pressure swing adsorption (PSA), water scrubbers, organic physical scrubbers, and amine scrubbers [9,10]. However, water scrubber is the common choice to reduce the CO2 content in biogas since it is a commonly used technology with the average yield of the biomethane (CH4) upgrade reaching up to 96.78% [8, 11, 12]. This technology also does not require chemicals in the process even though it requires a lot of water [13]. The process of cleaning CO_2 in biogas depends on the principle that CO_2 is more soluble in water than CH_4. Biogas with high pressure enters the absorption tank and meets the flow of water being sprayed from the top of the tank. CO2 will dissolve into the water and will flow into the flash tank. The gas that comes out of the top of the absorption tank already has a high concentration of biomethane (CH_4) (> 96%) yet still needs to be dried to reduce water content. In the flash tank, the dissolved CO_2 in the water still carries the remaining CH_4 and other impurities. The remaining CH4 is then flown back into the biogas inlet, while CO2 and other contaminants are flown into the desorption tank for disposal. Lastly, the low-pressure air is flown to the desorption tank, while the water is mostly recycled. In case the water is lacking, extra water is added (makeup water) [8,14].

2.2. Gas supply in Indonesia

Initially, the development of Indonesia's natural gas industry was more for export. The construction of LNG (liquefied natural gas) refineries in Badak (East Kalimantan) and Arun (Aceh) in the 1970s made Indonesia the world's largest LNG exporter. In the same era, natural gas was exploited in Cilamaya (West Java), channeled through transmission pipes to be used as raw material for fertilizer (Cikampek), fuel/support for the iron smelting plant (Cilegon), and as city gas in some of the routes it passes. In the 1980s several "Pemjadig" (gas distribution network development) projects were carried out in a number of cities in Java and Sumatra. Natural gas reserves in the north-west sea of Java and in the Madura Strait are exploited, piped to a combined cycle power plant in Java (PLTGU Muara Karang and Tanjung Priok in West Java, PLTGU Gresik in East Java, etc.) and used as fertilizer and raw materials for petrochemicals (in Gresik, East Java). Natural gas transmission Grissik (Sumbagsel) - Duri, Riau (544 km) was built, starting its operation in 1998. This development has been followed by the Grissik -Batam-Singapore and Sumbagsel-West Java transmission lines. However, these efforts have not been able to shift the share of petroleum in the national primary energy mix. As national LPG production was inadequate, LPG was imported as much as 3.3 million tons in 2013 and 3.6 million tons in 2014 due to the increasing demand for LPG. Indonesia's natural gas content is generally in the form of methane and ethane, while LPG is produced from the content of propane and butane natural gas [2].

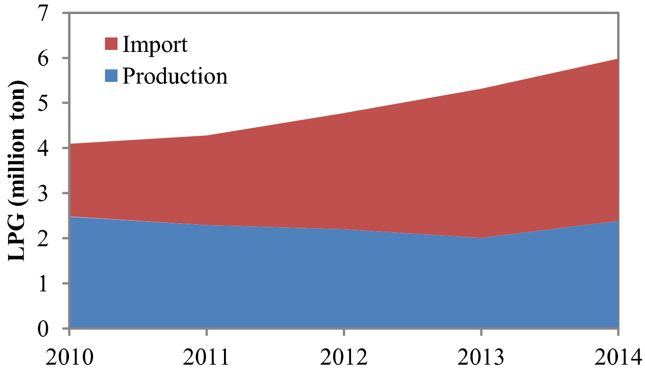

Figure 1. Production and import of LPG [2].

3. Methodology

This article is written based on the results of studies or literature related to biomethane. The research method includes secondary data collection from the Central Bureau of Statistics and the Ministry of Energy and Mineral Resources in the form of official websites, online books, review of journals related to the conversion of bioethanol from agricultural waste and organic waste, data processing (calculation of bioethanol potential that can be produced) and analysis, and discussions.

4. Result and Discussion

4.1. Energy transition in Indonesia

One effort in energy transition in Indonesia can be seen through the energy mix policy. Under the Collective Regulations, these policies will put Indonesia on a path to decarbonization. Government Regulation Number 79/2014, concerning National Energy Policy, sets out the ambition to transform, in 2025 and 2050, that the main energy supply mix is as follows: a) new and renewable energy at least 23% in 2025 and at least 31% in 2050; b) oil must be less than 25% in 2025 and less than 20% in 2050; c) coal at least 30% in 2025 and at least 25% in 2050; d) gas at least 22% in 2025 and at least 24% in 2050. Currently, the contribution of renewable energy (RE) has only reached around 9% (9.15%) of the total national energy mix. Achieving the target of RE contribution in 2025 of 23% is a formidable challenge although it is not impossible to achieve [15].

In the industrial sector, energy diversification from fuel oil to coal, gas, and biomass has taken place so that fuel consumption is no longer dominant. Natural gas has the third-largest reserves in the world after coal and oil. Natural gas was not initially consumed as an energy source due to transportation difficulties, so it was always burned when it was co-generated with petroleum. The products of natural gas used are LPG (Liquid Petroleum Gas), CNG (Compressed Natural Gas), LNG (Liquid Natural Gas), and Coal Bed Methane (CBM) which are non-conventional energy sources that are being developed in Indonesia. CNG is a natural gas that is compressed without going through a refining process and stored in metal cylinders. CNG is relatively cheaper because it does not go through a refining process and is more environmentally friendly. LPG and LNG are natural gas produced from the refining and separation of petroleum. Butane and propane will turn into LPG and methane will turn into LNG [16].

Gas energy is believed to be clean energy which price is relatively cheap compared to other energies. The Downstream Oil and Gas Regulatory Agency (BPH Migas) notes that the average pipeline gas price in Java is US$9-US$11 per MMBtu. The price of other gases such as compressed natural gas (CNG) is US$11 - US$15 per MMBtu and retail liquefied natural gas (LNG) is US$17 - US$19 per MMBtu. Whereas, the average price of fuel oil (BBM) and liquefied petroleum gas (LPG) is US$20 - US$23 per MMBtu [17]. As such, to increase its domestic utilization, in 2008, the government implemented the construction of city gas networks (*jargas*) through APBN funding, starting with the implementation of the FEED and DEDC. In 2014, 16,949 household gas networks were built in 5 locations, namely Semarang City, Bulungan, Sidoarjo, Bekasi District, and Lhoksumawe. From 2009 s.d. 2014, the cumulative development of the city gas network through APBN funding reached 25 locations and was allocated to 86,460 house connections. Apart from funding from the state budget, up to 2014, PGN has also built jargas for 92,858 house connections in 10 cities [2].

Meanwhile, in the transportation sector, the role of BBM is still difficult to replace with other types of fossil energy. As for the household sector, electricity and LPG are still the most consumed types of energy, following the usage of LPG to replace kerosene. In line with this, the decline in fuelwood consumption was also followed by an increase in LPG consumption from 5.3 million tonnes (14%) in 2013 to 5.8 million tonnes (17%) in 2014. Conversely, kerosene consumption decreased from 6.4 million BOE (1.9%) in 2013 to 4.9 million BOE (1.7%) in 2014. The decline in kerosene consumption was caused by the substitution policy for kerosene with LPG for cooking in households and small businesses. This program has been implemented since 2007 and succeeded in reducing kerosene consumption by around 8.28 million kiloliters by 2014, saving around 40 trillion rupiahs. The number of 3 kg LPG units that have been distributed in that period reached 49,269,666 units [2, 14].

4.2. Potential of biomethane

Indonesia has quite a large potential for renewable energy resources, one of which is from waste. Waste in the form of urban waste, agricultural sector, industrial sector, and others can be used to be converted into energy, either in the form of fuel/heating or electricity. According to the Ministry of Energy and Mineral Resources [15], Indonesia has a biomass potential of 885.2 million Gigajoules (GJ) per year. Potential calories obtained include the type of rubber plantation rejuvenation waste (496.0 million GJ per year), remaining lodging (11.0 million GJ per year), sawmill industry waste (10.6 million GJ per year), empty palm oil bunches (15 , 4 million GJ per year), palm oil residue (35.3 million GJ per year), palm fruit shells (17.2 million GJ per year), sugarcane bagasse (78.0 million GJ per year), rice husks (179.0 million GJ per year), coconut shell (18.7 million GJ per year) and coconut husk (24.0 million GJ per year) (Figure 2). The potential source of electricity from the waste can reach 50 thousand MW, which is the second largest potential energy resource after hydro on a large scale. Utilization of this waste is still around 1600 MW or about 3.25 percent of the existing potential [2].

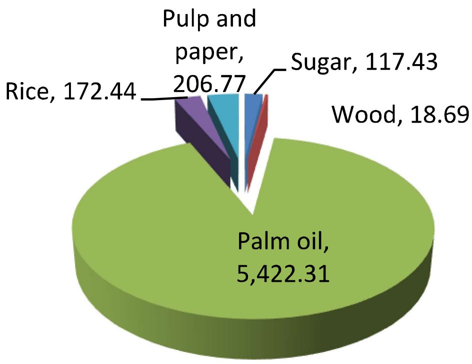

Figure 2. Potential of bioenergy (MW) [15].

From the Bioenergy Based Power Plant Development Program conducted by National Electricity Company (PLN-Persero), the existing capacities of the existing power plants originating from Biomass (oil palm-based), biogas, and urban waste connected to the electricity grid PLN was only 61 MW in February 2012, which will be increased later by 197 MW in 2013 and further increased by 544 MW in 2014 (so that it becomes 741 MW in 2013/2014). The utilization of biogas is one of the targets for bioenergy-based renewable energy development as stipulated in the National Energy General Plan (RUEN). However, the achievement of biogas utilization is still far from the target of RUEN in 2025. From the electricity sector, for example, the Biogas Power Plant (PLTBg) is targeted to reach a capacity of 5.5 GW in 2025, yet, the realization is only around 1.33% [15].

Non-electricity-based bioenergy development can also be implemented in the biogas development program. In this biogas development, there is the development of household-scale biogas and communal biogas. The biogas is developed by various parties including the State Budget of the Directorate General of EBTKE, the BIRU Program in collaboration with DJEBTKE and HIVOS, other ministries/ institutions, Regional Revenues and Expenditures Budget (APBD), special allocation funds, and other private sectors. Most of this biogas development utilizes livestock manure as raw material, but communal biogas has also been developed by utilizing human waste which is implemented in the communal biogas boarding school. The Ministry of Energy and Mineral Resources has built communal biogas in 20 Islamic boarding schools in 10 provinces since 2016. Based on the data collection on the implementation of direct biogas development that has been carried out by the Directorate General of EBTKE, as of May 29, 2020, installed household biogas has reached 47,505 units throughout Indonesia, producing 75,044.2 m3/day of biogas or around 26.72 million m3/year. In connection with the commercial biogas PLTBg, currently, there are nearly 96.21 MW of data.

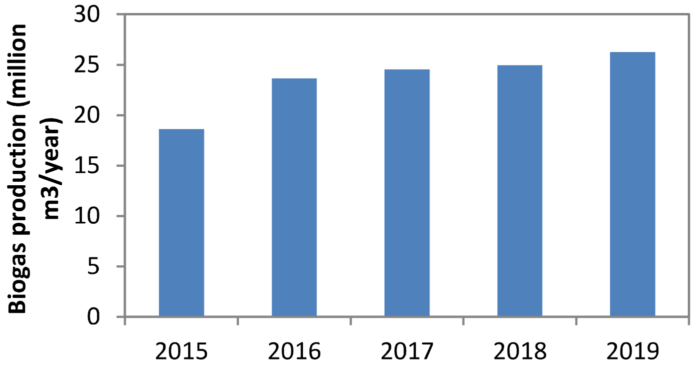

Figure 3. Progress of biogas production [15].

4.3.1. Livestock manure. Indonesia has quite a lot of livestock potential, including large ruminants such as beef cattle and dairy cows. Based on the implementation of the 2018 inter-census agricultural survey (SUTAS), it is known that the estimated population of large ruminants in 2018 was 17.9 million. From this figure, there are 16.43 million beef cattle, 581,822 dairy cows, and 894,278 buffalos. In 2019, the population is projected to grow to 18.12 million large ruminants [18]. Considering that a single livestock can produce up to 10 kg of manure per day, it has the potential to become an alternative energy source (biogas) and reduce the dependency of the community, especially family farmers, on fuel, oil and electricity. If an average of 10 kg of manure is produced per cow per day, Indonesia can produce 179,000 tons of cow feces every day.

4.3.2. Sewage Sludge. Based on the last recorded data in 2015, the total population in Indonesia is 238,518,000. This number is projected to increase in 2020 to 271,066,000 people. However, not all members of the population are supported by adequate sanitation facilities. Based on the 2006 National Socio-Economic Survey, [18] only 40.67% of the total number of households were equipped with a septic tank; the number is worse in the village, which is around 24.37%. This means that most Indonesian people dispose of their black water directly into the environment without any treatment. According to Nagamani and Ramasamy [19], human feces can produce up to 28 L/kg of biogas. With 1 m3 of biogas, we can turn on a 60-100 Watt lamp for 6 hours or cook 3 meals for 5-6 people, as it produces the equivalent of 1.25 kWh of electricity [20].

4.3.3. POME. In 2017, Palm oil production in Indonesia reached 37.8 million tons with large palm oil mills (POM) spread across the regions of Sumatra, Kalimantan, and Sulawesi [22, 23]. The by-products of the POM include liquid waste known as palm oil mill effluent (POME). POME can produce biogas which can be further processed into biomethane. The Winrock study [24] shows that the production capacity of fresh fruit bunches (FFB) from POM in Indonesia reaches 34,280 tons per hour with 23,996 m3 of POME produced per hour. This production capacity will be able to produce biomethane of 54.5 million standard cubic feet (SCF) or the equivalent of 11.5 million BOE (equivalent to barrels of oil) annually if all these by-products are being maximized. Meanwhile, the current biomethane production is equivalent to 10% of the current natural gas consumption of 564.3 million SCF or equivalent to 20% of LPG consumption (57 million BOE) [25].

4.3.4. Municipal solid waste. With a high number of the population living in the urban area, the amount of waste produced reaches 175,000 tons/day. Most of this waste is transported and dumped in a landfill (69%) and only a small percentage is composted and recycled (7%) [26]. Furthermore, only 10.28% of the population sort and reuse household waste in 2013 [27]. Based on its characteristics, most of the waste in Indonesia is classified as organic waste. In fact, Indonesia is one of the countries with the highest content of organic waste in Asia (70.2%), followed by China (67.3%) [28]. In urban areas, the volume of organic waste can reach 70% of the total waste [29]. Based on a survey conducted in 2005-2006, the composition of organic waste in Indonesian cities could reach up to 52% of all urban waste [30].

Vegetable waste dominates the total waste with an average of 2 tons/day. The composition of vegetable waste that is mostly found, among others, are spinach, chicory, mustard greens, cabbage, and a small portion of other vegetables. This vegetable waste will usually be transported to landfills, while the rest will be left behind. Vegetable waste that is left behind has not received special handling and will cause environmental pollution [31]. However, vegetable waste could provide good nutrition for microbes and does not contain pathogens, as such it is suitable for anaerobic digestion or composting [32].

The Ministry of Environment aims to develop a waste-to-energy (WtE) investment financing program for several projects, including (a) collecting methane gas in cattle farm waste (biogas); (b) increasing the efficiency and collects methane gas in tofu industrial waste (biogas); (c) agricultural waste (biomass); (d) processing industry (heat to energy); (e) general WtE (biomass from oil palm fronds, biogas from palm oil mills, and domestic waste (human waste)); [5]. Of the various types of WtE, four types of WtE are proposed to be supported through financial investment, namely (a) biogas reactor from cattle farm waste; (b) biogas reactor from tofu industrial waste; (c) developing power generator in the oil palm plantation and industry; and (d) utilization of agricultural biomass for heating/drying, particularly for rice husk biomass.

5. Conclusion

In line with the direction of energy conversion, LPG has become a strategic commodity that is widely needed by the community as a substitute for kerosene. However, this leads to several problems, mainly related to scarcity and likely price surges. This study aims to reexamine the concept of energy conversion by considering and utilizing optimally the already available domestic energy sources. The prospect of biomethane as an environmentally friendly renewable energy has considerable potential in meeting energy needs due to limited fossil fuel reserves and concerns about increasing GHG emissions.

Acknowledgment

The authors would like to thank the European Commission and the INEA for the support of the DiBiCoo project. DiBiCoo has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857804.
Disclaimer: The sole responsibility of the content of this paper lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither the INEA nor the European Commission is responsible for any use that may be made of the information contained therein.

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