Sustainable bioindustrial agriculture: concept, implementation, and its potential for bioenergy production

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Abstract. This study is aimed to explain the concept of Sustainable Bioindustrial Agriculture (SBA), its implementation in Indonesia, and the potential of SBA for bioenergy production, as well as for reducing Green House Gas (GHG) emission. The results of the study. SBA is an agricultural system which principally manages and optimally utilizes all biological resources, including biomass and agricultural organic waste, for the welfare of the community in an ecosystem in harmony with the principles of reduce, reuse, and recycle. Crop-Livestock Integration System (CLIS) is very important component of SBA. The implementation of SBA in Indonesia has not yet been fully meet the target. There is a big potential for the development of SBA in the country, including for the production of bioenergy, especially biogas. The production of biogas within such system is very potential for reducing the impact of climate change i.e. through reducing GHG emission.

1. Introduction
Geographically, Indonesia is in the area around the equator, even passed by the equator. Its position brings extraordinary blessings, including abundant sunshine for most of the year, its land resources are fertile, and rich in biodiversity of biological resources. It is therefore, Indonesia aspires to become a world food barn by 2045, when the age of The Republic of Indonesia reach 100 years [1-2]. However, there are challenges to achieve that goal, including: (a) the population that continues to increase which demands to fulfillment of food needs also continues to increase, (b) land degradation and environmental damage due to long duration of applying agrochemicals from outside which are very high and do not pay attention to sustainability for future farming, and (c) the rate of agricultural land conversion for non-agricultural purposes is quite alarming.

The use of chemical pesticides and fertilisers in Indonesia and other countries for agriculture has seen a sharp increase and has reached alarming levels with gave implications for human health, the ecosystem and ground water [3-5]. Not only chemical fertilizers, chemical pesticides can also harmfull for the environment. According to Kavalekar [3], in India, due to heavy usage of chemical fertilizers and harmful pesticides on the crops, sustainability of the agriculture systems collapsed, cost of cultivation soared at a high rate, income of farmers stagnated, food security and safety became disturbed. It is therefore very important to use new method to improve soil soil fertility, pests and disease control.
Due to the low aspect of sustainability in farming in the past led to thoughts of experts from many aspects concerning the sustainability of farming/agriculture. It must be admitted that in Indonesia, the application of green revolution technology (in the era of the green revolution) has produced tangible results that are recognized by the world, namely the achievement of rice self-sufficiency in 1984. However, with various criticisms from scientists regarding the practice of applying those technology, finally the conceptual thinking emerged, i.e. sustainable green revolution, which means sustainable agricultural business, starting around the 1990s [6].

Sustainable agriculture generally refers to four main points of interest, namely: (a) present and future food sufficiency, (b) the present and future economic viability of agricultural business, (c) environmental sustainability and quality of natural resources, and (d) preservation of biodiversity [7].

According to Arora [8], agricultural sustainability can be achieved through the use and implementation of agricultural technology that is able to increase crop production to meet the needs/demands for the growing population, while at the same time maintaining and protecting the environment and natural resources.

Bioindustrial agriculture (BA) is an agricultural system that considers the sustainability aspects of farming, land resources and the environment, but still maintains high agricultural productivity through optimal use of internal inputs, and is able to produce bioenergy or renewable energy [9]. Thus, BA is an ideal manifestation or an ideal model of a sustainable agricultural system. Hendayana [10] argued that the development of BA was an anticipatory step towards the tendency for agricultural changes to occur in the future. The future agriculture is predicted to face changes mainly due to climate change. The tendency to change is characterized by: (a) the increasing need for quality food, feed, and fiber, (b) scarcity of land and water, (c) increasingly scarce fossil energy, and (d) changes in demand for environmental services. According to Manurung [9], this trend of change has consequences for the need for economic transformation that leads to: the increasing need for bioproducts, bioenergy, healthy lifestyles and biocultural consumption patterns, adaptation and mitigation capacity, as well as efficiency and conservation.

This study will provide an understanding of the concepts of sustainable bioindustrial agriculture (SBA), the implementation of SBA in Indonesia, and its potential for bioenergy production and reducing the impact of climate change.

2. The concept of sustainable bioindustrial agriculture (SBA)

Manurung [9] explained that the essence of agriculture is to accommodate the photosynthesis process or to harness the transformation of electromagnetic energy from sunlight into chemical energy in the biomass of agricultural plants. In the BA, agricultural cultivation and processing should minimize the use of external inputs or other sources of limited availability energy (i.e. fossils), but conversely, in agricultural cultivation, it should be able to restore the role of plants as primary producers of biomass that can be used as food raw materials, non-food bioproducts, and bioenergy in a sustainable manner. The bioindustry is defined as any facility or processing business that uses biomass as a feedstock or uses microorganisms or biological enzymes (bio-enzymes) that are extracted or synthesized from organisms in one or more stages of their processing to produce food, feed, energy, and various kinds of bioproducts.

The SBA is an agricultural system that principally manages and/or optimally utilizes all biological resources, including biomass and/or agricultural organic waste, for the welfare of the community in an ecosystem in harmony. The keywords of the SBA system lie in all biological resources, agricultural biomass and waste, science and technology, bioprocessing, and genetic engineering. The concept of SBA is also said to be a stage in rearranging agricultural structures and systems to build an agricultural economy in synergy between production and distribution in the framework of agricultural renewal [11]. It was also stated that there are several points of thought that can be adopted in understanding the ideal of SBA, namely:

a. Producing little waste to preserve nature or reduce environmental pollution,
b. Using little external production input to reduce the threat of increasing global warming through the crop-livestock integration system,
c. Playing a role in increasing added value in producing food products as well as processing biomass, and its waste becomes new high value bioproducts (for example cosmetics, medicines, functional food, industrial raw materials, pesticides, etc.),
d. Following the principles of environmentally friendly integrated agriculture, so that its products can be accepted by global market,
e. As a biorefinery based on advanced science and technology, the SBA can be used to produce high value of healthy food and non-food, as well as increasing exports of processed products and reducing dependence on imports of various agricultural commodities (for example soybeans, fruits, various vegetables, animal feed, milk, meat, etc).

In the SBA system, agricultural land is seen as an industrial unit with all of its production factors to produce food and other products (bioproducts and waste) which are managed into bioenergy by managing zero waste (non-waste) for industrial purposes with the principle of reduce (less external input), reuse, and recycle (recycling). However, it must be stressed that the SBA must benefit from economic, social and environmental aspects. Based on the explanation above, it can be said that, for Indonesia, systematic thinking from the SBA perspective is how to obtain the maximum possible solar electromagnetic energy that is abundant through agriculture [12]. Architecture of a SBA system is presented in Figure 1.

Figure 1. The architecture of SBA systems [12].

In line with the main ideas described above, the Plant-Livestock Integration System (PLIS) is considered an important, or perhaps the main component of SBA [10] [12] [13] [14], Brown and Brown [15] defined sustainable agriculture, which is nota bene is SBA, as an integrated system of plant and livestock cultivation practices that have a specific location application in the long term. Thus, PLIS is an agricultural system characterized by a synergistic relationship between plant and livestock. For this reason, technological innovation plays an important role in optimizing the performance of PLIS.

The main objective of the SBA development is to release farmers’ dependence on external inputs and market rulers who dominate the use of agricultural resources. According to Gold [16], sustainability in bioindustrial agriculture is an agricultural system capable of maintaining productivity and its social use, or, farming systems that are capable of maintaining their productivity and usefulness
to society indefinitely. The system must have characteristics: not damaging the environment, resource-conserving, socially supportive, and commercially competitive.

3. The implementation of SBA in Indonesia

It must be admitted that the implementation of SBA in Indonesia has not appeared as a massive movement in various regions according to agroecosystem conditions and local resources [17-18]. However, what cannot be denied is that from various examples of its implementation in various regions, the SBA has a positive impact, not only for increasing crop/agricultural production in general, but also for the provision of healthy and nutritious food, increasing the added value of agricultural products, resulting in improved fertility/land carrying capacity, and increased farmers’ income. Haryono et al. [11] stated that the development of sustainable BA need convergence of programs through effective coordination and support from all sectors.

In this study, an example will be given regarding the application of the SBA model in North Sumatra, which was carried out in Tanjung Jati Village, Langkat Regency for three years, 2013-2015 [14]. This activity is carried out by integrating three components, namely: food crops (rice, soybeans, peanuts and sweet potatoes), estate crops (oil palm) and livestock (cattle and goats). The relationship between the three components and other aspects is presented in Figure 2. Based on the implementation of this activity, several results can be noted, including:

a. Food crop farming and livestock business are carried out by individual farmers. The synergy between those two kinds of activities in oil palm plantations become the greatest contribution to the driving factor for agricultural and livestock business in the area.

b. Based on the analysis of community perceptions of farming of three kinds of business (food crops, estate crops, and livestock), the improvement in the application of the integration farming model is needed, namely in the context of farmer community participation. Farmers need to carry out this activity by joining farmers into the Farmer Group or the group of Farmer Group.

c. In general, the application of the integrated model of food crops and livestock in this oil palm plantations is following the principles of the SBA model. The results include: (a) increased use of crop residues as animal feed, (b) increased cropping index, (c) increased farming efficiency, and (d) there is potential to yield bioenergy/biogas from cattle manure.

![Figure 2. An example of Integrated agriculture between food crops, plantation crops and livestock as a SBA model in Langkat Regency, North Sumatra [14].](image_url)
Different potentials in different regions (for example the island base) create a variety of agricultural potentials between regions, while simultaneously enabling the development of SBA. For example, the island of Sumatra stands out with Indonesia's leading commodities from the plantation sector, including oil palm and rubber. Java Island is relatively superior in almost all commodities of food agriculture, horticulture, livestock and aquaculture. Bali and Nusa Tenggara also excel, apart from rice and maize in livestock commodities. Sulawesi Island is superior with plantation commodities (cocoa and coconut), while Kalimantan is quite potential with forestry and oil palm commodities [19]. Besides, the readiness of technology, both for on farm and off farm, also has the potential to support the development of SBA. To maintain the sustainability of land resources, for example, the technology which is ready to use for soil conservation in situ is available [4], also the technology for making ruminant animal feed based on local resources [20], and also the post-harvest technology for SBA [21]. In addition, research results demonstrated that the SBA model was able to increase the added value of agricultural products and farmers' income and also able to support the sustainability of agricultural businesses in development areas [22-25]. And, regarding the development of SBA in Indonesia, The Government hopes that its implementation must be carried out by applying industrialization principles and farmer-based corporations in an area [11].

4. The potential of SBA for bioenergy production

Up to now, humans are very dependent in fossil fuels [26-27]. And, continuity in consuming fossil fuel will also lead to dwindling of oil reserves. Therefore, renewable energy is needed for substitution or change fossil fuels. In crop livestock system (CLS), whereby it become the main component of SBA, the poor management of livestock waste contributes to environmental problem. Moreover, according to Varquez et al. [28], the animal manure and wastewater have high concentration of metals (such as copper, zinc, arsenic, and cadmium), mainly due to the mineral components of livestock feed that are excreted in manure and to the corrosion that have negative effect in animal enclosure. Conversely, livestock waste can become valuable when it is managed correctly.

Biogas is one of the form of renewable energy. These gases, actually can be derived from a wide range of organic waste such as biomass, human, and animal waste through the process of anaerobic digestion and it can be used as energy. The conversion of biogas from manure, especially cow manure has an advantages energy because such energy is environmentally friendly, as leftover from the process (biogas slurry) can be used as organic fertilizer [29-31]. Moreover, the use of biogas can also reduce atmospheric GHG (Green House Gas) and other emissions [32-33].

In this study, we only want to show the aspect of cow manure which is abundant in the area/location of SBA since livestock is a main component of the system, especially for biogas production. Basically, biogas technology is not a new technology in Indonesia, because around the 1970s this technology have been demonstrated. The potential of manure in Indonesia is very large so that it has also a big opportunity to be developed into biogas [30, 34-36]. For example, according to Abdullah (1991 in Widodo [31], a beef cattle weighing 520 kg is capable of producing 29 kg of wet manure/day (12% dry matter), while a dairy cow weighing 640 kg is capable of producing wet manure as much as 50 kg (14% dry matter). It was reported [37] that the beef cattle population in Indonesia in 2018, 2019, and 2020 were 16,432,945 heads, 16,930,025 heads, and 17,466,792 heads, respectively. Abdullah et al. (1991 in Widodo [31]) also informed that per kg of cow and buffalo dung can produce 0.023-0.040 m³ of biogas. Utilization of waste in this way is economically very competitive especially in remote areas where it is usually lacking in supply of fuel oil/gas and inorganic fertilizers. Besides, these practices contribute to the agriculture sector which is environmentally friendly and sustainable [34, 38-39].

The process of biogas production involves multiple related biochemical processes with microorganism that work together to achieve the degradation of organic matter into methane and carbon dioxide. The first stage is hydrolysis, in which many complicated components are transformed into simple molecules and components. In this stage, generally, the complicated carbohydrates, lipids and proteins are transformed into simple sugar molecules and/or amino acids, and further fatty acids.
Furthermore, i.e. the acidogenesis stage, the resulting materials are transformed into volatile fatty acids, hydrogen and carbon dioxide. The volatile fatty acids then to be converted to hydrogen, carbon dioxide and acetic acids in the acetogenesis stage, and finally, the methanogenesis stage decomposes the hydrogen, carbon dioxide and acetic acid, and produces methane [31, 40-42]. All those processes occurred in an anaerobic/closed digester.

Putri et al. [29] showed that the mixture of manure and water (1 : 3 ratio) and manure : rumen (1 : 2 ratio) produced the highest volume of biogas as compared to other ratios, and the highest biogas production occurred on average at day 23. This is important information, especially to be used for the development of biogas production in the field. Figure 3 show a schematic of two simple biogas digesters which are usually used in China and India, whereas Figure 4 is an example of a biogas reactor design in Indonesia (floating drum model). This reactor is capable of producing 200 liters of a mixture of cow dung and water, with the volume of biogas produced for 3 days is 2.721 m³ with an average gas formation of 0.074 m³ per day. The total combustion time that can be used to heat water is 181 minutes with an average final temperature of 91.5 °C [44].

![Figure 3. Type of biogas production digester: (a) Chinese system, and (b) Indian system [43].](image)

![Figure 4. An example of digester design for biogas production from cow dung [44].](image)

Widodo [31] has also shown various forms of utilization of biogas, including for cooking food, petromax lamps, and driving motors, whereas Agustian [30] showed that biogas plays a significant role in substituting the use of LPG for farmers up to 3-4 tubes per month. By processing livestock manure into biogas through an anaerobic digester, the methane gas produced will be burned/utilized and produce heat energy that can be used for various purposes, as exemplified above. Thus, processing
livestock manure into biogas and its utilization greatly supports the creation of future agriculture that is environmentally friendly and sustainable, i.e. sustainable bioindustrial agriculture (SBA), and also to contribute to reduce the negative impact of climate change through reducing atmospheric GHG and other emissions.

Concerning the national energy policies, it is important to understand that as stated in the attachment to Presidential Regulation No. 22/2017 that the use of new and renewable energy (NRE) is still low, namely around 5%. The government is targeting the use of NRE (including biogas) in 2025 to be 23% and at least 31% by 2050 of the total national energy mix [45]. This shows the huge opportunities for developing NRE in Indonesia starting from now. Therefore, all efforts for the development of SBA together with the development of biogas from livestock manure, in which CLS is inside, is very strategic. If this can be done massively, those not only will increase the use of NRE significantly, but also will significantly contribute to reduce GHG emissions. Furthermore, for the implementation of the development of biogas, a strategy is needed, i.e. including the development of biogas at the household scale should be carried out in a coordinated manner and integrated between agencies. Several points are needed for the efforts to develop biogas using raw materials from cow manure, i.e.: (a) support and commitment from the government considering that there are quite a lot of livestock farming and are scattered in rural areas, (b) good planning, especially in the early stages of revamping the center for national cattle areas, (c) good coordination between agencies in the biogas digester assistance program so that it is more organized and evenly distributed in various regions, and (d) program synergy between the biogas development program and the national livestock development program.

5. Conclusion
The SBA system is agriculture that views land as an industrial unit with all of its production factors to produce food and other products (by-products and waste) which are managed into bioenergy by managing zero waste (non-waste) for industrial purposes with the principle of reduce (less external input), reuse, and recycle (recycling) and such system is benefit from economic, social and environmental aspects. The implementation of the SBA can contribute to reduce the negative effect of climate change.

The development of sustainable bioindustrial agriculture in Indonesia has not yet been carried out massively, although many research results indicated that from the economic of view, the implementation of SBA was economically feasible. The successful development of sustainable SBA requires convergence of programs through harmonious coordination and support from all sectors and actors of development. Crop Livestock Integration System (CLIS) become the main aspect/component in SBA, because crops and livestock can live in synergy and mutual benefit and will produce higher quality of food and other products of high economic value as raw materials for numerous industrial purposes.

Biogas become one of the important products from the SBA. The potential for producing and developing biogas from the SBA system in Indonesia is very huge and, if it can be implemented together with the development of the SBA system in the field, it will help reaching the national new and renewable energy (NRE) use to target and will have a broad positive impact on rural area development and also for reducing the impact of climate change through the reduction of GHG emission.

References
[1] Kementan 2017 Pengembangan Bioindustri di Kawasan Pertanian: Potensi Bisnis Sektor Pertanian yang Ramah Lingkungan [Online] Available: www.ojk.go.id/sustainable-finance/id/Lists/Agenda%20Nasional/Attachments/43/04.%20Kementan
[2] Kencana M R B 2020 Wujudkan RI Jadi Lumbung Pangan Dunia, Jokowi Dorong Inovasi Produk Pertanian www.merdeka.com/uang/wujudkan-ri-jadi-lumbung-pangan-dunia-jokowi-
[3] Kawalekar J S 2013 Role of biofertilizers and biopesticides for sustainable agriculture J. Biol. Innov. 2 73-8

[4] Nurjaya D, Erfandi, and Pratiwi E 2015 Pemulihan Lahan Sawah Terdegradasi dengan Pengelolaan Limbah Pertanian In situ (Jakarta: IAARD Press) p 58

[5] Azad Md A K 2020 Re: What are The negative effects of chemical fertilizers in human health [Online] Available: https://www.researchgate.net/post/what_are_the_negative_effects_of_chemical_fertilizers_on_human_health/5f80b0834749de3788218068/citation/download

[6] Las I 2009 Revolusi Hijau Lestari untuk Ketahanan Pangan ke Depan Tabloid Sinar Tani 14 Januari 2009 [Online] Available: www.new.litbang.pertanian.go.id/artikel/232/pdf/Revolusi%20

[7] Sumarno 2018 Pertanian Berkelanjutan: Persyaratan Pengembangan Pertanian Masa Depan Mewujudkan Pertanian Berkelanjutan: Agenda Inovasi Teknologi dan Kebijakan (Jakarta: IAARD Press) pp 3-31

[8] Arora N K 2018 Agricultural sustainability and food security Environmental Sustainability 1 217-9

[9] Manurung R 2014 Pengembangan Sistem Pertanian-Bioindustri Berkelanjutan: Peluang dan Tantangannya Prosiding Seminar Nasional Hasil Penelitian Tanaman Aneka Kacang dan Umbi 2014 (Bogor: Pusat Penelitian dan Pengembangan Tanaman Pangan) pp 32-45

[10] Hendayana R 2015 Perspektif Pengembangan Pertanian Bioindustri [Online] Available: www.slideshare.net/rachmatendayana/perspektif-pengembangan-pertanian-bioindustri---

[11] Haryono, Syakir M, Hendriadi A, Rohlini, Prastowo B, Las I, Tafakresnanto C, Ritung S, Richana N, and Mardiyanto S 2015 Model Pengembangan Kawasan Pertanian Bioindustri (Jakarta: IAARD Press) p 98

[12] Simatupang P 2014 Perspektif Sistem Pertanian Bioindustri Berkelanjutan Reformasi Kebijakan Menuju Transformasi Pembangunan Pertanian (Jakarta: IAARD Press) pp 61-79

[13] Bamualim A and Tienamurti B 2009 Konsepsi Sistem Integrasi Antara Tanaman Padi, Sawit, dan Kakao dengan Ternak Sapi Sistem Integrasi Ternak Tanaman: Padi-Sawit-Kakao (Jakarta: Puslitbang Peternakan, Balitbangtan) pp 1-14

[14] Hanifah V W and Wasito 2018 Perception on Integration of food Crops and Livestock in Oil Palm Plantation to Reach Bioindustrial Agriculture Model: Case in North Sumatera Province, Indonesia Journal of Science, Technology and Innovation Policy 4 1-10

[15] Brown R C and Brown T R 2014 Biorenewable Resources: Engineering New Products from Agriculture (2nd Ed.) (United State: John Wiley & Son, Inc. Iowa State Press) p 373

[16] Gold M V 2007 Sustainable Agriculture: Definitions and Terms. Special Reference Briefs Series No. SRB 99-02 (Betsville: National Agricultural Library, USDA)

[17] Tangendjaya B 2017 Kapan Sistem Pertanian Berkelanjutan Dapat Terealisir di Indonesia? Ragam Pemikiran Pengembangan Pertanian 2017: Buku Forum Komunikasi Profesor Riset (Jakarta: IAARD Press) pp 207-13

[18] Simatupang P 2018 Perspektif Implementasi Pertanian Berkelanjutan di Indonesia Mewujudkan Pertanian Berkelanjutan: Agenda Inovasi Teknologi dan Kebijakan (Jakarta: IAARD Press) pp 551-72

[19] BPS 2014 Potensi Pertanian Indonesia: Analisis Hasil Pencacahan Lengkap Sensus Pertanian 2013 (Jakarta: Badan Pusat Statistik)

[20] Kuswandhi 2012 Pengembangan pakan ternak ruminansia berbasis sumberdaya local Memumbani Iptek Pertanian (Jakarta: IAARD Press) pp 123-40

[21] BBPP Pertanian 2015 Inovasi Teknologi Pascapanen Pertanian Bioindustri (Jakarta: IAARD Press) pp 337

[22] Rawung J B M, Indrasti R and Bakrie B 2018 Sustainable Agricultural Bio-industry Development: Integration of Cassava Cultivation with Beef Cattle Husbandry in North Sulawesi Province IJEAB 3 1331-9
[23] Adwirawan I G L P, Arwana I K, Murtiningsih N G A E, and Wiswasta I G N A 2019 Impact of the development of Industrial Bio Agricultural Model against the additional value of farming on dry land in Tabanan Bali International Journal of Contemporary Research and Review 10 21289-96

[24] Natalia B, Wiswasta I G N A, Arwana I K, and Sujana I P 2019 Impact of Development of Bio-Industrial Agricultural Models on Catlle Growth and Environmental on Dry Land in Tabanan Bali IJCR 10 20306-14

[25] Elizabeth R and Anugrah I S 2020 Pertanian Bioindustri Meningkatkan Daya Saing Produk Agroindustri dan Pembangunan Perlganjan Berkelanjutan Mimbar Agribisnis: Jurnal Pemikiran Masyarakat Ilmiah Berwawasan Agribisnis 6 871-89

[26] Florio C, Florentino G, Corcelli F, Ulgiati S, Domonlet S, Gusewell J, and Eltrop L 2019 A life cycle assessment of biomethane production from waste feedstock through different upgrading technologies Energies 12 718

[27] Lim C I and Biswas W K 2019 Sustainability implications of the incorporation of a biogas trapping system into a convetional crude palm oil supply chain Sustainability 11 792

[28] Varquez D D, Cummings S C A, Rodriguez C S, de Anda J, and Hernandez M S C 2020 Evaluation of Biogas Potential from Livestock Manures and Multicriteria Site Selection for Centralized Anaerobic Digester Systems: The Case of Jalisco, Mexico Sustainability 12 3527

[29] Putri D A, Saputro R R, and Budiono 2012 Biogas Production from Cow Manure Int. Journal of Renewable Energy Development (IJRED) 1 61-4

[30] Agustian A 2018 Kontribusi Pengembangan Biogas Berbasis Kotoran Sapi terhadap Rumah Tangga Pertanian Mendukung Sistem Pertanian Berkelanjutan Mewujudkan Pertanian Berkelanjutan: Agenda Inovasi Teknologi dan Kebijakan (Jakarta: IAARD Press) pp 161-94

[31] Widodo T W 2018 Pemanfaatan Biogas dalam System Pertanian Berkelanjutan: Agenda Inovasi Teknologi dan Kebijakan (Jakarta: IAARD Press) pp 131-59

[32] Gore A 2010 Our Choice: Rencana untuk Memecahkan Krisis Iklim (Terjemahan oleh P. Hando Hadi dari Buku “Our Choice: A Plan to Solve the Climate Crisis, 2009”). (Yogyakarta: Kanisius) p 248

[33] Supriatna J 2018 Konservasi Biodiversitas: Teori dan Praktik di Indonesia (Jakarta: Yayasan Pustaka Obor Indonesia) p 542

[34] Prihandana R and Hendroko R 2007 Energi Hijau: Pilihan Bijak Menuju Negeri Mandiri Energi (Jakarta: Penebar Swadaya) p 248

[35] Herawati T 2012 Refleksi sosial dari mitigasi emisi gas rumah kaca pada sektor peternakan di Indonesia Wartazoa 22 35-45

[36] Syarifah I and Widiawati Y 2017 Profil emisi gas rumah kaca dari sapi potong di 34 provinsi menggunakan metode Tier-2 Prosiding Seminar Nasional Teknologi Peternakan dan Veteriner 2017 (Bogor: Litbang Pertanian) pp 280-91

[37] BPS 2020 Populasi Sapi Potong menurut Provinsi (Ekor): data seri 2018-2020 [Online] Available: www.bps.go.id/indikator/24/469/1/populasi-sapi-potong-menurut-provinsi.html

[38] Bahri S and Tiesnamurti B 2012 Strategi Pembangunan Peternakan Berkelanjutan dengan Memanfaatkan Sumberdaya Lokal Jurnal Litbang Pertanian 31 142-52

[39] Santos A J, Fuah A M, dan Salundik 2015 Integrasi biosistem peternakan sapi potong, biogas dan sayur di lahan pasang surut Tanjabtim, Provinsi Jambi Jurnal Ilmu Produksi dan Teknologi Hasil Peternakan 3 146-52

[40] Kao C Y, Chiu S Y, Huang T T, Dai L, Wang G H, Tseng C P, Chen C H, and Lin C S 2012 A mutant strain of micro algae Chlorella sp. for the carbon dioxide capture from biogas Biomass and Bioenergy 36 132-40

[41] Ramaraj R and Dussadee S 2015 Biological purification processes for biogas using algae cultures (A review). Special Issue: Renewable Energy Applications in the Agricultural Field
and Natural Resource Technology International Journal of Sustainable and Green Energy 4 20-32

[42] Moreda I L 2016 The potential of biogas production in Uruguay Renewable and Sustainable Energy Review 54 1580-91

[43] Sejahrood A J, Najavi B, Ardabili S F Z, Shamshirband S, Mosavi A, and Chau Kw 2019 Limiting factors for biogas production from cow manure: energo-environmental approaches. Engineering Applications of Computational Fluid Mechanics 13 954-66

[44] Putra G M D, Abdullah S H, Priyati A, Setiawati D A, dan Muttalib S A 2017 Rancang bangun reaktor biogas tipe portable dari limbah kotoran ternak sapi Jurnal Ilmiah Pertanian dan Biosistem 5 369-74

[45] Lampiran Peraturan Presiden Republik Indonesia No. 22 Tahun 2017 Tentang Rencana Umum Energi Nasional [Online] Available: https://sipuu.setkab.go.id/PUUdoc/175146/Lampiran%20I%20Perpres%20Nomor%2022%20Tahun%202017.pdf