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Benefits of Biogas as a Renewable Energy Source in Supporting Sustainable Development Goals (SDG$_s$) in the KPSP Setia Kawan Region, Pasuruan, Indonesia

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ABSTRACT

KPSP (Cooperative of Dairy Farmers) Setia Kawan, Nongkojajar, Pasuruan, East Java, Indonesia, is one of the largest cooperatives of dairy farms in Indonesia, which consists of approximately 11,225 farmers with a population of 25,273 dairy cows. Milk production to date has reached ± 94,000 liters per day or ± 1,128,000 liters per year, which is increasing due to the milk needs of the Indonesian people, with the number of dairy cattle population in the KPSP Setia Kawan area has the potential to produce renewable energy sources, namely biogas by processing livestock manure waste. Processing livestock waste into biogas is very profitable and can play a role in the Sustainable Development Goals (SDGs) program.Processing livestock waste into renewable Energy through biogas is very appropriate because biogas can balance the use of fossil energy, which is increasingly depleting, and the use of biogas is more environmentally friendly and has economic and social benefits as a pillar of sustainable developmentThis systematic review comprehensively examines the benefits of biogas as renewable Energy in supporting the sustainable development goals program based on the three pillars of sustainable development, namely environment, economy, and social, that support the SDGs Sustainable Development Goals program. The research shows a powerful contribution benefit between the three pillars of sustainable development and sustainable development goals at KPSP Setia Kawan on biogas as renewable Energy.

Keywords: KPSP Setia Kawan, Biogas, Sustainable Development Goals (SDGs), Sustainable Development

1. INTRODUCTION

Setia Kawan Dairy Farmer Cooperative (KPSP Setia Kawan), located in Wonosari Village, Tutur District (Nongkojajar), Pasuruan Regency, East Java Province, Indonesia, is the largest dairy farming cooperative in Indonesia with its primary business venture in the production of pure dairy milk business supplied to PT Indo lacto Purwosari, Pasuruan as a partner.

The business fields of the KPSP Setia Kawan cooperative include fresh milk division, savings and loans, trade, services, and waste processing business units with a total membership of approximately 11,225 people and a dairy cattle population of 25,273 heads, according to (Jatim Bsip., 2024). The rapid development of the KPSP Setia Kawan cooperative cannot be separated from the history of the beginning of the establishment of the cooperative in 1911 by the Dutch when raising dairy cows and producing milk in the area around Nongkojajar with local people to

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meet the needs of fresh milk, especially for the Dutch at that time, Given the environmental conditions that are very suitable and possible for raising dairy cows in the region because of the cool climate, located on the western slopes of the Tengger Bromo mountains, Pasuruan, East Java with an altitude of between 400 - 2000 meters above sea level, air temperature 5^0C -18^0 Celsius see map figure 1. Dairy cows prefer a cool climate with an ambient temperature of 4-21°C.

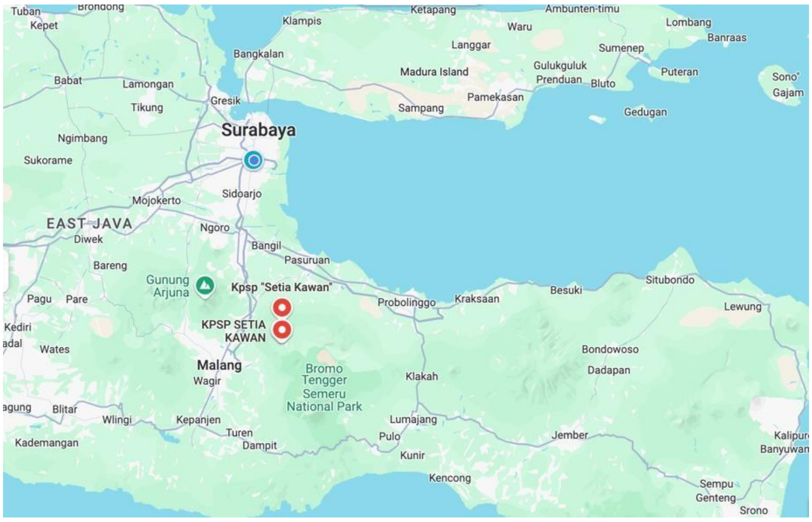

Figure 1. KPSP Setia Kawan Nongkojajar area west of the Tengger Bromo mountains, Pasuruan, East Java (Source: KPSP document, 201

Along with the development of the times after the independence of the Republic of Indonesia, in 1964 established Koperasi Berdikari, and in 1967, Koperasi Karya and Koperasi Berdikari merged into the Dairy Cow Cooperative Center (PKLP) Setia Kawan. These two cooperatives both accommodate and market cow's milk. In 1996, KUD Setia Kawan changed its status to KPSP (Koperasi Peternakan Sapi Perah Dairy) Setia Kawan, which is based in Nongkojajar, Pasuruan, until now with the leading business service as a provider of fresh cow's milk from its members. Recognized as the largest provider of fresh cow's milk in East Java to its partners, the increase in the number of dairy cattle population around the Nongkojajar area at KPSP Setia Kawanv has caused several aspects of problems such as environmental, health, social, and economic. Environmental and health issues, if not managed wisely and correctly, will negatively impact the area around the farm in Nongkojajar due to livestock waste. The most correct and appropriate solution is to process livestock waste into biogas as a source of renewable Energy for the surrounding area in particular, making the environment clean and health under control.

Cattle waste in one day can produce 25-30 kilograms per head of feces solid waste) and urine (liquid waste) in dairy cows (Phillips, 2001) will make an average of 60 liters of solid and

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liquid waste (urine) or 0.06 m3 per day. Livestock waste on dairy farms will be a negative factor for the environment and health such as water pollution (groundwater and surface water), air pollution (unpleasant stench in the surrounding environment), soil pollution (can pollute the soil body), social, environmental conflicts, health impacts around livestock waste (the presence of harmful bacteria when polluted in soil and water around the local environment). All of the above will cause the beauty of the surrounding environment (ecology), air, water bodies, and human health problems to have a negative impact (Nurtjahya et al., 2003).

Efforts to minimize livestock waste by processing livestock waste into biogas as renewable Energy, livestock waste becomes a renewable alternative energy raw material without worrying about its availability. It becomes clear Energy, which has significant environmental, economic, and social benefits (Ezeudu et al., 2021).

Dairy farming activities in the Nongkojajar area positively impact the processing of manure waste into biogas as renewable Energy for sustainable development in the environment, economy, and society (S. Ningrum et al., 2019; T. Haryati, 2006). In rural areas and developing countries such as Indonesia, it is necessary to provide Energy for cooking, heating, power generation, and transportation. Using biogas as a substitute for conventional fuels from fossil fuels improves air quality due to not using wood fuel indoors and reduces dependence on traditional biomass fuels such as firewood (Ogundari, 2023).

Biogas is the product of the biological process of fermentation of organic waste, known as anaerobic digestion (AD) in a reactor with an inexhaustible feedstock that can be supplied continuously (M. JB Kabeyi & AO Oludolapo., 2020 and M. Lebuhn, B. Munk, & M. Effenberger., 2014). Biogas consists of methane (CH4) in the range of 50-70% and carbon dioxide (CO2) at a concentration of 30-50%. The main content is CH4 Methane) and CO2 (carbon dioxide) gas in biogas is dominant and depends on the substrate's nature and the reactor's pH. In addition to these two gases, biogas also contains small amounts of other compounds, such as nitrogen (N2) at a concentration of 0-3%, which can come from saturated air in the influent, water vapor (H2O) at a concentration of 5-10%, or higher at thermophilic temperatures, which comes from moderate evaporation, oxygen (O2) at a concentration of 0-1%, which enters the process from the influent substrate or leaks, hydrogen sulfide (H2S) at a concentration of 0-10.000 ppm resulting from the reduction of sulfate contained in some waste streams, ammonia (NH3) originating from the hydrolysis of material proteins or urine (Muñoz et al, 2015, Petersson & Wellinger., 2009).

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Biogas is a sustainable, flexible, and highly committed source of Energy that addresses the dual predicament of energy security and ecological maintenance, burdening the regular disintegration of natural matter. Biogas generation offers a defensible option in contrast to petroleum derivatives (fossil energy), moderates the discharge of ozone-depleting substances, and adds to the circular economy. One of the most convincing benefits of biogas lies in its natural advantage of being renewable from organic waste (Igbum., et al., 2019). Biogas can also support sustainable development because it includes three-dimensional aspects such as economic, environmental, and social, which are interrelated in fulfilling sustainable Energy in an area that makes energy independence (Rustijarno., 2009, Rajendran., et al., 2012; Orskov., et al., 2014, Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju., 2022).

Biogas production is a well-established sustainable process for generating renewable energy to treat organic waste. The increasing interest in utilizing biogas as a substitute for natural gas (biogas from fossils) or exploitation as a transportation fuel opens new avenues in the development of biogas upgrading techniques as well as due to the depleting and non-renewable reserves of existing natural gas with the existence of biogas which deserves special attention today (Irini Angelidaki et al., 2018).

The potential of biogas as a renewable energy source can support several sustainable development goals (SDGs), which makes it an essential contributor to global sustainable development efforts and has significant potential as a renewable energy source in industrial, transportation and domestic (household) applications that are efficient against the worldwide energy crisis as a substitute for fossil energy (Atelge et al., 2020). Biogas production in sustainable development (SDGS as Affordable, Clean, environmentally, economically and socially friendly Energy), by providing a renewable (alternative) energy source can reduce greenhouse gas emissions (Yetano-Roche et al., 2020). Biogas has a vital role in the global energy transition from fossil fuel-based to renewable Energy which is based on low- carbon energy, the potential of biogas is enormous to make as electrical Energy in the energy transition as a renewable energy fuel source (P.P.G. Machado et al., 2021, G. Liu & J. Bao., 2017).

Several studies have been conducted that the use of biogas as renewable Energy contributes to the sustainable development goals program which is better known as SDG s For example in research (Lohani et al., 2021) informs that the use of biogas on a small scale contributes to SDG 1, SDG 3, SDG 5, SDG 7, SDG 13, and SDG 15, 2021) informs that the use of biogas on a small scale contributes to SDG 1, SDG 3, SDG 5, SDG 7, SDG 13, and SDG 15. Previously on September 25, 2015 at the United Nations (UN) Headquarters, world leaders

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endorsed the Sustainable Development Goals agenda, the SDGs have 17 targets, including: (SDG 1) no poverty anywhere; (SDG 2) no hunger, improve nutrition, and promote sustainable agriculture; (SDG 3) get a healthy and prosperous life for all; (SDG 4) quality education and lifelong learning for all; (SDG 5) gender equality by empowering women and girls; (SDG 6) get clean water and sustainable proper sanitation for all; (SDG 7) get clean and renewable Energy; (SDG 8) decent work and equitable economic growth; (SDG 9) industry, innovation and infrastructure in line with needs; (SDG 10) reduced or no inequality; (SDG 11) sustainable urban and rural settlements; (SDG 12) responsible consumption and production; (SDG 13) responsive to climate change; (SDG 14) care for marine ecosystems; (SDG 15) on land ecosystems; (SDG 16) peace and justice; (SDG 17) comprehensive partnerships to achieve sustainable development.

In addition to that, similar things were informed by (Shaibur et al., 2021 and Rosenthal et al., 2018). In other studies such as in (Rahman et al., 2019) concluded that the application of biogas will help realize SDG 3, SDG 4, SDG 5, and SDG 7. More recently according to (Orner et al., 2020) informed that biogas from agricultural waste contributes positively to SDG 6. As can be seen from this study and other studies namely (Samer M et al., 2020., Lundmark R, 2021 and Sahota S, 2018), most studies do not provide a clear relationship between biogas and SDGs. Most of the previous studies focused on improving biogas technology and linking biogas to specific SDGs. In addition, most previous studies did not propose methods or guidelines to improve the contribution to SDGs. Therefore, this study aims to analyze the contribution of using biogas as a renewable energy in supporting sustainable development into the related 17 sustainable development goals (SDGs) program, especially in this case in the area of KPSP Setia Kawan in Nongkojajar, Pasuruan Regency, East Java which is one of the largest cooperatives in Indonesia as a dairy farmer cooperative has been able to build approximately 1500 biogas reactors with a fixed dome type and the future target is to be able to reach 3000 biogas reactors.

2. RESEARCH METHODS

Based on the preliminary background above, in the preparation of this journal, the method used is descriptive research method. Descriptive research methods refer to (Arikunto, 2010) by collecting existing data in the field as a supporting factor for the object under study and analyzing its role, looking for literature reviews, looking for references, and reading journals and concluding, both national and international journals as references

The purpose of this journal research is to find out the extent of the benefits of biogas as renewable Energy in sustainable development in the KPSP Setia Kawan Nongkojajar Pasuruan

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area which includes Economic, Social and Environmental aspects as 3 pillars of sustainable development that contribute to the 17 SDG sustainable development goals s program at KPSP Setia Kawan Nongkojajar Pasuruan.

The author also analyzes what efforts KPSP Setia Kawan should make to be more targeted in the biogas program in the sustainable development goals.

3. RESULTS AND DISCUSSION

Biogas as a Renewable Energy Source

Biogas is in the category of bioenergy where the source of raw materials comes from biomass (organic matter) such as from livestock waste, agriculture and organic waste materials include any material derived from plants, animals, organic waste and can be decomposed into carbon dioxide (CO_2), methane (CH_4), and a small content of other gases such as hydrogen sulfide (H(2)S), nitrogen (N_2), and water vapor through the fermentation process (Biosantech, T. A. S., et al., 2013).

Biogas energy plays a key role in human life in economic, social and environmental development. In recent decades, technological advances have determined relevant changes in people's lifestyles. In addition, the increase in human population as well as overall industrial development has led to an exponential rise in global energy demand (Kang M, et al., 2020). In particular, energy reserves will be depleted in the coming decades due to the massive increase in energy demand as the human population is increasing significantly. Therefore, the energy sector worldwide must identify renewable energy sources as new alternatives to replace fossil fuels. This is also important from an environmental point of view. In fact, it is well documented that fossil-derived fuels are the most important source of pollution and global warming, mainly due to the production of CO_2 and sulfur compounds (Martins F., et al 2018, Lelieveld J., et al 2019, Kularathne, I.W., et al 2019).

Biogas as a renewable energy source can support remote communities especially in rural areas where it is difficult to reach and is also ideal for grid decentralization as well as industry into the transformation of the electric energy generation sector (Nwokolo, et al., 2020).

Biogas is one type of renewable Energy where the raw material is easily reproduced and can always be perbaruhin. Based on this understanding, biogas energy is renewable Energy (Sri Wahyuni, 2011).

From the description above, why use biogas as a renewable energy source at KPSP Setia Kawan Nongkojajar Pasuruan from dairy cow manure because the raw materials are readily

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available and very qualified with a high number of cattle population. Figure 2 illustrates the renewable energy biogas scheme from dairy cattle manure waste as raw material at KPSP Setia Kawan which supports sustainable development goals.

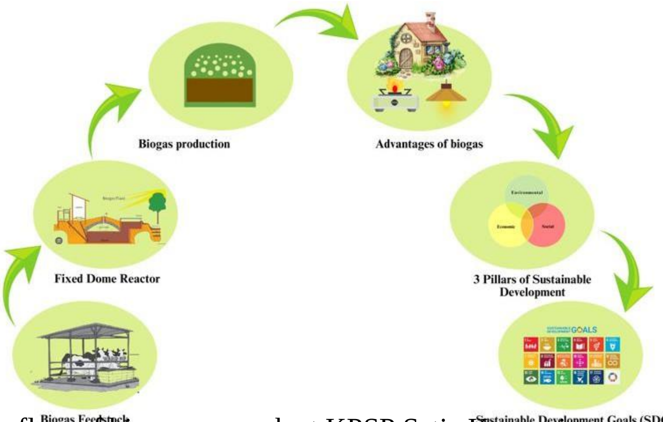

Figure 2. Schematic flow of biogas research at KPSP Setia Kawan in supporting the Sustainable Development Goals

In this study, the introduction informs as a brief historical background about KPSP Setia Kawan as a dairy cattle cooperative in the Nongkojajar area, Pasuruan, Indonesia, about biogas, raw materials, types of biogas reactors in KPSP Setia Kawan, biogas process, benefits of using biogas, 3 pillars of sustainable development and sustainable development goals (SDGs). Then the biogas flow scheme that supports sustainable agriculture goals in Figure 2. Finally, the study concludes with conclusions and suggestions.

Biogas

Anaerobic digestion or anaerobic decomposition is another term for the biological process in which microorganisms break down organic matter without the use of oxygen. This is the process by which to obtain biogas or more commonly known as fermentation and from the results of fermentation will get gas which we call biogas and can be used as fuel for various purposes. This can be applied both on a micro scale and macro scale (for cities). Biodegradable waste can come from a wide range of human, social and environmental activities. These include food waste, agricultural waste, livestock waste, food waste, and sludge from wastewater treatment processes. In the fermentation process of livestock manure, which is carried out by decomposing bacteria, methane (CH_4), carbon dioxide (CO_2) and hydrogen sulfide (H_2S) and other minor gases are produced. This fermentation process is also called the bioconversion process.

Biogas Process

The process of making biogas is carried out in 3 processes, namely; 1. Hydrolysis Stage

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(dissolution stage), 2. Acidification Stage (acidification stage) and 3. Methanogenic Stage (methane gas formation stage). The process of the stages of phase I, II and III can be seen in Figure 3 below

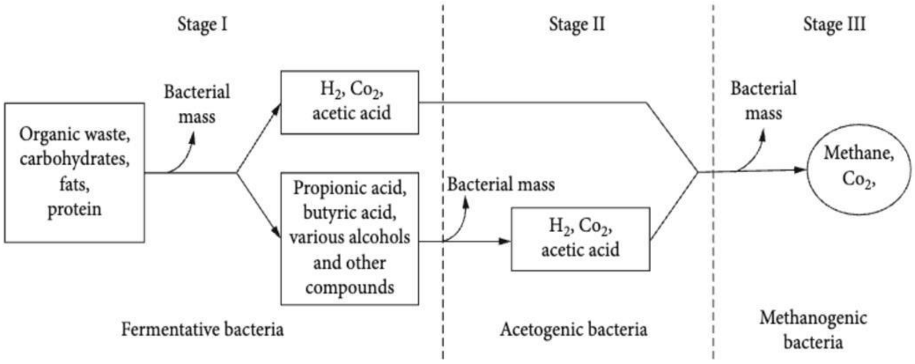

Figure 3. Process stages of biogas formation (Source, Energypedia. 2020

The three phases of the standard biogas formation process are hydrolysis, acetogenesis, and methanogenesis-simplified and shown in Figure 3. Water vapor (H2O), siloxane, H2S, H2 , CH4 , CO(2), and other gases are all mixed together in the biogas produced.

Biogas production efficiency and yield are influenced by a variety of factors, including feedstock composition, temperature, pH, retention time, and digester (biogas reactor) design. Organic feedstock composition plays a vital role in biogas production, with high-carbon materials such as crop residues and energy crops typically producing more methane than nitrogen-rich substrates such as manure or food waste (Atelge et al., 2020).

Biogas Feedstock

Biogas feedstock can be in solid or slurry form and sometimes concentrated. The primary raw materials in biogas production are agricultural waste, livestock waste, organic waste from urban waste and other organic waste waste.

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In table 1 we can see how much gas from the raw materials as below:

Table 1. Methane content results from different feedstocks (M. Prussi., et al. 2019)

Substrate	Gas yield (L/kg Vs*)	Methane content (%)
Pig manure	340-550	65-70
Cow manure	90-310	65
Poultry droppings	310-620	60
Wheat straw	200-300	50-60
Rye straw	200-300	59
Barley straw	250-300	59
Oats straw	290-310	59
Corn straw	380-460	59
Flax	360	59
Hemp	360	59
Grass	280-550	70
Elephant grass	430-560	60
Sunflower leaves	300	59
Agricultural waste	310-430	60-70
Fallen leaves	210-290	58
Algae	420-500	63

From table 1, we can see that the gas yield and methane content of 60% in cattle waste is in accordance with what is in KPSP Setia kawan, where biogas production with raw materials from cattle waste and has excellent potential as renewable Energy and shows gas yields and methane content for various substrates at the end of the retention time of 10-20 days at a process temperature of about 30° C, after the biogas reactor is fully filled, biogas appears on day four to five andreaches its peak on day twenty to twenty-five, the methane gas content is 50 to 70% methane (CH_4), 30 to 40% carbon dioxide (CO_2) and other gases in small amounts (Fitria B., 2009).

The potential of dairy cattle in KPSP Setia Kawan Nongkojajar is enormous as we know in the introduction that currently the number of livestock is around 25,723 cows. The source of Energy from biogas is very dependent on cattle waste for now, as a view that from the livestock waste of beef cattle, dairy cattle and buffaloes have the most significant livestock waste from other livestock can be seen from table 2

Tabel 2. Total livestock waste by type (Widarto and Sudarto., 1997)

No	Livestock Type	Total Manure Per Day (kg)	Content percentage	
			Water	Dry ingredients
1	Beef cattle	28	80	20
2	Dairy cows	28	80	20
3	Baffalo	35	83	17
4	Goat	1.13	74	26
5	Sheep	1.13	74	26
6	Pig	3.41	67	33
7	Chicken	0.18	72	28
8	Ducks	0.34	62	38

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Efficient biogas production requires well-conditioned feedstock to enhance the life and activity of microorganisms. Thus, biogas is suitable for use in rural and peri-urban areas compared to industrialized areas (Tagne RFT., et al. 2021). Biogas production from animal manure, especially cattle, is very potential and has many advantages. In addition to utilizing livestock waste, the process residue (biogas) can be used as an organic fertilizer that is rich in essential nutrients for plants. It is also very environmentally friendly (Ginting N., 2007).

Type of Biogas Reactor at KPSP Setia Kawan

A biogas reactor is a process device that converts organic matter into biogas, which is a natural gas produced from anaerobic bacterial fermentation under airtight conditions that allow for anaerobic degradation and collection of the resulting biogas.

In the procurement of biogas reactors at KPSP Setia Kawan, the type of fixed dome biogas reactor used is Figure 5 and was first introduced to this water pressure digester model from China (fixed dome) in 1966 (Song D. 1993) This model has a brick or concrete structure underground with a fixed dome for biogas storage. An outlet tank collects the sludge when biogas accumulates in the fixed dome.

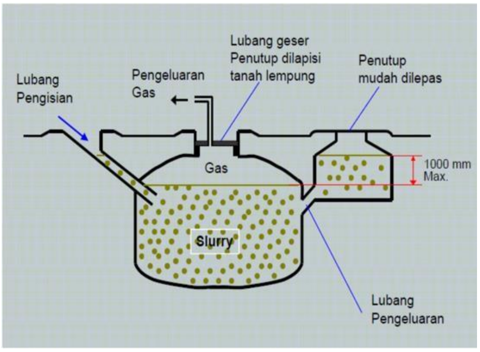

Figure 5: Fixed dome reactor

(source Chengdu biogas Research Institute, Chengdu, China.1989)

Almost all household biogas digesters are fixed dome reactor models and we can also find biogas reactors in the KPSP Setia Kawan Nongkojajar Pasuruan area. The existing reactors at KPSP Setia Kawan have a wide selection of volume variants, namely volumes of 4 M^3, 6 M^3, 8 M^3, 10 M^3, and 12 M^3. Adjustment of the type of volume in the biogas reactor is adjusted to the number of cows of the farmers at a volume size of 4 M^3 recommended 2-3 cows and the most significant size 12 M^3 with 6 cows, almost most farmers use a volume size of 8 M^3 for their biogas reactors. The lifespan of this fixed dome reactor is relatively long, it can be more than 20 years with good maintenance.

Regarding the funding of the biogas reactor, KPSP Setia Kawan collaborated with HIVOS (one of the significant NGOs from the Netherlands, Biru (Yayasan Rumah Energi), PT Nestle, DNS

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(Ministry of Environment) and the Ministry of Energy and Mineral Resources from the government side.

From the beginning in 1989 KPSP Setia Kawan succeeded in building household-scale biogas reactors with a fixed dome type of 2 units and continued to develop until now with a total of approximately 1547 reactor units, in table 3 we can see the development of biogas reactors built from 1989 to 20220. In its journey, KPSP Setia Kawan targets to be able to build 3000 biogas reactors

Table 3. Biogas reactors built by KPSP Setia Kawan 1989-2020

No	Livestock Type	Total Manure Per Day (kg)	Content percentage	
			Water	Dry ingredients
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8	Ducks	0.34	62	38

The use of biogas in KPSP Setia Kawan is almost entirely used for the needs of the farmer's family such as for cooking and partly as home lighting at night. Each biogas reactor can be used for the needs of 1 to 3 family homes.

Advantages of Using Biogas

The results of processing livestock manure waste into renewable Energy, namely biogas at KPSP Setia Kawan, have many advantages such as:

- As a renewable energy source based on biogas from livestock waste processing. (Bagher AM, et al. 2015).
- Pollution prevention, from biogas production reduces soil and water pollution, reduces the amount of waste that accumulates in landfills, and thus saves money and underground water.
- Make a source of employment in the local area in the biogas business in the field of construction and maintenance on biogas reactors from upstream to (Renewable Energy, 2019).
- Economic impact: biogas improves the economy of farmers, especially requiring lower investment costs than other renewable energy sources (Rao PV., et al. 2010 and Parsaee M., et al. 2019).
- Environmental impact: biogas also has a lower environmental impact and a higher energy yield (Parsaee M., et al 2019 and Rittmann BE, 2008). In addition, widespread biogas will

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reduce deforestation as it will produce biofertilizers that are important for the soil and reduce the use of wood (logging).

- Waste management: Biogas is an effective and appropriate means of organic waste management, reducing pathogens and odors, producing bioenergy, and biofertilizers (O'Connor S., et al 2021).
- In rural areas, biogas is effectively used for cooking purposes; for example, in China and India, biogas effectively replaces different biomass and coal sources (Yu L., et al 2008 and K.R. Smith, R. Uma., et al 2000).
- Biogas can be upgraded to biomethane and then used as a transportation fuel such as in vehicles, buses and agricultural equipment (De Souza SN., et al and Moraes BS., et al 2014).
- Biogas can be used for heat applications such as in electric compost, space heating, etc. and combined power and can be combined with different energies (O'Connor S., et al 2021).
- Biogas can be used as fuel for electricity generation directly in (Wasajja H., et al. and Cozzolino R, et al., 2017).
- Biogas can fulfill part of the energy needs in various industries. For example, in the sugarcane industry, biogas can be used to supply Energy in distillation and the heat required for bioethanol vaporization (Moraes BS, et al., 2015) and as fuel for agricultural machinery (Khan IU., et al., 2017).
- Today, biogas can be converted to biomethane which can be used as a fuel for vehicles, a substitute for natural gas for industrial, commercial, and domestic use, or fed into the natural gas grid to replace natural gas. Carbon dioxide can be extracted from biogas and used as a feedstock for greenhouses and also as a feedstock for chemical fuel production (S. Jain., 2019).

From the above discussion, it is evident that biogas has several advantages compared to natural gas from fossil fuels, and has shown high potential to replace natural gas in a variety of applications ranging from household use (small scale) this can be proven in the field from the observation that farmers in KPSP Setia Kawan who have processed their livestock waste into biogas are used for their household needs such as fuel in the stove daily and partly for lighting lamps at night.

Sustainability Development

Biogas has been recognized as a sustainable renewable energy source with the potential to reduce greenhouse gas (GHG) emissions and reduce dependence on depleting fossil fuels, however, the availability and development of sustainable energy resources is a multifaceted and

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complex issue that demands a comprehensive study of the environmental, social and economic benefits of biogas (Kapoor.R., et al 2020).

Three Pillars of Sustainable Development

Biogas as a renewable energy in sustainable development has three pillars that are beneficial in the fields of environment, economy, and social.

Environmental Pillar

The use of biogas as a renewable fuel source in the KPSP Setia Kawan area dramatically affects the surrounding environment such as:

- The use of biogas has significantly improved indoor air quality (ambient air pollution) in homes using biogas stoves (R.S. Ramazanov, D.Y., et al 2024).
- Not relying on wood fuel for cooking causes adverse environmental effects such as deforestation for fuel use, which in turn has important implications for watershed management and soil erosion (Suyadi, S., 2024).
- Reducing carbon footprint by processing livestock waste into biogas (Wawrzyniak, A., 2024).
- Not dependent on fossil fuels which are depleting day by day because fossil fuels are non-renewable fuels (Erianto, F. D. U., and Sudiar, N. Y., 2024).
- In addition, biogas whose waste is collected in the form of bioslurry as organic fertilizer and returned to agricultural land can increase soil nutrients to fertilize organically (Ridlo, D. T., 2024).
- Biogas fuel helps reduce greenhouse gas emissions from the consumption of wood fuel, livestock manure, agricultural residues and kerosene (fossil fuel) for cooking and lighting. Through the sustainable use of biogas technology, CO_2 associated with biogas combustion can be reabsorbed in the process of photosynthesis. All CH_4 and CO_2 emissions associated with burning fuel wood, livestock manure, agricultural residues and kerosene (fossil fuels) can be reduced when replaced with biogas as a renewable fuel (Bajgain and Shakya, 2005) and (Pence, I., et al 2024). Similarly, the use of biogas use in the KPSP Setia Kawan area can contribute to reducing greenhouse gases that will be emitted into the air because the consumption of kerosene and firewood in the KPSP Setia Kawan area is reduced. In addition, methane gas emitted from manure will be decreased after entering into the biogas process system.

Pillars of the Economy

Economic benefits felt in the KPSP Setia Kawan area:

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- A cost-effective solution to transform high-cost production outputs such as waste treatment into income-generating opportunities for farmers, rural communities and KPSP Setia Kawan as an organizational platform for dairy farmers.
- Create new income streams in rural areas of KPSP Setia Kawan and build resilience to commodity price fluctuations.
- It can reduce agricultural costs for biogas residue such as organic fertilizer (bioslurry) and generate new income streams (Suprianto, A., et al. 2024).
- Driving economic growth and offering local jobs in construction, engineering, project management and more Reduces waste volumes, which means costs are often lowered for facilities such as wastewater plants (Meena, P. K., et al 2024).
- Opportunities to create local businesses such as MSMEs whose fuel energy is from biogas (Hartini, S., et al 2024).
- Save from fossil fuels because it does not incur costs for the purchase of fossil fuels (Fitri, R. M., et al 2024).
- The use of biogas is not only as a stove fuel but is very multipurpose such as: as a generator fuel, heating, cooling machine, transportation equipment etc. (Khan, M. U., et al 2024).
- Reducing the use of chemical fertilizers which from biogas pulp will produce bioslurry as organic fertilizer (Anggraeni, I. D., et al 2024).
- Feedstock production combined with the operation of biogas plants in the KPSP Setia Kawan area makes the use of biogas economically attractive for the farmers and provides them with additional household income. The farmers also gain a new and vital social function as an energy provider. This is in line with the study conducted by (Maharjan and Singh, 2003).

Pillars of the Social Sector

Social impact of using biogas:

- Health and sanitation benefits: Smoke is one of the leading causes of acute respiratory infections in women, infants and children (Mardana. B, 2009), with the use of biogas significantly improving indoor air quality. Since in the KPSP Setia Kawan area women and girls are primarily involved in cooking activities, they are the first beneficiaries of biogas technology to improve their health conditions and with biogas burning being relatively clean, it reduces eye diseases, headaches, coughs associated with smoke from wood fuel and livestock manure using traditional three stoves. In addition, the management of livestock manure using biogas digesters results in better hygienic conditions & helps keep the household environment clean & reduces the chances of spreading infectious and other

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diseases.

- The use of biogas technology has a positive impact on education. According to biogas users in the KPSP Setia Kawan area, key informants and energy experts, time can be saved because biogas has enabled girls to attend school, which was previously not possible because they were involved in daily household chores such as collecting firewood and dung. The results show; families are motivated to send their children to school and children have more time to study in homes with biogas installations than those without (Francisco López, A., et al. 2024).
- Biogas production requires labor for the manufacture of technical equipment, construction, operation and maintenance of biogas installations (Klimek, K., et al. 2020) This also occurred in the manufacture of biogas reactors at KPSP Setia Kawan which involved all of the above fields.
- The benefits on gender, namely women and girls in rural areas, biogas systems have been able to meet the practical and strategic needs of gender because women and girls are responsible for preparing and processing food and working in the kitchen where biogas as fuel plays a role in this (Sherka, T. D., et al 2024).

It can be concluded that sustainable development is a strategy to encourage the use of biogas as a renewable energy source while making natural resources (organic waste) efficient. In business, the three pillars of sustainable development are:

- Economic; Efficient and responsible use of resources results in long-term profitability and business continuity.
- Environment; Reducing waste and carbon footprint and maximizing energy efficiency helps reverse negative environmental impacts such as pollution and global warming.
- Social; Focus on initiatives such as safety, health, and diversity and gender that support the creation of healthier communities that are able to sustain themselves. The three pillars can be illustrated in Figure 6.

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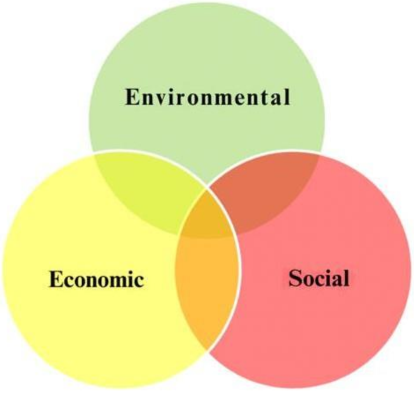

Figure 6. Three Pillars of Sustainability
(source Purvis .B., et al. 2019).

Sustainable Development Goals Through Biogas as Sustainable Energy

Biogas demonstrates alignment with the sustainable development goals (SDGs) by addressing multiple dimensions of sustainable development, thereby contributing to poverty alleviation, improving energy access, ensuring food security and protecting the environment. The UN SDGs serve as a comprehensive framework for addressing global challenges and promoting sustainable development, with biogas playing an essential role in achieving several key goals.

On September 25, 2015 (Bernstein, 2017) the United Nations agreed, and adopted 17 aspirational Sustainable Development Goals (SDGs) endorsed by 193 countries as part of a global partnership to end poverty and hunger in its many forms, mitigate the effects of climate change, and ensure prosperous, fulfilling, and peaceful lives for all. The SDGs are targets to be achieved by 2030, giving governments and companies time to make urgent and necessary changes to realize and deliver change in sustainable development. The 17 sustainable development goals can be seen in detail from Figure 7.

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Figure 7. 17 United Nations Sustainable Development Goals
(United Nations, Gusmão Caiado et al., 2018)

17 The Sustainable Development Goals (SDGs) are global commitments as shown in the figure above:

1. (SDG1) No poverty
2. (SDG2) Zero hunger
3. (SDG3) Healthy and prosperous life
4. (SDG4) Quality education
5. (SDG5) Gender equality
6. (SDG6) Clean water and proper sanitation
7. (SDG7) Clean and affordable Energy
8. (SDG8) Decent work and economic growth
9. (SDG9) Industry, innovation and infrastructure
10. (SDG10) Reduce inequality
11. (SDG11) Sustainable cities and settlements
12. (SDG12) Responsible consumption and production
13. (SDG13) Addressing climate change
14. (SDG14) Marine ecosystems
15. (SDG15) Terrestrial ecosystems

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16. (SDG16) Peace, justice and resilient institutions
17. (SDG17) Partnerships to achieve goals

Within the United Nations Organization, UNEP is the international agency responsible for setting the environmental agenda and promoting the implementation of ecological aspects of sustainable development together. The United Nations Environment Program (UNEP), established in 1972, is responsible for environmental issues within the United Nations structure.

UNEP recognizes the multi-faceted contribution of the Biogas industry to the various SDGs outlined in the 2030 Agenda for Sustainable Development, highlighting its potential to drive sustainable development, mitigate climate change, and improve the welfare of communities around the world, the contribution of biogas at KPSP Setia Kawan supports sustainable development programs.

The 17 Sustainable Development Goals were created because they provide a global framework that can be used to address the world's biggest problems, such as poverty and climate change, etc., which will refer to the three pillars of sustainable development. The goals are all interconnected, and success in one area can impact another.

Contribution of Biogas 3 Pillars of Development to 17 Sustainable Development Goals (SDGs)

The following explains that the contribution of biogas as a renewable energy source to the sustainable development goals (SDGs) in the KPSP Setia Kawan area rests on three pillars, namely; (1) Economic, (2) Social, and (3) Environmental, as shown in figure xxx, of the three pillars of sustainable development biogas contributes to 17 sustainable development goals are SDG (1), SDG (2), SDG (3), SDG (4), SDG (5), SDG (6), SDG (7), SDG (8), SDG (9), SDG (11), SDG (12), SDG (13), SDG (14), SDG (15), SDG (16), and SDG (17).

The relationship between the 3 pillars of sustainable development with the 17 sustainable development goals in the use of biogas as a renewable energy source at KPSP Setia Kawan Nongkojajar can be seen in Figure 8.

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Figure 8. Biogas linkages in the KPSP Setia Kawan Nongkojajar area from the 3 pillars of sustainable development on sustainable development goals (SDGs)

Biogas is proven to have a direct impact and contribution to the sustainable development goals (SDGs) through the 3 pillars of sustainable development (social, economic and environmental)

Biogas Contribution to Sustainable Development Goals

The contribution of biogas in the following section is the contribution of biogas to sustainable development goals (SDGs) which are related to the 3 pillars of sustainable development as described in table 4 in figures 6 and 7 which are the benefits and linkages of biogas to the 3 Pillars of Sustainable Development and

Sustainable Development Goals (SDGs) in the use of biogas as a renewable energy source at KPSP Setia Kawan Nongkojajar Pasuruan.

From Table 4, it is clear that biogas has a significant role in meeting sustainable development goals in the KPSP Setia Kawan Nongkojajar Pasuruan area. Among these goals, biogas has a considerable influence on sustainable development goals (SDGs), especially SDG7 fuel saving and clean and affordable for daily needs, for example for cooking, obtained from processing livestock waste into biogas as a sustainable renewable energy source. Biogas produced in the Setikar area of Nongkojajar is obtained from KPSP Setia Kawan members who partner with the KPSP Cooperative and third parties, namely Hivos as a partner in the construction and capital incentives in the procurement of biogas reactors this is also in accordance with SDGs 17 and the residual results of biogas in the form of bioslurry, they also sell to KPSP Setia Kawan which can increase the income of the farmers themselves SDGs 1, 8, 12, 2, 9, and 3.

It is also interesting to see the linkage between the indicators of contribution from the 3 pillars of sustainable development (economic, social and environmental) to the sustainable development goals (17 agendas or programs) and all of them are based

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on biogas, namely:

- Increase total Energy produced (SDG 7: affordable and clean Energy).
- Reduce air and water pollution (SDG 3: good health and well-being, SDG 15: life on land).
- Increase agricultural productivity and reduce land use change (SDG 2: zero hunger and SDG 15: life on land).
- Improve waste management (SDG 11: sustainable cities and communities, SDG 12: responsible consumption and production).
- Increase total wastewater treatment (SDG 6: clean water and sanitation).
- Reduce methane impacts (SDG 3: good health and well-being, SDG 15: life on land).
- Improve current biogas technology (SDG 2: zero hunger and SDG 15: life on land and SDG 9 industry, innovation and infrastructure).
- Reduce the impact of fouling from livestock waste (SDG 3: health, sanitation and hygiene).
- good well-being (SDG 15: life on land).
- Reduce operating costs SDG 11: sustainable cities and towns and communities, SDG 12: responsible consumption and production).

Multi Effects of Biogas from the 3 Pillars of Economic, Environmental and Social on Sustainable Development Goals (SDGs)

The use and utilization of biogas in KPSP Setia kawan is very significant, causing multiple effects on economic development, natural resources and Energy, which results in the 3 pillars of sustainable development that contribute to the 17 sustainable development goals (SDGs) program. From these multiple effects we can get as below:

- Productive economy can be found in the KPSP Setia Kawan area including: 1. Entrepreneurship (in the food and beverage stall business around the KPSP Setia Kawan area), 2. Agriculture (organic fertilizer business both individuals and groups or third parties who receive from farmers who have run the biogas program and the residual results in the form of bioslurry as organic fertilizer), 3. Trade (there are building shops around the KPSP Setia Kawan area and biogas support material stores), 4. Labor (trained biogas fitters and transportation services related to the development and use of biogas).
- Preservation of natural resources with the processing of livestock waste into biogas will have an impact on preserving the utilization of water resources including: 1. agriculture (irrigating rice fields +/- 600 hectares in the Nongkojajar area of Tutur village, Pasuruan,

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irrigating 400 hectares of peppers, 50 hectares of chrysanthemums, and 1200 hectares of fruits), 2. plantation (water utilization for coffee farmers 75 hectares in the Nongkojajar area (Tutur village) Pasuruan), 3. Livestock sector (Dairy cattle cultivation +/- 11,225 farmers with 25,273 heads in Tutur village).

- Utilization of Biogas as renewable Energy: 1. Replacement of firewood (can reduce the use of wood as fuel and will have an impact on reducing the supply of timber in the forest, with firewood will have an effect on health and greenhouse gases), 2 LPG (natural gas), (there are limitations of fossil fuels from LPG), 3. Biogas (with biogas can convert livestock waste into fuel), efficiency, increased environmental cleanliness, can increase added value with the presence of bioslurry as organic fertilizer from biogas residue and is very safe in its application.

4. CONCLUSIONS

Biogas is one of the promising and effective renewable energy sources, mainly as a fuel for cooking which can be applied directly from the biogas reactor to the cooking device, namely the biogas stove and others can be used as fuel for lighting at night, for now the use is proven at KPSP Setia Kawan as cooking fuel and lighting at night. A very significant contribution of biogas was found in achieving Sustainable Development Goals (SDGs) 1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and 17 based on the 3 pillars of Sustainable Development (Economy, Social and Environmental) for farmers in the KPSP Setia Kawan area who have processed their livestock waste into biogas with a total of 1500 biogas reactors with a fixed dome type with a target of 3000 reactors coordinated by the KPSP Setia Kawan cooperative as a forum for farmer members and biogas partner NGO Hivos as procurement and incentive funds in making fixed dome type biogas reactors.

The benefits of using biogas as a sustainable source of new renewable Energy have an impact on the multi-effects of productive economies, natural resources, and the utilization of biogas as a fuel energy source in the KPSP Setia Kawan Nongkojajar Pasuruan area.

Advice

The development of biogas technology is still affected by several barriers, the most significant of which are the lack of investment capital for its members, and the lack of access to knowledge and technical expertise to maintain the technology (SDG9) and stake holder partnerships with companies and government of course (SDG17). At present, there are still 1500 biogas reactors built on a household scale with a fixed dome model, which is still far

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from the number of members and the livestock population in KPSP Setia Kawan, even though this is a massive potential for the KPSP Setia Kawan cooperative to be able to process livestock waste into biogas with an enormous potential for livestock waste with 25,723 livestock. This requires an approach from policy makers, stakeholders, and investors in biogas development that prioritizes investment in renewable energy infrastructure, promotes innovation, and increases the deployment of renewable energy technologies on an industrial scale such as communal systems in addition to the current household scale.

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