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# ANALYSIS OF BIOMETHANE PRODUCTION POTENTIAL AND MITIGATION OF BIOMETHANE EMISSIONS FROM PIG FARMS IN NORTH SULAWESI PROVINCE

## Analisis Potensi Produksi Biometan dan Mitigasi Emisi Biometan dari Ternak Babi di Provinsi Sulawesi Utara

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### ABSTRACT
*The potential for biomethane production from livestock manure as renewable energy has good prospects, considering that the number of pigs in North Sulawesi Province increases yearly. Therefore, it is necessary to analyze the potential for biomethane production, replacing the use of LPG, and mitigate biomethane emissions from pig farms. The results showed that from 2015-2021, the most significant biomethane production was in 2021, amounting to 7,887 tons of $CH_4$/year in the Minahasa Regency area, 2,496 tons of $CH_4$/year (31.65%) in Tomohon City, 805 tons of $CH_4$/year (10.20%) in South Minahasa Regency, 779 tons of $CH_4$/year (9.88%), and in other areas 3,807 (48.27%). Biomethane can replace 8.59 million kg of Liquefied Petroleum Gas (LPG). The results of mitigating biomethane emissions in 2021 reached 34.22 Gg $CO_{2eq}$, and using biomethane to replace LPG reached 11.59 Gg $CO_{2eq}$. Total greenhouse gas emissions can be reduced to 45.81 Gg $CO_{2eq}$. Biomethane from pig manure has promising potential as a new renewable energy and requires further investigation.*

**Keywords**: *biomethane potential, greenhouse gas emissions, livestock manure.*

### ABSTRAK
Potensi produksi biometana dari limbah peternakan babi sebagai energi baru terbarukan memiliki prospek yang baik, mengingat jumlah ternak babi di Provinsi Sulawesi Utara meningkat setiap tahunnya. Oleh karena itu perlu dilakukan analisa potensi produksi biometana dan penggantian penggunaan LPG dengan biogas serta mitigasi emisi biometana dari peternakan babi. Hasil analisa menunjukkan dari tahun 2015-2021 potensi produksi biometana terbesar berada pada tahun 2021 yang mencapai 7.887 ton $CH_4$/tahun, potensi ini tersebar di daerah Kabupaten Minahasa 2.496 ton $CH_4$/tahun (31,65%), Kota Tomohon 805 ton $CH_4$/tahun (10,20%) , Kabupaten Minahasa Selatan 779 ton $CH_4$/tahun (9,88%), dan daerah lainnya 3.807 (48,27%). Biometana yang dihasilkan dapat menggantikan penggunaan Liquefied Petroleum Gas (LPG) sebesar 8,59 juta kg. Hasil mitigasi emisi biometana dari peternakan babi pada tahun 2021 mencapai 34,22

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Gg $CO_{2eq}$ dan pemanfaatan biometana menggantikan LPG mencapai 11,59 Gg $CO_{2eq}$. Sehingga total emisi gas rumah kaca yang dapat dikurangi sebesar 45,81 Gg $CO_{2eq}$. Biometana dari limbah ternak babi memiliki potensi yang menjanjikan sebagai energi terbarukan baru dan membutuhkan penelitian yang lebih lanjut.

**Kata Kunci:** gas rumah kaca, potensi biometana, feses peternakan

## INTRODUCTION

Energy is an important parameter in national economic development that can influence the growth of the industrial sector, transportation, services and household activities (Prihatiningtyas et al. 2019). Any energy used in carrying out these activities needs to pay attention to the level of energy sustainability, both regarding availability and the environment, as well as other considerations in the form of economic value and stability of energy supply (Tumiran 2014). Looking at the primary energy supply, the energy sources commonly used in Indonesia in 2021 are dominated by fossil energy in the form of coal (36.15%), crude oil (32.10%), natural gas (16.16%), and other energy amounting to (15.59%) (KESDM 2021). Final energy consumed in 2021 is 123.10 MTOE which is divided into four sectors including the transportation sector 54.4 MTOE, industry 41.20 MTOE, household 20.10 MTOE, commercial 5.90 MTOE, and other sectors amounting to 1.50 MTOE (Setjen 2022).

Energy use in the household sector is ranked third, and the most widely used energy is electrical energy (47.18%) followed by Liquefied Petroleum Gas (LPG) (46.94%), biomass (3.78%), kerosene (1.78%), gas (0.21%) and the last is biogas (3.78%) (KESDM 2021). The LPG energy that is widely used today is a type of subsidized LPG that is actually only intended for the poor but is widely used by the rich. Because the target market of LPG users is not appropriate, the need for subsidized LPG is increasing, resulting in shortages and long queues to obtain subsidized LPG (Osak et al. 2016). LPG is no longer sustainable energy due to this scarcity.

Energy stability is an important point in increasing regional and urban economic development. North Sulawesi Province has a potential source of alternative energy that is environmentally friendly, stable, and economical. According to Yaqoob et al. (2021) biogas is one efficient and useful form of alternative energy. Both urban and rural locations can use biogas as a source of fuel energy, and constructing a biogas production unit doesn't come at a high cost. (Sutaryo et al. 2020). Biogas energy can be produced from easily decomposed organic materials such as livestock manure, human manure, or household waste (Maluegha et al. 2018; Siddiki et al. 2021; Pan et al. 2021). The energy produced from biogas has a calorific value ranging from 13,720 – 27,440 kJ $Nm^{-3}$, with a methane concentration of 40% - 80% (Fitriyah and Wahyudi 2020).

The use of biogas energy from livestock manure can be developed and utilized to meet household needs and address environmental problems (Afotey and Sarpong 2023). North Sulawesi Province is one of the regions with the largest number of pigs in Indonesia. However, the handling of livestock waste has not been managed properly.

Biogas energy is obtained from the fermentation process of organic materials carried out anaerobically in a digester (Meyer et al. 2021; Sawyerr et al. 2019). Apart from producing biogas energy, the anaerobic digester process can also produce by-products in the form of organic fertilizer, which can be used for agricultural activities (Naghavi et al. 2020). In addition to creating fertilizer and biogas, turning pig farm waste into biogas can lessen pollution in the environment caused by greenhouse gases released into the atmosphere, such as methane gas from the open fermentation process of livestock manure (Siddiki et al. 2021). Where, the agricultural sector becomes one of the contributors to 18% of the world's greenhouse gases (GHG) (Makara et al. 2021). In Indonesia, from the greenhouse gas inventory report by The Ministry of Environment and Forestry, 2020 GHG emissions produced from the livestock sector in 2018 reached 108,598 Gg $CO_{2eq}$ or 5th out of 6 types of activities. According to Ersoy and Ugurlu (2020) methane emissions can cause a global warming potential of 21 $CO_{2eq}$. The impact of global warming is global climate change (Anwaq et al. 2020). So the management of pig manure needs to be managed to get benefit for the community and reduce the negative impact that can be caused by poorly conducted pig farming activities, which can make pig farm areas more and more difficult (Suriman et al. 2021). In addition, the problem of pig waste can slow down the rate of growth of pig breeders, which will affect the demand for pork in the Northern Sulawesi Province (Badan Pusat Statistik 2022).

Research on the management of livestock manure into biogas has been widely carried out, such as in research by Wang et al. (2021), Siddiki et al. (2021), Yaqoob et al. (2021), Afotey and Sarpong (2023), and Siddiki et al. (2021). The research has been conducted using the data from the test parameters carried out in each country. The test parameters of pig manure in Indonesia, specifically in the North Sulawesi Province, were still not obtained. In this research, the potential for biomethane production and biomethane gas emissions was calculated using sampling and laboratory testing from pig manure in North Sulawesi Province. The pigs cultivated in this area are of the Landrace pig breed with Phylum Chordata, klass Mamalia, Ordo Artiodactyla, Famili Suidae, genus Sus, spesies Sus scrofa, and Subspesies Sus scrofa domesticus (Dewi 2017). The focus of this research gap is to calculate the potential for biomethan production in the North Sulawesi Province using the parameters of pig manure testing data developed in the area, perform GHG calculations in the pig farming sector, and present the results in the form of spatial. This study aims to determine the potential of manure produced from pig farms in North Sulawesi Province, analyze biomethane production resulting from biogas production originating from pig manure in North Sulawesi Province and determine biomethane emissions from pig farms and the reduction in $CO_2$ equivalent emissions produced after using pig manure as biogas to substitute LPG. The results of this research can provide a new data of the potential for biomethane production from pig manure in North Sulawesi Province to be used as a substitute for fossil fuels in the household sector, as well as a distribution map of the potential for biomethane production and a reduction in the potential for global warming from pig farming activities and the replacement of LPG with biogas.

## METHODS

This research was conducted in North Sulawesi Provinci, Indonesia (Figure 1), in June-November 2023. North Sulawesi Province is one of the regions with the largest number of pigs in Indonesia. The growth of pig livestock in North Sulawesi province in 2015 - 2021 reached 4.58%, with the largest number of pig livestock in the Minahasa, Tomohon and South Minasaha areas reaching 51.73%. The primary data in this research is the number of pigs was collected from the North Sulawesi Provincial Central Statistics Agency in 2022. Calculation of the potential production of raw materials from livestock waste is carried out by analyzing the amount of pig manure measured per year based on the body weight and life span of pigs, and biomethane production is estimated based on the annual volume of output from raw pig manure materials (Wang et al. 2021).

Variables that specifically correlate with the calculation of biomethane production potential include total solids and raw material availability (Siddiki et al. 2021; Nehra and Jain 2023). As for the analysis of the greenhouse gas inventory, it can be carried out using the guidelines of the 2006 IPCC. The methodology used to calculate the estimates of greenhouse gas emissions in the farming sector can use the Tier-1 method (IPCC 2006). The following paragraphs provide detailed estimates.


**Figure 1.** Research location

The first is to determine the potential for biomethane production. The data required is the amount of livestock manure available and the potential biomethane that can be produced from pig manure. The production of pig manure really depends on the type of livestock, feed and conditions of the pigs being developed (Suyitno et al. 2010), then to evaluate the availability of the number of manure in the pig farms can actually be determined by sampling some farmers who develop pig species such as Landrace, given the species of the pig farming that is widely developed in the area of the North Sulawesi Province. with an estimated weight of 100 kg pigs, pigs can produce an average of 2.30 kg/day of manurel (Suyitno et al. 2010; Yan et al. 2021). using the equation given by Liu et al. (2023), the potential of pig farm manure can be determined.

$$M = \sum_{i=1}^{n} N_i * T_i * P_i \quad (1)$$

Where $M$ is the potential amount of manure that can be produced (kg/year); $N_i$ is the number of pigs; $T_i$ is the life cycle of pigs until they are suitable for harvest. According to Yan et al. (2021) the average life cycle of pigs can reach 199 days/year. and $P_i$ is the production of pig manure (kg/day).

The potential production of biogas that could be produced from pig farms can be calculated using the following equation (Liu et al. 2023).

$$Q = \sum_{i=1}^{n} (M_i * f_i * \gamma_i) \quad (2)$$

Where $Q$ is the total production potential of biogas that can be produced (m$^3$/year); $M_i$ is the number of manure generated (kg/year); $F_i$ is a dry matter ratio of pig manure of 22.58% obtained from testing sample of pig manure in laboratory Industrial Certification and Services Center (BSPJI); and $\gamma_i$ is the potential for biogass production in pig manure of 0.45 (m$^3$ kg$^{-1}$), gained from Liu et al. (2023) and Ahiekpor (2021).

The total biomethane production that can be obtained from the potential biogas production of pig farms is achieved by multiplying the total amount of biogase production by the biometane content of the biogass. According to Anukam et al. (2019) the content of biomethan in biogas from pig manure materials is 60%.

Second, the use of biogas can be used to provide energy for the household sector as well as replace fossil energy use such as kerosene, firewood, LPG and can also be used as lighting lamps (Maluegha et al. 2018; Kulkarni et al. 2021). The substitution value of biogas with other energy can be seen in (Table 1). The use of biogas as a substitute for LPG according to Esteves et al. (2019) has great potential in the future. So the development and construction of household scale anaerobic digester installations needs to be carried out.

According to Afotey and Sarpong (2023), using the following equation, the amount of biogas conversion to other energy can be determined. Where $CS$ is the fuel conversion factor, which is obtained in (Table 1), and $TBP$ is the amount of biogas production ($m^3$).

$$Biogas\ equivalent = \sum(CS * TBP) \quad (3)$$

**Table 1.** Biogas quantity 1 $m^3$ with other energy (Nehra & Jain, 2023; Artiani & Handayasari, 2017).

| Energy type | Unit | Equivalent |
|---|---|---|
| Electricity | kWh | 4.698 |
| Kerosene oil | L | 0.620 |
| Fuelwood | kg | 3.474 |
| Coal | kg | 1.46 |
| LPG | kg | 0.433 |

Third, to be able to determine methane gas emissions ($CH_4$) resulting from pig farming activities in North Sulawesi Province, this study use the guidelines from the 2006 IPCC with the Tier-1 method (Heriyanti et al. 2022). The types of livestock that contribute a lot to GHG ($CH_4$) emissions are ruminant livestock such as cows, sheep, buffalo, and goats, because ruminant livestock produce GHG ($CH_4$) emissions in the enteric fermentation process and production of manure (IPCC 2006). The type of pig farming itself is a monogastric type of livestock, which produces the largest GHG ($CH_4$) emissions only in manure production, so in this study, enteric fermentation was not considered. However, GHG ($CH_4$) emission mitigation was carried out using a Tier-1 approach from livestock manure management and assumes that every pig farmer carries out anaerobic management of pig manure to produce biogas, which is used in the household sector to replace the use of LPG (Calbry-Muzyka et al. 2022).

Estimation of $CH_4$ emissions from manure management on pig farms can use the following equation (Calbry-Muzyka et al. 2022; Pizarro-Loaiza et al. 2021).

$$CH_{4\,management} = EF_{(T)} * N_{(T)} \quad (4)$$

Where $CH_{4management}$ is GHG emissions from pig manure management (kg $CH_4$/year), $EF_{(T)}$ is the emission factor according to certain types of livestock. In the IPCC (2006), the emission factor value for pigs is 7 kg $CH_4$/year, and $N_{(T)}$ is the number of pig populations in one year.

Fourth, to determine the global warming potential (GWP) from methane gas emissions ($CH_4$) and the use of biogas as a substitute fuel for LPG in the household sector, it can be determined using the following equation (Thiangchanta et al. 2022).

$$GWP_{tot} = GWP_{CH4} + GWP_{LPG} - GWP_{Biogas} \quad (5)$$

Where $GWP_{tot}$ is the total global warming potential emissions, $GWP_{CH4}$ is Greenhouse Gas (GHG) emissions from the livestock sector in the form of $CH_{4management}$ emissions wich are multiplied by $CH_4$ emission factor to become $CO_{2eq}$. According to Ersoy and Ugurlu (2020), the global warming potential of methane gas ($CH_4$) is 21 $CO_{2eq}$. Meanwhile, $GWP_{LPG}$ and $GWP_{Biogas}$ are obtained by multiplying the total amount of energy by the energy factor for each energy (Yu et al. 2008). The value of each fossil energy factor can be seen in Table 2.

$$GWP_{fuel} = FS_{fuel} * EF_{GHG\,fuel} \quad (6)$$

Conversion of biogas energy into other alternative energy can reduce direct GHG pollution in the environment (Jelínek et al. 2021). Considering that the combustion of biogas through the conversion of biomethan to carbon dioxide has a smaller value compared to other fuels in terms of the greenhouse gas (GHG) emissions generated (Biogas Rumah 2021).

**Table 2.** Potential GWP factor (yu et al. 2008)

| Energy Type | $CO_2$ (g $kg^{-1}$) |
|---|---|
| Firewood | 1450 |
| Biogas | 748 |
| LPG | 3075 |
| Electricity | 1.0577 (t $MWh^{-1}$) |

To make the processed data easier to understand in order to manage biomethane potential, the data that has been obtained is then managed by geographic data or spatial data, using the Quantum Geographic Information System (QGIS) application, thus producing new information or a new display that is more effective (Fitriyani and Martunis 2021; Setiyowati et al. 2021). Data for the Indonesian Earth Map (RBI) for North Sulawesi province was obtained from the Geospatial Information Agency (BIG).

## RESULTS AND DISCUSSION

The population of pig farms in North Sulawesi Province obtained from the Central Statistics Agency (BPS) is spread across 11 districts and four cities with a total population of 426,923 pigs in 2021 which can be seen in Figure 2. The largest population of pig farms was in Minahasa Regency and was followed by Tomohon City, South Minahasa and North Minahasa Regencies. These four regions were close to each other and 60.11% of the total pig farms in North Sulawesi province are in these four regions.

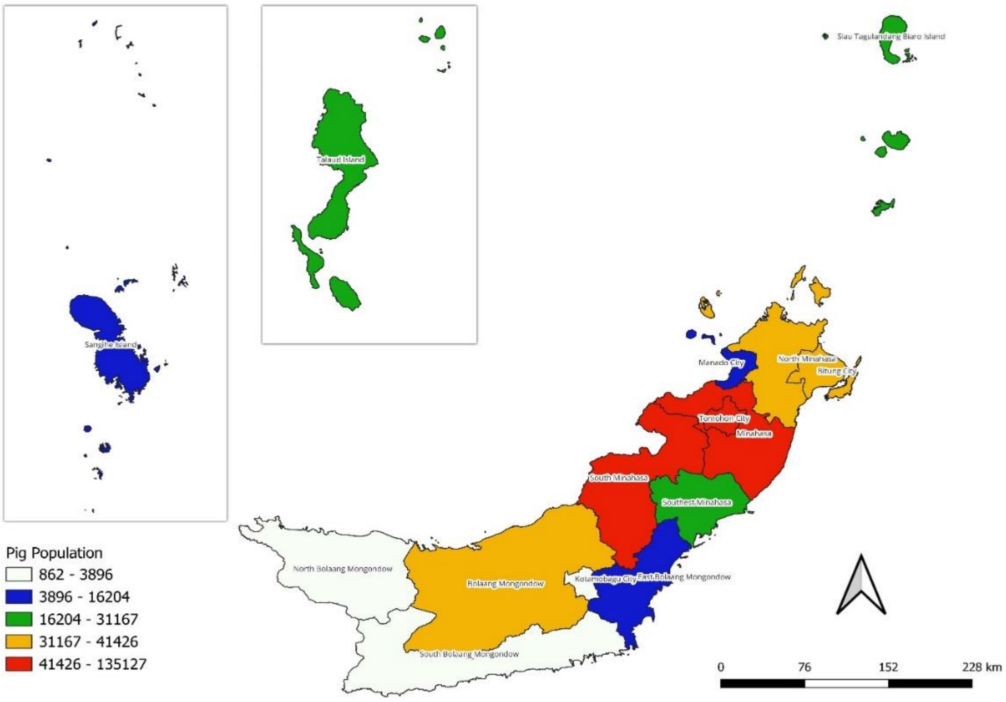


**Figure 2.** Distribution of pig livestock

Waste from pig farms production can be determined using equation 1, and in Table 3 it can be seen that the potential production of pig manure reached 186.86 thousand tonnes in 2015, and this waste production increases every year until in 2021 it reaches 195.43 thousand tonnes. The increase in pig manure production that occurs between 2015-2021 in North Sulawesi Province can reach an average of 4.58% each year. The increase in livestock waste production is in line with the increase in the number of pigs being cultivated. The largest amount of manure production is in the Minahasa Regency area, amounting to 61.85 thousand tons in 2021 (Table 3) spread across 25 sub-districts and the growth rate of manure production in Minahasa Regency reached 17.61% from 2015-2021. The city of Kotamobagu has experienced a significant increase in the number of pigs, so the production of manure has also increased to 671 tons in 2021, this increase is due to the land for pig farms is still large enough in the area. The pig production of manure in North Sulawesi Province from 2015 to 2021 reached 1.33 million tons. By utilizing pig waste into biogas, conversion efficiency can be increased and GHG emissions can be reduced (Nehra and Jain 2023; Jelínek et al. 2021).

The potential for biogas production produced from pig waste can be determined using equation 2. The total potential for biogas production in 2021 reaches 19.86 million $m^3$ and the total potential biomethane production in the same year is 7.89 thousand tons (Table 4). Biogas and biomethane production in North Sulawesi Province is dominated by Minahasa Regency at 31.65% and the lowest is in South Bolaang Mongondow Regency at 0.20% as can be seen in Figure 3. The distribution of biogas production potential which can be seen in Figure 3 is spread across South Minahasa Regency, Minahasa Regency and Tomohon City. These districts and cities produce 51.73% of the total biogas production in North Sulawesi Province. Meanwhile, the areas of southern Bolaang Mongondow, North Bolaang Mongondow and Kotamobagu City have less potential for biogas production from pig manure.

Biogas and biomethane production potential from biogas is increasing every year, although in 2020 there was a decrease in production (Table 4). This was the result of a decrease in public demand for pork, resulting in reduced pig farming, and greatly affected the potential for biogas and biomethane production in that year. The potential rate of biogas and biomethane production produced from 2015-2021 reaches 4.58% annually. The potential for biogas production from pig manure waste in North Sulawesi Province provides good benefits and is a new energy transformation for utilizing biomass into sustainable energy that can be used daily (Theofanous et al. 2014). Installation of a fixed dome anaerobic digester is one of the methods that is widely used by biogas managers, considering that the lifespan of a fixed dome digester construct can reach 15 years if operated correctly, and is easy to use and maintain (Osak et al. 2016).

**Table 3.** Manure production (tons) 2015-2021

| Distric/City | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
| Bolaang Mongondow | 11,465 | 12,809 | 14,090 | 15,499 | 17,049 | 17,405 | 18,874 |
| Minahasa | 52,588 | 56,795 | 57,742 | 58,311 | 59,477 | 56,504 | 61,848 |
| Sangihe Island | 23,670 | 23,725 | 24,153 | 23,937 | 24,476 | 6,641 | 6,653 |
| Talaud Island | 10,653 | 10,951 | 11,296 | 11,305 | 11,644 | 11,075 | 12,853 |
| South Minahasa | 14,809 | 15,994 | 16,708 | 16,958 | 16,418 | 18,256 | 19,306 |
| North Minahasa | 9,893 | 10,031 | 10,624 | 11,320 | 11,159 | 14,658 | 16,384 |
| North Bolaang Mongondow | 742 | 890 | 748 | 577 | 582 | 407 | 454 |
| Sitaro Island | 6,134 | 6,140 | 8,326 | 7,752 | 7,829 | 7,926 | 7,926 |
| Southeast Minahasa | 7,098 | 6,004 | 6,304 | 6,346 | 6,580 | 12,399 | 8,048 |
| South Bolaang Mongondow | 255 | 283 | 312 | 349 | 391 | 422 | 395 |
| East Bolaang Mongondow | 1,522 | 1,614 | 1,695 | 1,808 | 1,652 | 1,841 | 2,061 |
| Manado City | 2,238 | 2,.453 | 2,502 | 2,638 | 2,648 | 2,733 | 2,769 |
| Bitung City | 10,286 | 10,801 | 11,665 | 12,598 | 13,606 | 14,048 | 17,247 |
| Tomohon City | 35,335 | 29,796 | 23,343 | 21,709 | 21,846 | 19,178 | 19,937 |
| Kotamobagu City | 176 | 191 | 279 | 348 | 435 | 431 | 671 |

The distribution of biomethane potential from 2015-2021 is changing, in Figure 4 the area of Minahasa District and Tomohon City is a consistent area with a large biometane potential, followed by a significant increase in the biometane production potential in Bolaang Mongondow, South Minahasa and North Minahase District.

Sangihe Islands Region is one of the areas that has experienced a decrease in the potential of biomethane production. The regions with the lowest biomethane production potential every year are in the South Mongondow district and the East Mongondov district. This is due to the fact that there are still fewer pigs in the area. The livestock that were grown in the area were cattle and goats (BPS 2022).

**Table 4.** Biogas and biomethane potential production

| Year | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|
| Biogas (million $m^3$) | 18.99 | 19.15 | 19.28 | 19.45 | 19.89 | 18.69 | 19.86 |
| Biomethane (tons) | 7,542 | 7,607 | 7,660 | 7,727 | 7,902 | 7,423 | 7,887 |

The potential of the biogas produced can be converted into other forms of energy that can be used by the surrounding community, especially in the household sector adjacent to the digester installation, such as a substitute for LPG and firewood for cooking, for lighting, and also converting biogas into electricity (Nehra and Jain 2023; Alemayehu 2015; Vu et al. 2015). By using equation 6, this study found that substitution of biogas energy with other energy. The substitution value resulting from potential biogas production from 2015 to 2021 can be seen in Table 5. The total potential for biogas substitution with other energy in 2015–2021 is equivalent to 58.59 thousand tons of LPG, 470.09 thousand tons of firewood, 83.89 million liters of kerosene, and 672.38 GW of electricity. The energy produced is quite large and can provide good benefits for the energy needs of the household sector.

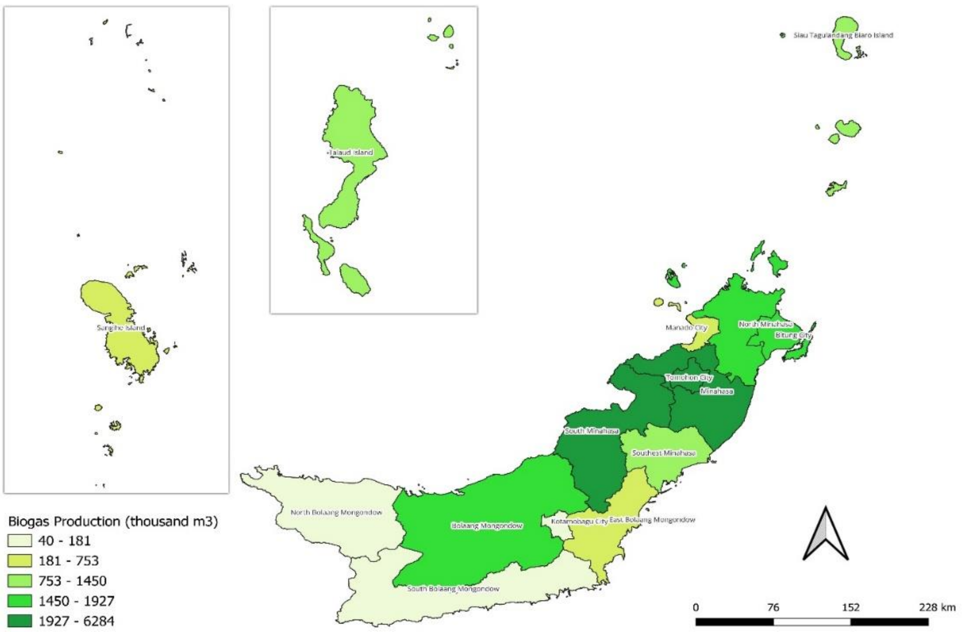


**Figure 3.** Biogas production potential in 2021

The potential for LPG produced from biogas substitution in 2021 can save the use of 3 kg of LPG gas cylinders for poor communities by 2.86 million cylinders. Referring to the report Wiratmaja (2016), the cost of subsidized LPG is IDR 4,250 $kg^{-1}$, so the savings provided from energy substitution can reach IDR 36.54 billion and if LPG subsidies are reduced and the majority of people use non-subsidized LPG, the savings that can be generated could reach IDR 72.90 billion, considering that the price of non-subsidized LPG is IDR 8,479 $kg^{-1}$. The benefits of using biogas as a substitute for

LPG can reduce imports of LPG, because up to now, LPG produced in the country still uses imported raw materials of as much as 70% (Gobel et al. 2021).

The potential of biogas as a substitute for LPG in the household sector has been a lot done research, one of them by Dewi and Supriana (2020) who carried out the analysis of the benefits of Biogas from PT Jatinom Indah Farm that can distribute biogass for 252 households with the quantity of biomass required as much as 327.60 $m^3$ which can provide benefits amounting to IDR 1.18 billion.

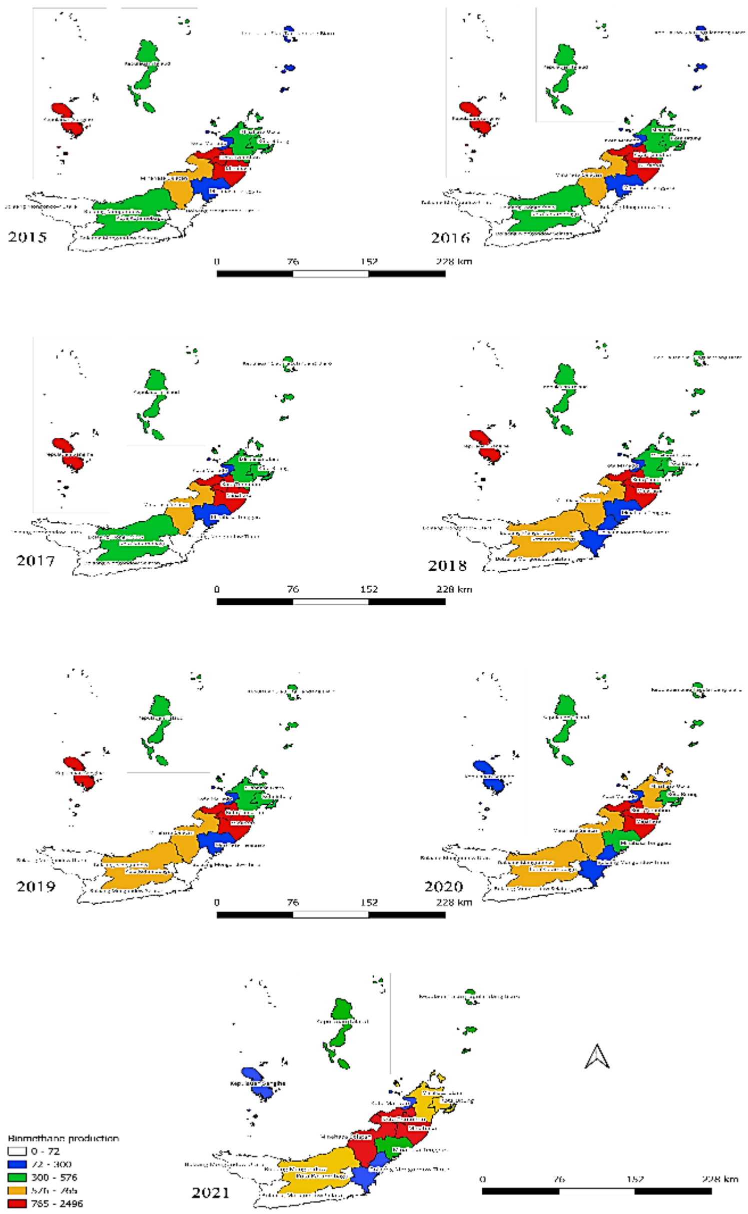


**Figure 4**. Distribution of biomethane potential from 2015-2021

The biogas formation process in an anaerobic digester can produce waste in the form of sludges (Silva et al. 2022). the resulting sludge can be used as raw material for plant fertilizers, given that the sludger from an anaeroobic Digester has a mineral element that can be processed as organic fertilizer in both solid and liquid forms (Budiyono et al. 2014; Sari et al. 2018). However, in this study the calculation of the benefits of sludge as organic fertilizer is not taken into account. In addition to economic benefits, managing pig stools into biogas with anaerobic digester processes can provide benefits such as reduced GHG emissions (Haryanto et al. 2017).

**Table 6.** Total CH4 emissions from manure management (tons) 2015-2021

| Distric/City | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
| Bolaang Mongondow | 95.60 | 106.80 | 117.49 | 129.24 | 142,.16 | 145.12 | 157.38 |
| Minahasa | 438.49 | 473.57 | 481.47 | 486.21 | 495.94 | 471.14 | 515.70 |
| Sangihe Island | 197.37 | 197.83 | 201.40 | 199.59 | 204.09 | 55.37 | 55.47 |
| Talaud Island | 88.83 | 91.31 | 94.19 | 94.27 | 97.09 | 92.35 | 107.17 |
| South Minahasa | 123.48 | 133.36 | 139.32 | 141.40 | 136.90 | 152.22 | 160.98 |
| North Minahasa | 82.49 | 83.64 | 88.59 | 94.39 | 93.05 | 122.22 | 136.61 |
| North Bolaang Mongondow | 6.19 | 7.42 | 6.24 | 4.81 | 4.85 | 339 | 3.79 |
| Sitaro Island | 51.14 | 51.20 | 69.43 | 64.64 | 65.28 | 66,.09 | 66.09 |
| Southeast Minahasa | 59.19 | 50.06 | 52.56 | 52.91 | 54.87 | 103.34 | 67.11 |
| South Bolaang Mongondow | 2.13 | 2.36 | 2.60 | 2.91 | 3.26 | 3.51 | 3.29 |
| East Bolaang Mongondow | 12.69 | 13.46 | 14.13 | 15.07 | 13.78 | 15.35 | 17.19 |
| Manado City | 18.66 | 20.45 | 20,86 | 22.00 | 22.08 | 2279 | 23.09 |
| Bitung City | 85.77 | 90.06 | 97.27 | 105.05 | 113.45 | 117.14 | 143.81 |
| Tomohon City | 294.64 | 248.45 | 194.64 | 181.01 | 182.15 | 159.91 | 166.24 |
| Kotamobagu City | 1.47 | 1.60 | 2.32 | 2.90 | 3.63 | 3,59 | 5.59 |

Potential GHG emissions in the livestock sector can be determined using equation 4. Pigs are a type of monogastric livestock that produce low $CH_4$ emissions when compared to ruminant livestock, because pigs produce $CH_4$ emissions in the management process alone, whereas for enteric fermentation pigs are so small that they can be ignored (IPCC 2006). Using the IPCC 2006 Tier-1 method guidelines, it is possible to determine the amount of $CH_4$ Emissions generated by pig farming in the North Sulawesi Province. According to the 2006 IPCC guidelines, the count of livestock is obtained by multiplying the life span of pigs by the number of livestock and divided by the amount of days in a year that is 365 days, so that the total $CH_4$ emissions generated by the farming sector in 2015-2021 reachd 11.10 (Gg $CH_4$) and by 2021 alone reached 1.63 (Gg $CH_4$).

**Table 7.** Global Warming Potential from 2015-2021

| Year | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|
| CH4 livestock | 32.72 | 33.00 | 33.23 | 33.52 | 34.28 | 32.20 | 34.22 |
| Biogas | 14.20 | 14.33 | 14.42 | 14.55 | 14.88 | 13.98 | 14.85 |
| LPG | 25.28 | 25.50 | 25.68 | 25.90 | 26.49 | 24.88 | 26.44 |
| Total | 43.80 | 44.18 | 44.48 | 44.88 | 45.89 | 43.11 | 45.81 |

The distribution of the $CH_4$ potential emissions in the pig farming sector in the North Sulawesi Province can be seen in Table 6. The greenhouse gas emissions from the pig farming sector related to the $N_2O$ gas pollution are not taken into account, because pig farms conducted in the North Sulawesi Province are in the vicinity of the river, so manure from pigs are not discharged but thrown directly into the rivers (Suriman et al. 2021).

The potential for global warming resulting from livestock is $CH_4$ emissions that are released into the environment. Each $CH_4$ emission has a Global Warming Potential (GWP) of 21 $CO_{2eq}$ (Ersoy and Ugurlu 2020), so that the total global warming originating from livestock in North Sulawesi province reaches 34.22 Gg $CO_{2eq}$ in 2021 (Table 7). If pig farm manure are managed well from 2015-2021 and use of biogas to substitute LPG is carried out, the total reduction in global warming potential that can be obtained will reach 312.14 Gg $CO_{2eq}$ (Table 7).

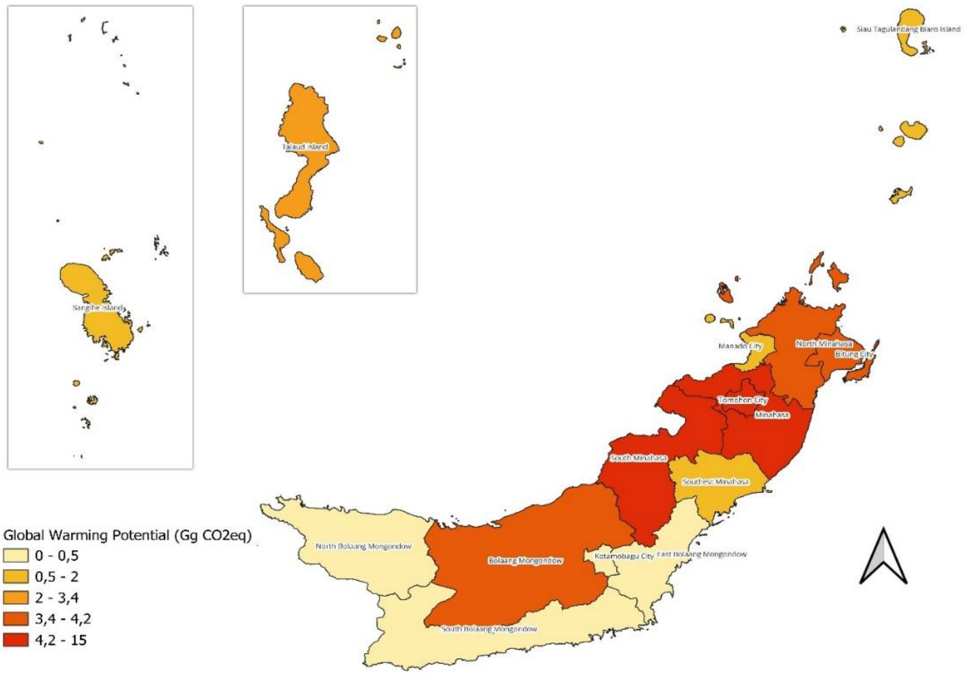


**Figure 5.** Global Warming Potential at North Sulawesi Province 2021

The distribution of GWP in the North Sulawesi Province in 2021 can be seen in Figure 4. South Minahasa district, Minahase district and Tomohon City are the regions that produce the largest GWP emissions compared to other regions. The population of these three districts represents 26.08% of the total population of the North Sulawesi Province, while the regions with the lowest GWP spread are in North Mongondow District, South Mongondov District, Kotamobagu City, and East Mongondou District with a total population of 13.97% (BPS 2022).

## CONCLUSION

The production potential of pig manure as a raw material for the formation of biomethane in the North Sulawesi Province has significant potential. In 2021, the province can produce 195,426 tons/year, with the most significant manure production in North Minahasa Regency at 61,848 tons/year and the lowest production in the South Bolaang Mongondow Regency area. Resulting in potential biomethane production in 2021 of 7,887 tons $CH_4$/year. This biomethane production can substitute LPG in the household sector, reaching 8,598 tons, or equivalent to 2.86 million 3 kg of gas cylinders. The potential for reducing global warming emissions from biomethane by managing pig manure in North Sulawesi Province and substitution of LPG fuel with biogas from anaerobic digesters can reach 45.81 Gg $CO_{2eq}$/year. Minahasa Regency has the most significant potential reduction in GWP compared to other regions, namely 14.50 Gg $CO_{2eq}$/year or 31.65%. Other areas with the most significant potential reduction in GWP are Tomohon City, which reached 4.67 Gg $CO_{2eq}$/year or 10.20%, and South Minahasa Regency with 4.53 Gg $CO_{2eq}$/year or 9.88% of the total GWP.

## REFERENCES

Afotey B, Sarpong GT (2023) Estimation of biogas production potential and greenhouse gas emissions reduction for sustainable energy management using intelligent computing technique. Meas Sensors 25:100650. doi: 10.1016/j.measen.2022.100650

Alemayehu YA (2015) Status and benefits of renewable energy technologies in the rural areas of ethiopia: A case study on improved cooking stoves and biogas technologies. Int J Renew Energy Dev 4:103–111. doi: 10.14710/ijred.4.2.103-111

Anukam A, Mohammadi A, Naqvi M, Granström K (2019) A review of the chemistry of anaerobic digestion: Methods of accelerating and optimizing process efficiency. Processes 7:1–19. doi: 10.3390/PR7080504

Anwaq S, Asaad I, Budiharto, Ratnasari, Wibowo H, Gunawan W (2020) Laporan Inventarisasi GRK 2020 dan Monitoring, Pelaporan, Verifikasi (MPV). Kementrian LIngkungan Hidup dan Kehutanan, Jakarta

Artiani GP, Handayasari I (2017) Optimalisasi Pengolahan Sampah Organik Dengan Teknologi Biodigester Sebagai Upaya Konservasi Lingkungan. J Kaji Ilmu dan Teknol 6:95–105. doi: 10.33322/kilat.v6i2.127

Bensah EC, Antwi E, Ahiekpor J (2021) Guide for the Design and Construction of Fixed-Dome Biodigester. Kumasi Technical Univesity, Kumasi

Biogas Rumah (2021) Indonesia Domestic Biogas Program 2021. Jakarta Selatan

BPK PSU (2023) Peta Wilayah Provinsi SUlawesi Utara. In: https//sulut.bpk.go.id/peta-situs/. Accessed 1 Desember 2023

BPS (2022) Provinsi Sulawesi Utara Dalam Angka 2022. BPS, Statistic of Sulawesi Utara Province, Sulawesi Utara

Budiyono B, Widiasa IN, Johari S, Sunarso S (2014) Increasing Biogas Production Rate from Cattle Manure Using Rumen Fluid as Inoculums. Int J Sci Eng 6:31–38. doi: 10.12777/ijse.6.1.31-38

Calbry-Muzyka A, Madi H, Rüsch-Pfund F, Gandiglio M, Biollaz S (2022) Biogas composition from agricultural sources and organic fraction of municipal solid waste. Renew Energy 181:1000–1007. doi: 10.1016/j.renene.2021.09.100

Dewi GAMK (2017) Materi ilmu ternak babi. Universita Udayana, Denpasar

Dewi I, Supriana WF (2020) Feasibility Analysis Of Biogas Chicken Manure Business Development. J Sains Terap 10:62–69. doi: 10.29244/jstsv.10.2.62 - 69

Ersoy E, Ugurlu A (2020) The potential of Turkey's province-based livestock sector to mitigate GHG emissions through biogas production. J Environ Manage 255:109858. doi: 10.1016/j.jenvman.2019.109858

Esteves EMM, Herrera AMN, Esteves VPP, Morgado C do RV (2019) Life cycle assessment of manure biogas production: A review. J Clean Prod 219:411–423. doi: 10.1016/j.jclepro.2019.02.091

Fitriyah Q, Wahyudi MPE (2020) Feasibility Study of Purified Biogas Into Gas Bottling in Indonesia. J Integr 12:129–133. doi: 10.30871/ji.v12i2.2289

Fitriyani, Martunis (2021) Sistem Informasi Geografis Persebaran Tambak Ikan di Kecamatan Kembang Tanjong Menggunakan Qgis. J Real Ris 3:104–112. doi: 10.47647/jrr

Gobel R, Panjaitan A, Sutedja R, Priambudhi, Wahono FA, Chandra A, Wicaksono B (2021) Reformasi Kebijakan Subsidi LPG Tepat Sasaran: Mengurangi Kesenjangan dan Menjamin Pemerataan, 1st edn. Sekretariat Wakil Presiden Republik Indonesia, Jakarta

Haryanto A, Cahyani D, Triyono S, Murdapa F, Haryono D (2017) Economic benefit and greenhouse gas emission reduction potential of a family-scale cowdung anaerobic biogas digester. Int J Renew Energy Dev 6:29–36. doi: 10.14710/ijred.6.1.29-36

Heriyanti AP, Purwanto P, Purnaweni H, Fariz TR (2022) Greenhouse Gas Emissions and Biogas Potential From Livestock in Rural Indonesia. J Pendidik IPA Indones 11:35–46. doi: 10.15294/jpii.v11i1.34465

IPCC (2006) Emissions from livestock and manure managemen. In: Dong H, Mangino J, McSllister TA (eds) 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The Institute for Global Environmental Strategies, Kanagawa

Jelínek M, Mazancová J, Van Dung D, Phung LD, Banout J, Roubík H (2021) Quantification of the impact of partial replacement of traditional cooking fuels by biogas on global warming: Evidence from Vietnam. J Clean Prod 292. doi: 10.1016/j.jclepro.2021.126007

KESDM (2021) Handbook Energy & Economic Statistics Indonesia. Ministry of Energy and Mineral Resources,

Jakarta
Kulkarni I, Zang JW, Leandro WM, Parikh P, Adler I, Fonseca-zang WA Da, Campos LC (2021) Closed-Loop Biodigesters on Small-Scale Farms in Low- and Middle-Income Countries : A Review. MDPI 1–20. doi: 10.3390/w13192744
Liu T, Ferrari G, Pezzuolo A, Alengebawy A, Jin K, Yang G, Li Q, Ai P (2023) Evaluation and analysis of biogas potential from agricultural waste in Hubei Province, China. Agric Syst 205:103577. doi: 10.1016/j.agsy.2022.103577
Makara L, Lytour L, Chanmakara M (2021) Practical Biogas Plant Development Handbook: Potential Biogas resources, Legal Review, and Good Practice of Biogas Construction in Cambodia. Biogas Technology and Information Center, Cambodia
Maluegha BL, Ulaan TVY, Umboh MK (2018) Perancangan Digester Untuk Menghasilkan Biogas Dari Kotoran Ternak Babi di Desa Rumoong Bawah Kabupaten Minahasa Selatan. J Tekno Mesin 4:167–174
Meyer EL, Overen OK, Obileke KC, Botha JJ, Anderson JJ, Koatla TAB, Thubela T, Khamkham TI, Ngqeleni VD (2021) Financial and economic feasibility of bio-digesters for rural residential demand-side management and sustainable development. Energy Reports 7:1728–1741. doi: 10.1016/j.egyr.2021.03.013
Naghavi R, Abdoli MA, Karbasi A, Adl M (2020) Improving the quantity and quality of biogas production in tehran anaerobic digestion power plant by application of materials recirculation technique. Int J Renew Energy Dev 9:167–175. doi: 10.14710/ijred.9.2.167-175
Nehra M, Jain S (2023) Estimation of renewable biogas energy potential from livestock manure: A case study of India. Bioresour Technol Reports 22:101432. doi: 10.1016/j.biteb.2023.101432
Osak RE, Hartono B, Fananai Z, Utami HD (2016) Potentials of Biogas and Bioslurry Utilization and Subsidy Incentives Policy Recomendation in Indonesia. Indones Cent Anim Res Dev 213–221. doi: 10.14334/proc.intsem.lpvt-2016-p.213-221
Pan SY, Tsai CY, Liu CW, Wang SW, Kim H, Fan C (2021) Anaerobic co-digestion of agricultural wastes toward circular bioeconomy. iScience 24:102704. doi: 10.1016/j.isci.2021.102704
Pizarro-Loaiza CA, Antón A, Torrellas M, Torres-Lozada P, Palatsi J, Bonmatí A (2021) Environmental, social and health benefits of alternative renewable energy sources. Case study for household biogas digesters in rural areas. J Clean Prod 297. doi: 10.1016/j.jclepro.2021.126722
Prihatiningtyas S, Sholihah FN, Nugroho MW (2019) Biodigester untuk Biogas, 1st edn. Fakultas Pertanian. Universitas KH. Wahab Hasbullah, Jombang
Sari W, Budiarsa Suyasa IW, Sila Dharma IG. (2018) Upaya Pengolahan Limbah Kotoran Babi Menggunakan Komposter Rumah Tangga. ECOTROPHIC J Ilmu Lingkung (Journal Environ Sci 12:104. doi: 10.24843/ejes.2018.v12.i02.p01
Sawyerr N, Trois C, Workneh T, Okudoh V (2019) International Journal of Energy Economics and Policy An Overview of Biogas Production: Fundamentals, Applications and Future Research. Int J Energy Econ Policy | 9:105–116. doi: 10.32479/ijeep.7375
Setiyowati R, Retno Sari Saputro D, Widyaningsih P (2021) Pelatihan Pembuatan Peta Digital Berbasis Sistem Informasi Geografis Di Desa Rejoso. Pengabdi Kpd Masy 4:52–56. doi: 10.36257/apts.vxix
Setjen DEN (2022) Laporan Analisis Nerasa Energi Nasional. Dewan Energi Nasional, Jakarta
Siddiki SYA, Uddin MN, Mofijur M, Fattah IMR, Ong HC, Lam SS, Kumar PS, Ahmed SF (2021) Theoretical calculation of biogas production and greenhouse gas emission reduction potential of livestock, poultry and slaughterhouse waste in Bangladesh. J Environ Chem Eng 9:105204. doi:

10.1016/j.jece.2021.105204
Silva HL de C e, Córdova MEH, Barros RM, Filho GLT, Lora EES, Santos AHM, Santos IFS dos, Botan MCC de O, Pedreira JR, Flauzino BK (2022) Lab-scale and economic analysis of biogas production from swine manure. Renew Energy 186:350–365. doi: 10.1016/j.renene.2021.12.114
Suriman DKP, Soputan JEM, Kalele JAD, Rawung VRW (2021) Kombinasi feses sapi dan babi sebagai sumber biogas. Zootec 41:181. doi: 10.35792/zot.41.1.2021.32560
Sutaryo S, Sempana AN, Lestari CMS, Ward AJ (2020) Performance Comparison of Single and Two-Phase Biogas Digesters Treating Dairy Cattle Manure at Tropical Ambient Temperature. Trop Anim Sci J 43:354–359. doi: 10.5398/tasj.2020.43.4.354
Suyitno, Sujono A, Darmanto (2010) Teknologi Biogas, 1st edn. Graha Ilmu, Yogyakarta
Theofanous E, Kythreotou N, Panayiotou G, Florides G, Vyrides I (2014) Energy production from piggery waste using anaerobic digestion: Current status and potential in Cyprus. Renew Energy 71:263–270. doi: 10.1016/j.renene.2014.05.003
Thiangchanta S, Khiewwijit R, Mona Y (2022) Environmental impact of the biogas production from dairy cows. Energy Reports 8:290–295. doi: 10.1016/j.egyr.2022.10.204
Tumiran (2014) Paradigma Baru Kebijakan Energi Nasional Menuju Ketahanan dan Kemandirian Energi. Dewan Energi Nasional, Jakarta
Vu TKV, Vu DQ, Jensen LS, Sommer SG, Bruun S (2015) Life cycle assessment of biogas production in small-scale household digesters in Vietnam. Asian-Australasian J Anim Sci 28:716–729. doi: 10.5713/ajas.14.0683
Wang Y, Zhang Y, Li J, Lin JG, Zhang N, Cao W (2021) Biogas energy generated from livestock manure in China: Current situation and future trends. J Environ Manage 297:113324. doi: 10.1016/j.jenvman.2021.113324
Wiratmaja I (2016) Kebijakan LPG 3 KG. Kementrian ESDM Republik Indonesia, Jakarta
Yan B, Yan J, Li Y, Qin Y, Yang L (2021) Spatial distribution of biogas potential, utilization ratio and development potential of biogas from agricultural waste in China. J Clean Prod 292:126077. doi: 10.1016/j.jclepro.2021.126077
Yaqoob H, Teoh YH, Ud Din Z, Sabah NU, Jamil MA, Mujtaba MA, Abid A (2021) The potential of sustainable biogas production from biomass waste for power generation in Pakistan. J Clean Prod 307:127250. doi: 10.1016/j.jclepro.2021.127250
Yu L, Yaoqiu K, Ningsheng H, Zhifeng W, Lianzhong X (2008) Popularizing household-scale biogas digesters for rural sustainable energy development and greenhouse gas mitigation. Renew Energy 33:2027–2035. doi: 10.1016/j.renene.2007.12.004