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Biogas Energy Prediction as a Green Energy Producer in West Lombok Using a Statistical Approach

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Abstract

The use of green energy is increasingly becoming a major concern in efforts to achieve energy sustainability. One of the renewable energy sources that has great potential is biogas, which is produced from the processing of organic waste. This study aims to analyze and predict the potential of biogas energy as a green energy producer in West Lombok using a statistical approach. The data used include the amount of available organic waste, biogas production capacity, and factors that influence energy conversion efficiency. The statistical methods applied include linear regression, historical trend analysis, and predictive modeling to estimate the potential energy that can be produced in the long term. The results of the study indicate that biogas production in West Lombok has significant prospects, with the potential to contribute to a green energy system that can reduce dependence on fossil fuels. Based on the results, the potential for green energy in the region is 450-600 MWh per year in West Lombok and the technology scale can increase efficiency up to 60-80%. This study can be the basis for policymaking in encouraging the use of biogas energy as part of the transition to sustainable energy in the region.

Keywords:
Green Energy, Linear Regression, Biogas, Forecasting, West Lombok

1. Introduction

Energy is a fundamental element in economic development and social welfare. As global energy demand increases, dependence on fossil fuels still dominates the electricity and transportation systems. However, excessive use of fossil fuels has caused various environmental problems, such as increased greenhouse gas emissions, air pollution, and climate change. Therefore, the transition to environmentally friendly green energy is an urgent need, including in Indonesia which has great potential in developing renewable energy. [23] One form of promising green energy is biogas. Biogas is produced through the anaerobic fermentation process of organic materials, such as livestock waste, agricultural waste, and household waste. The methane gas (CH_4) contained in biogas can be used as fuel for power plants or as an alternative energy source for households and industries. In addition to providing energy benefits, biogas also contributes to reducing environmental pollution due to poorly managed organic waste [1].

As an archipelagic country, Indonesia has great potential to develop green energy with high biodiversity [8]. According to the Ministry of Energy and Mineral Resources (ESDM), the potential for renewable energy in Indonesia reaches more than 400 GW, with solar power dominating at 207.8 GW and hydro energy around 75 GW [9]. The biomass potential, including biogas from organic waste, can be a solution to reduce dependence on fossil fuels. The development of green energy in Indonesia is a strategic step in realizing national

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energy security and reducing the impact of climate change [18]. Research on biogas utilization in Indonesia has focused on technical aspects and small-scale implementation. Studies that combine energy potential analysis with statistical prediction models are still limited, especially in the context of green energy development at the regional level. [4]

Biogas is a renewable energy source produced from the anaerobic fermentation process of organic materials such as agricultural waste, livestock manure, household, and food industry waste. [16] This process is carried out in a biodigester, where microorganisms decompose organic materials and produce methane gas (CH_4) [11]. Biogas has various uses, ranging from cooking fuel, and electricity generation, to vehicle fuel after going through a purification process [10]. The residue from the biogas production process can be used as an organic fertilizer to increase soil fertility. Biogas not only contributes to reducing dependence on fossil fuels but also helps in waste management [3].

West Lombok is one of the areas with great potential in the utilization of biogas. This region has a rapidly growing agricultural and livestock sector, producing large amounts of organic waste every day. Unfortunately, most of this waste has not been optimally utilized and has instead become a source of environmental pollution. The utilization of biogas can be a strategic solution in waste management as well as a source of sustainable green energy for the local community [2]. Therefore, this study conducts the utilization of biogas using a data approach to harvest accurate calculations. We employ a biogas energy prediction model using a statistical approach, which allows analysis of raw material availability, production capacity, and energy conversion efficiency.

This study covers the background, and problem formulation of statistical prediction methods, including data collection techniques and statistical analysis [24]. The presentation of research results shows the findings obtained in graphs and tables [11]. The main objective of this study is to analyze the potential of biogas energy in West Lombok using a statistical approach [5]. Therefore, this study can be a clear research direction for biogas energy production in West Lombok.

2. Related Works

Biogas energy prediction as a green energy producer using a statistical approach involves analyzing historical and real-time data from anaerobic digestion processes to estimate future biogas output. Communities can calculate relationships between input variables by leveraging statistical methods such as regression analysis, time series forecasting, and principal component analysis. Furthermore, statistical prediction aids in energy planning, cost-benefit analysis, and the integration of biogas into smart grid systems. An article has researched the procedure for calculating the potential of cattle as raw material for biogas. The sample used is the number of cattle in each province in Indonesia, where the first thing to do to calculate the conversion results of one cow into electrical energy is to calculate the weight of the cow by multiplying the number of cows in each province by the average weight of cattle in Indonesia [32].

Another work researched that showing 1 kilogram of cow weight can produce 0.3 m^3 of biogas. The research conducted by Afazeli can be a reference for converting cow waste. The results of this study can be used as a reference for calculating the potential for Biogas that can be produced from the data obtained and then analyzed to determine the greatest potential for clustering [3]. Another paper calculated the amount of greenhouse gases that can be reduced where in his research it states that CH_4 is 23 times more dangerous than CO_2 as a greenhouse gas. The study pays attention to economic aspects in which to find out the benefits of using biogas produced by the digester when compared to LPG and to find out when the capital (initial investment) will return (knowing the break-even point). [6]

Another research focused on the potential of biomass as a renewable energy source. The paper collected data from BPS with the calculation indicators used being biomass waste in the form of plants that can be converted into electricity in the form of rice, corn, and coconut. This study is used as a reference with different waste variations. While this study focuses on livestock that can produce the largest biogas sources. [22]. An article presented Multiple Linear Regression to undergo biogas energy prediction research with several independent variables [17].

3. Proposed Method

The research method used in this study aims to analyze and predict the potential of biogas energy as a green energy source in West Lombok. To achieve this goal, this study applies a quantitative method with a statistical approach, especially linear regression and time series analysis. Linear regression is used to identify the relationship between variables that affect biogas production, while time series analysis is used to predict biogas production trends based on historical data. [30]

This study began with collecting data related to the availability of biogas raw materials in West Lombok, such as livestock waste (cattle). The data was collected through field surveys, interviews with livestock breeders and farmers, and literature reviews from official reports and academic publications. [14] In addition, biogas production data from existing biogas installations were also collected as a basis for regression and time series analysis. Simple linear regression was used to see the relationship between the volume of raw materials and biogas production. [27] The regression model used has the following basic form:

$$Y = \beta_0 + \beta_1 X + \varepsilon$$

Where Y is the amount of biogas energy produced (in kWh or m^3), X is the amount of raw material (kg or tons), β_0 is the intercept, β_1 is the regression coefficient, and ε is the error term. If there is more than one independent variable, a multiple linear regression model is used to consider additional factors such as ambient temperature and humidity. [12] After the relationship between the independent and dependent variables is determined through linear regression, the time series method is used to analyze the pattern of biogas production over time. Biogas production data that has been collected from previous years is analyzed using a combined forecasting model, namely: Moving Average, Exponential Smoothing, and Autoregressive Integrated Moving Average (ARIMA). [25]

3.1 Data collection

The data used in this study were obtained from various sources, including Interviews with managers of the Central Statistics Agency to determine the number of cattle in each sub-district. Secondary data from related agencies, such as the West Lombok Agriculture and Livestock Service, and literature studies on the conversion of biogas into electrical energy [3][7]. Fig.1 depicts the dataset of biogas energy production to conduct this study.

Fig. 1 Field Data Collection and Livestock Survey

3.2 Data processing

Data processing is carried out with supporting software: Microsoft Excel, IBM SPPS Statistics 25, and LEAP. Data normalization is categorized based on the type of waste source [31]. Calculation using the standard formula of the linear regression method with predictive analysis based on the volume of cattle in each sub-district that can be converted into methane gas. Prediction of electrical energy produced using a linear regression to estimate the relationship between biogas volume and electrical energy output [32].

3.3 Method Testing

To ensure the accuracy, a three-step testing process was implemented. First, data validation was conducted through manual calculations by comparing the predicted biogas potential with values generated by the regression model. Second, statistical testing was performed by evaluating the regression model using key performance indicators such as the coefficient of determination (R^2) and MAPE to assess prediction accuracy. Lastly, scenario simulations were carried out by varying waste quantities and conversion efficiency to analyze the model's sensitivity to input fluctuations [9][20].

4. Experimental Setup

The time series model allows the prediction of biogas production for future years, taking into account trends, seasonality, and fluctuations that occur in historical data. For example, if biogas production increases in the rainy season due to increased humidity that accelerates anaerobic fermentation, then this factor will be included in the prediction model to increase its accuracy. After the regression and time series models are applied, validation tests are carried out to assess the accuracy of the prediction results. Several evaluation methods used include Mean Absolute Error (MAE), Mean Squared Error (MSE), and Root Mean Squared Error (RMSE). [29]

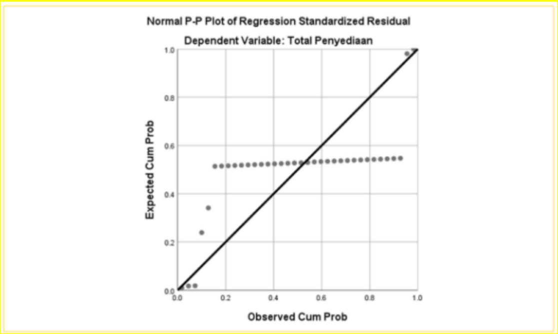

Fig.2 Linear Regression Model

The smaller the error value, the better the model used in predicting biogas production in West Lombok. Furthermore, the results of the biogas production prediction are compared with the energy needs of the local community. This is done to measure the extent to which biogas can contribute to regional energy security. [21] If the potential biogas production is greater than the electricity demand of households and small industries, then its utilization can be increased with better distribution and infrastructure strategies.

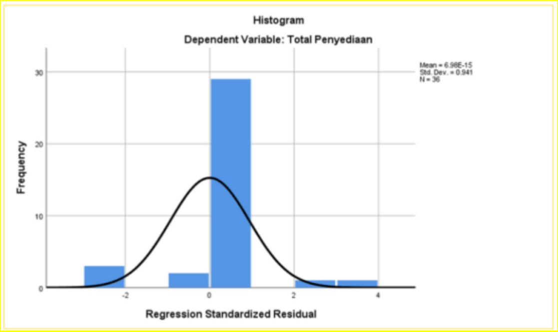

Fig. 3 Correlation of Dependent and Independent Variables

The method used in this study is expected to provide an accurate picture of the potential of biogas energy in West Lombok. By using a combination of linear regression and time series analysis, this study can provide data-based estimates that can be used as a reference for local governments and investors in developing biogas-based green energy infrastructure. [15] Overall, this study is not only academic but also applicable. The results of the analysis are expected to be the basis for making sustainable energy policies, as well as increasing public awareness of the importance of utilizing organic waste as an alternative energy source, with a data-based approach, biogas development can be carried out more systematically, efficiently, and have a positive impact on the environment and the local economy.

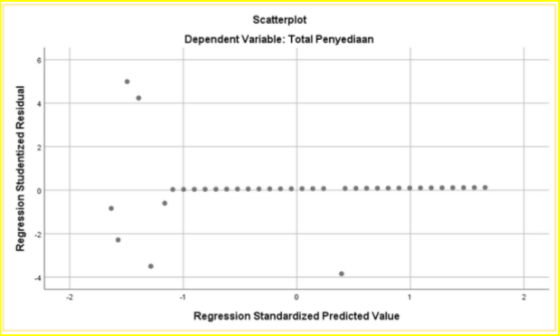

Fig. 4 Scatterplot of Energy Supply Prediction Regression

5. Result and Analysis

5.1 Population growth of West Lombok

The calculation results using the linear regression method show population growth that illustrates a consistently increasing pattern from 2020 to 2045. At the beginning of the period, the population was relatively stable, but since 2025, there has been a more significant acceleration in growth. The blue line representing the actual value data shows mild fluctuations, while the yellow line representing the future estimate shows a sharper and more sustainable trend. This reflects the projected increase in population influenced by factors such as birth rates, migration, and government policies in supporting social welfare. In 2045, population growth in West Lombok Regency is predicted to reach 982,885 thousand people.

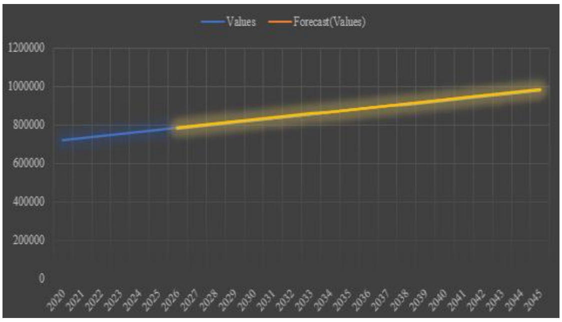

Fig. 5 Population Growth of West Lombok in 2025

5.2 Forecasting Electrical Energy Needs for Each Sector

The provision of fuel for various sectors continues to increase along with the increasing energy needs every year. This can be an opportunity and a challenge. [19] Programs and policies taken by policymakers must not harm the community and the country. The scarcity of fuel continues to occur in various regions, especially remote areas of the country. [28] Some types of fuel that need to be provided include: BBM (Fuel Oil): Solar, kerosene, premium, pertalite, pertamax. Gas: LPG, LNG, CNG Electricity: Main source from PLN, including new & renewable energy. [29]

The energy provision model for each sector by PLN aims to: Household → Stable electricity supply & energy subsidies for the community. Industry → Support economic growth with reliable electricity. Business -> Ensure smooth business and business operations. [24] Public and Social → Ensure smooth public service operations. Office Buildings -> Optimize office mobility and continuity. Street Lighting → Make cities brighter and safer. In this section, forecasting is carried out for increasing energy supply and consumption each year until 2045. The year 2010 is used as the base year (Y1) so that from 2010 - 2045 the total is Y = 36, for the years 2026 - 2045 (Y17 - Y36) a linear forecast model is used.

a. Avtur Needs in West Lombok

Avtur (Aviation Turbine Fuel) is a special fuel used for aircraft with turbine engines, such as commercial and military aircraft. Avtur has the main characteristics of a low freezing point, high thermal stability, and optimal energy content to ensure efficient aircraft engine performance in various atmospheric conditions. In addition to being the main source of power for aircraft, avtur also plays a role in keeping the fuel system clean and preventing the formation of ice or deposits that can interfere with engine performance.

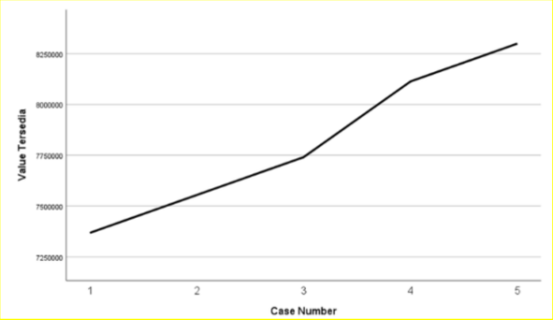

Fig.6 Need for Avtur Provision

b. Premium Needs for Transportation in West Lombok

Premium is a gasoline fuel with an octane rating of 88 used for motor vehicles, especially those with engines with low to medium compression ratios. The main function of premium in transportation is as an energy source that enables the combustion process in the engine, producing power to drive the vehicle. In addition, premium helps maintain smooth engine performance by providing stable combustion, although it produces higher emissions than fuels with higher octane ratings such as pertalite or pertamax.

Although its use has begun to decline along with the push towards more environmentally friendly fuels, premium still plays a role in supporting community mobility in various regions, especially in areas that have not fully switched to higher quality fuels.

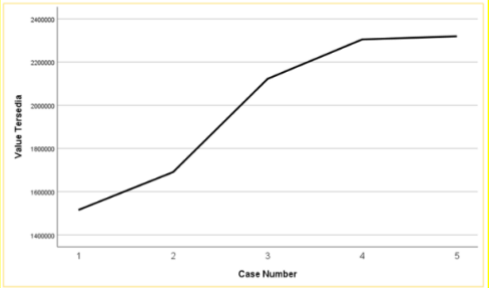

Fig.7 Premium Provision Needs for Transportation

c. Premium Needs for Industry in West Lombok

In the industrial sector, premium functions as fuel for various equipment and machines that require gasoline-based energy sources, especially those operating at low to medium compression ratios. Premium is used in small-scale generator engines, cutting tools, water pumps, and several types of light industrial equipment that require stable combustion for efficient operation. In addition, premium is also used in certain production processes, such as small and medium industries (IKM) that still rely on gasoline-fueled engines to support their activities.

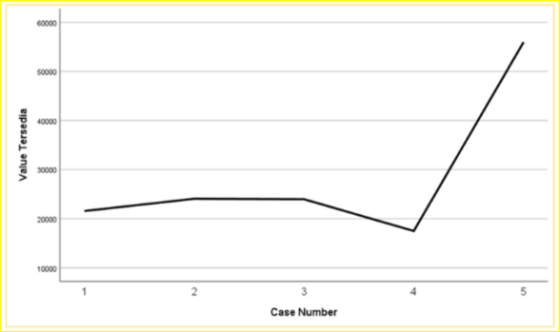

Fig. 8 Premium Provision Needs for Industry

d. Household Kerosene Needs in West Lombok

Kerosene has a primary function as household fuel, especially for cooking and lighting in areas that have not been reached by gas or electricity networks. As an easy-to-use energy source, kerosene is used in traditional kerosene stoves that are still widely used in rural or remote areas. In addition, kerosene is also used as fuel for kerosene lamps that function as alternative lighting during power outages. Although its use is decreasing along with the energy conversion program to more efficient and clean LPG, kerosene still has an important role for communities that do not yet have access to modern energy sources.

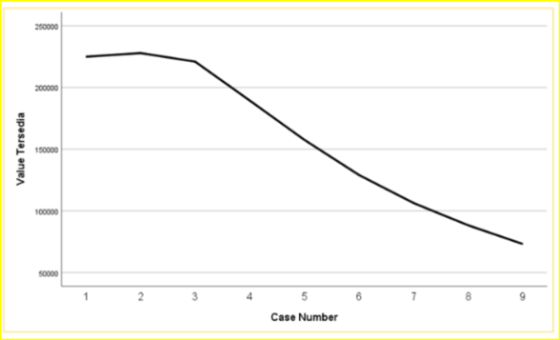

Fig.9 Graph of Kerosene Supply Needs for Households

e. Kerosene Needs for Industry in West Lombok

In the industrial sector, kerosene functions as fuel for various production and operational processes, especially in small and medium industries that still rely on conventional energy sources. Kerosene is used in the combustion process in the textile industry, drying agricultural products, and as fuel for heating machines and other equipment. In addition, kerosene is also used in the metal industry for heating and cleaning components before further processing. Although its use has begun to decline with the transition to more efficient fuels such as gas and diesel, kerosene still has a role in industries that have not fully switched to alternative energy.

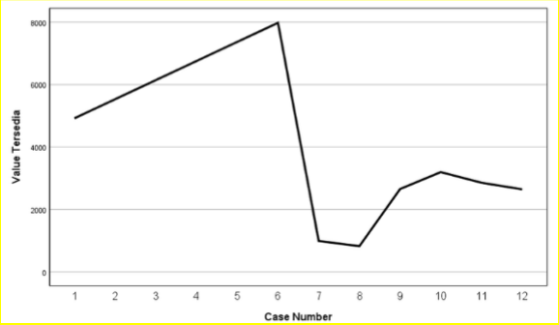

Fig.10 Graph of Kerosene Supply Needs for Industry

f. Diesel Oil Needs for Transportation in West Lombok

Diesel serves as the main fuel in the transportation sector, especially for diesel-engined vehicles such as trucks, buses, ships, and trains, with efficient combustion characteristics and high durability, diesel allows heavy vehicles to operate with great power and more efficient fuel consumption compared to gasoline. In addition, diesel is also used in sea transportation for cargo ships and fishing boats, which require fuel with stable performance on long-distance journeys. In land transportation, diesel supports logistics mobility and mass transportation which are the backbone of goods distribution and public transportation. Although renewable energy such as biodiesel and electric vehicles are starting to develop, diesel is still a vital component in the transportation system, especially for sectors that require fuel efficiency and high cruising range.

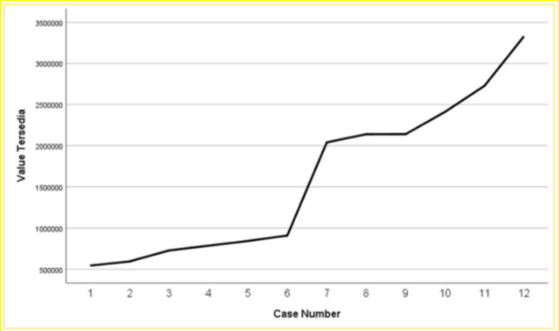

Fig.11 Graph of Diesel Oil Requirements for Transportation

g. Diesel Oil Needs for Industry in West Lombok

Diesel plays an important role in the industrial sector as the main fuel for various heavy machinery and equipment that require large power. Diesel is used in the manufacturing, mining, and construction industries to operate diesel engines such as generators, heavy equipment, and operational vehicles. In addition, diesel is also used in industrial heating processes, such as in cement production, metal processing, and chemical processing. The advantage of diesel lies in its efficiency in producing energy with high durability, making it the main choice for industries that require fuel with optimal performance. Although the trend towards renewable energy is growing, diesel is still a vital component in supporting industrial activities in various sectors.

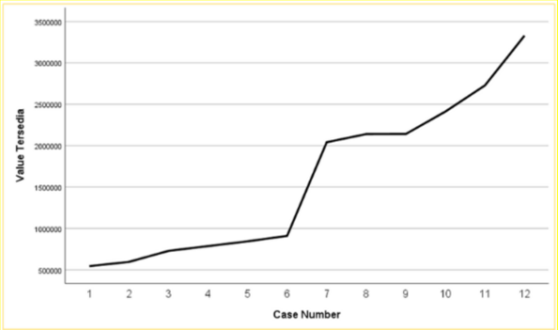

Fig. 12 Graph of Diesel Oil Requirements for Industry

h. Gas Supply and Demand in West Lombok

Gas supply and demand describe the dynamics of the energy balance showing how gas production, imports, and consumption evolve. In general, gas supply is influenced by factors such as domestic production, distribution infrastructure capacity, and energy policies that support natural gas exploration and utilization. [11] Meanwhile, gas demand increases in line with industrial growth, gas-based electricity needs, and the energy transition from dirtier fossil fuels to cleaner sources. In recent years, gas demand has tended to increase faster than supply growth, which has driven an increase in liquefied natural gas (LNG) imports in several countries.

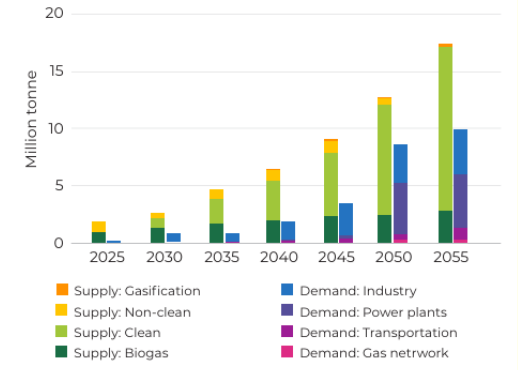

Fig.13 Gas Supply and Demand Graph

5.3 Energy Supply Model for Each Sector 2015-2025 in West Lombok

The energy supply model for each sector from 2010 to 2045 serves as a guide in planning and managing national energy needs, in line with economic growth and the energy transition towards more sustainable sources. In the industrial sector, this model ensures the availability of energy for manufacturing, mining, and construction operations by diversifying energy sources, including the use of natural gas, electricity, and renewable energy. In the transportation sector, the energy supply model functions in the shift from fossil fuel use to low-emission fuels such as biofuels and electric vehicles. In the household sector, this model supports the policy of converting energy from kerosene to LPG and increasing electricity use. Meanwhile, the commercial and government sectors adopt energy efficiency strategies and the integration of green energy technologies to support sustainability. With a planned energy supply model, the government can optimize the national energy mix, reduce dependence on fossil fuel imports, and accelerate the achievement of the net zero emission target by 2060.

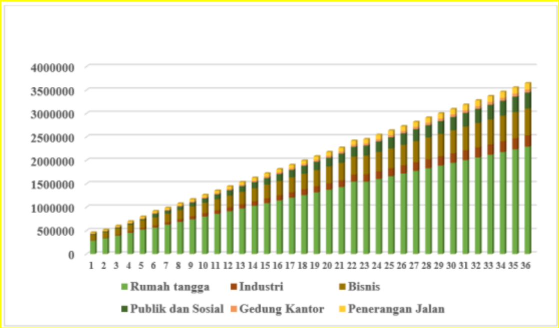

Fig. 14 Graph of Energy Supply Model for Each Sector 2015-2025

5.4 Energy Demand Projection by Fuel Type

Energy demand projections based on fuel type serve as a strategic planning tool in determining long-term energy policies, adjusting to economic growth, technological developments, and the transition to sustainable energy. [13] By projecting energy needs from various sources such as oil, natural gas, coal, and renewable energy, the government and industry players can optimize infrastructure, investment, and energy diversification to ensure stable availability. [26] In addition, these projections help identify trends in the shift from fossil fuels to more environmentally friendly energy sources, such as bioenergy, solar power, and renewable energy-based electricity. With accurate data, these projections play a role in reducing the risk of supply and demand imbalances, supporting national energy security, and helping to achieve low-carbon emission targets in the future..

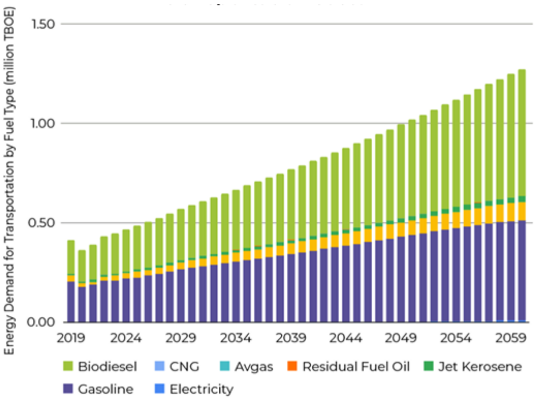

Fig.15 Energy Demand Projection Graph Based on Fuel Type

5.5 Prediction of Methane Gas and Green Energy Predicition

Sekotong ranks first as the area with the highest biogas potential, which is around 225,000 m³/year (18.9%), because this area has a large livestock land area and a cattle population. Infrastructure and communities also support the integration of communal biogas systems. Kediri contributes 16.4% of the total potential, equivalent to 195,000 m³/year, supported by the many dense livestock villages and its proximity to energy distribution lines. Gerung has a dense village structure and technological support that allows for higher efficiency in biogas production (170,000 m³/year or 14.3%). The combination of access to information and livestock population is the main strength of this sub-district. [12] Lembar and Narmada follow as medium zones with potentials of 12.6% and 10.9% respectively. Lembar excels because its coastal villages have begun to adopt integrated livestock farming, while Narmada is developing because of the potential for integration between agriculture and livestock farming in the agro-energy system. Gunungsari and Kuripan contribute 9.2% and 7.6% respectively, and are considered areas with potential for development, especially on a household scale. Labuapi, Lingsar, and Batulayar are below 6%, with the main challenges being dense settlements and limited land for biogas installations. However, microbiogas development is still possible in certain villages with active cattle populations.

Table 1: Prediction Results and Percentage of Biogas Production

No	Kecamatan	Prediksi produksi biogas (m³/tahun)	Presentase (%)	Warna
1	Sekotong	225.000	18,9	🟧
2	Kediri	195.000	16,4	🟦
3	Gerung	170.000	14,3	🟪
4	Lembar	150.000	12,6	🟪
5	Narmada	130.000	10,9	🟦
6	Gunungsari	110.000	9,2	🟩
7	Kuripan	90.000	7,6	🟩
8	Labuapi	65.000	5,5	🟨
9	Lingsar	35.000	2,9	🟦
10	Batu Layar	20.000	1,7	🟩
Total		1.190.000	100	

Gunungsari (110,000 m^3/year), Gunungsari sub-district has a topography that is advantageous for the development of integrated agriculture and livestock farming. With an even distribution of villages and many small-scale farmers, this area shows the potential for growth in community-based biogas production. Access to infrastructure and proximity to Mataram also allow for efficient distribution of digester technology. Kuripan (90,000 m³/year – 7.6%), Kuripan has medium potential, supported by several cattle-producing villages such as South Kuripan and Giri Sasak. Although not as large as Sekotong or Kediri, this area is still important as a point of synergy between the livestock and agricultural sectors. Biogas potential is more suitable for implementation in a microgrid scheme or household utilization. Labuapi (65,000 m³/year – 5.5%), With the growth of residential areas and small industries, Labuapi faces the challenge of limited land. However, several villages such as Telagawaru and Kuranji Dalang still maintain active livestock activities. The biogas potential in this sub-district is more suitable for a school-based approach or public facilities (biogas for shared kitchens, for example). Lingsar (35,000 m³/year – 2.9%), Lingsar Sub-district, which is better known as an agricultural and tourism area, has a low livestock population. However, the organic farming system and pro-environment local community can support an educational biogas pilot project, especially to support energy conservation and environmentally friendly agriculture. Batulayar (20,000 m³/year – 1.7%), Batulayar is the area with the smallest contribution to biogas potential because it is dominated by tourism and housing areas.

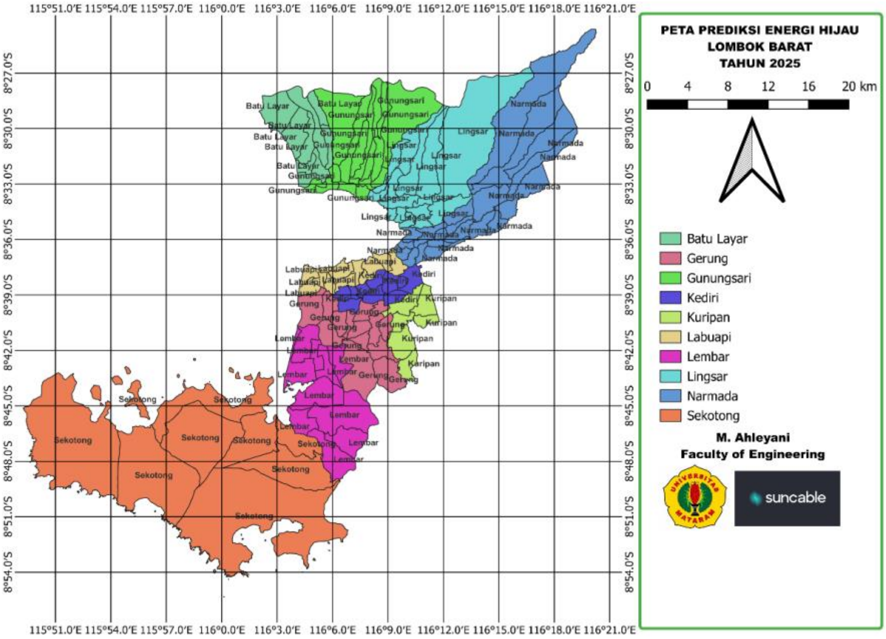

Fig. 16 Green energy prediction map in West Lombok in 2025 based on color classification

Sekotong ranks first as the area with the highest biogas potential, which is around 225,000 m³/year (18.9%) because this area has a large livestock land area and a cattle population spread evenly across many villages such as Central Sekotong and West Sekotong. Infrastructure and support from traditional livestock communities also support the integration of communal biogas systems. Kediri contributes 16.4% of the total potential, equivalent to 195,000 m³/year, supported by the many dense livestock villages and its proximity to energy distribution lines. This sub-district is a priority target for a village cooperative-based biogas project. Gerung, as the center of government, has a dense village structure and technological support that allows for higher efficiency in biogas production (170,000 m³/year or 14.3%). The combination of access to information and livestock population is the main strength of this sub-district. Lembar and Narmada follow as medium zones with potentials of 12.6% and 10.9% respectively. Lembar excels because its coastal villages have begun to adopt integrated livestock farming, while Narmada is developing because of the potential for integration between agriculture and livestock farming in the agro-energy system. Gunungsari and Kuripan contribute 9.2% and 7.6% respectively. Labuapi, Lingsar, and Batulayar are below 6%, with the main challenges being dense settlements and limited land for biogas installations.

6. Conclusion

Based on the results, the potential for green energy is around 450-600 MWh per year in West Lombok. The application of household and communal scale technology with an efficiency of 60-80%. In terms of methane gas production, an estimated analysis of the total cattle population during the period 2015–2024 shows that the potential for methane gas production reaches 1,200,000 to 1,500,000 cubic meters per year. This amount is obtained by assuming that each adult cow can produce around 0.24–0.30 m^3 of methane gas per day from its waste, with processing using an efficient digester system. If converted to electrical energy, this methane gas can produce up to 600 MWh per year, enough to meet the electricity needs of ±3,000 households sustainably.

The clustering of green energy-producing areas in West Lombok was carried out using livestock population data. The results show that the three main sub-districts Sekotong, Kediri, and Gerung, contribute 18.9%, 16.4%, and 14.3% of the West Lombok biogas population sample. These sub-districts have a high cattle population, an even distribution of villages, and proximity to energy distribution facilities and user markets. Meanwhile, other sub-districts contributed as follows: Lembar (12.6%), Narmada (10.9%), Gunungsari (9.2%), Kuripan (7.6%), Labuapi (5.5%), Lingsar (2.9%) and Batulayar (1.7%). This clustering is important as a basis for planning a region-based green energy program to support the Net Zero Emission (NZE) program of the Provincial Government.

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