aAdıyaman University
Journal of Engineering Sciences
Adyü J Eng Sci 2025;12(26):281-292
Adıyaman Üniversitesi
Mühendislik Bilimleri Dergisi
Adyü Müh Bil Derg 2025;12(26):281-292
https://doi.org/10.54365/adyumbd.1705671

Research Article / Araştırma Makalesi

Assessment of Biogas Potential from Animal Waste in Türkiye's TRB2 Development Region

Türkiye'nin TRB2 Kalkınma Bölgesinde Hayvansal Atıklardan Biyogaz Potansiyelinin Değerlendirilmesi

Ömer Arslan [1] *

[1] Muş Alparslan Üniversitesi, Mühendislik- Mimarlık Fakültesi, Makine Mühendisliği Bölümü, Muş, Türkiye.

Abstract

Türkiye currently relies on imported fossil fuels for approximately 70% of its energy consumption, highlighting the urgent need to transition to domestic and renewable energy sources. Biogas emerges as a compelling, environmentally friendly energy solution in this context. Biogas' production facilitates effective management of agricultural practices, animal husbandry, and domestic waste and contributes to the generation of clean energy. Furthermore, the by-product from the anaerobic digestion process serves as a valuable organic fertilizer, enhancing agricultural productivity. The TRB2 Development Region, which encompasses the provinces of Van, Muş, Bitlis, and Hakkari, is one of Türkiye's least developed areas in socio-economic terms and holds significant potential for animal husbandry. Given the region's high output of animal manure, its effective utilization is critical, especially within its predominantly rural demographic. This study explores the potential for biogas production from animal manure in the TRB2 Development Region. Research findings indicate that the region possesses substantial capacity for biogas generation, and the establishment of village-type biogas facilities could satisfactorily fulfill the daily energy requirements of rural communities. Additionally, the organic fertilizer produced through biogas processes is anticipated to enhance agricultural yields further. The study also investigates the broader impacts of biogas production on local agriculture and the economy, underscoring the important role of renewable energy sources in fostering regional development

Keywords: *Biogas, Livestock waste, TRB2 development region, Renewable energy, Sustainability*

Öz

Türkiye, günümüzde enerji tüketiminin yaklaşık %70'ini ithal fosil yakıtlardan karşılamaktadır. Bu durum, ülkenin yerli ve yenilenebilir enerji kaynaklarına yönelmesini zorunlu kılmaktadır. Bu bağlamda biyogaz, çevre dostu ve yerel bir enerji kaynağı olarak dikkat çekmektedir. Biyogaz üretimi; tarım, hayvancılık ve evsel atıkların etkin bir şekilde yönetilmesini sağlarken aynı zamanda temiz enerji üretimine katkı sunmaktadır. Ayrıca, anaerobik parçalama süreci sonucunda oluşan yan ürün, değerli bir organik gübre niteliğinde olup tarımsal üretimi desteklemektedir. Türkiye'nin sosyo-ekonomik açıdan en az gelişmiş bölgelerinden biri olan TRB2 Kalkınma Bölgesi, Van, Muş, Bitlis ve Hakkâri illerini kapsamaktadır. Bölge, hayvancılık faaliyetleri açısından önemli bir potansiyele sahip olup, buna paralel olarak yüksek miktarda hayvansal gübre üretimi de söz konusudur. Bu hayvansal gübrenin değerlendirilmesi, kırsal ağırlıklı nüfus yapısına sahip bölge için büyük önem taşımaktadır. Bu çalışma, TRB2 Kalkınma Bölgesi'nde hayvansal gübre kullanılarak biyogaz üretim potansiyelini araştırmayı amaçlamaktadır. Araştırma bulguları, bölgenin biyogaz üretimi açısından kayda değer bir potansiyele sahip olduğunu ortaya koymaktadır. Köy tipi biyogaz tesislerinin kurulması, kırsal kesimlerin günlük enerji ihtiyaçlarını karşılamada etkili olabilir. Bunun yanı sıra biyogaz üretimiyle elde edilen organik gübrenin tarımsal verimliliği artırabileceği değerlendirilmektedir. Çalışmada ayrıca yerel tarım ve ekonomi üzerindeki olası etkileri incelenerek yenilenebilir enerji kaynaklarının bölgesel kalkınmadaki rolü vurgulanmaktadır.

Anahtar Kelimeler:, *Biyogaz, Hayvan atığı, TRB2 kalkınma bölgesi, Yenilenebilir enerji, Sürdürülebilirlik*

* Corresponding e-mail (Sorumlu yazar e-posta): o.arslan@alparslan.edu.tr
Received (Geliş Tarihi): 24.05.2025, **Accepted (Kabul Tarihi):** 30.06.2025

1. Introduction

The growing reliance on fossil fuel resources has led to increased energy consumption, prompting a global acceleration towards renewable energy sources. This shift aims to alleviate the environmental challenges associated with fossil fuels and to address the urgent depletion of these resources [1] Countries such as Türkiye, which possess limited fossil fuel reserves, must optimize the deployment of local renewable energy resources to mitigate escalating energy costs and reduce existing deficits. Moreover, harnessing local renewable energy is essential for achieving a sustainable and environmentally friendly development model [2–4]. Biogas, a prominent renewable energy source, offers a clean energy solution and significantly enhances sustainable agricultural practices, fosters economic development in rural areas, and contributes to alleviating local environmental issues [5]. Furthermore, the production of biogas generates liquid organic fertilizer as a by-product. This organic fertilizer, obtained through anaerobic fermentation, demonstrates significantly greater efficacy than untreated animal manure by reducing the prevalence of pathogenic microorganisms [6].Therefore, animal waste is a compelling and sustainable option for biogas production.

Türkiye is a significant agricultural nation with considerable animal and plant production capabilities. However, biogas—an effective method for leveraging the potential of organic waste—remains limited. If fully harnessed, biogas could serve as a renewable and environmentally friendly energy source. Reducing harmful waste would also positively impact the rural economy by promoting a sustainable and high-quality environment [7]. The Eastern Anatolia Region boasts the highest potential for both small and large cattle in Türkiye, generating substantial animal manure. The TRB2 Development Region, which includes the provinces of Van, Muş, Bitlis, and Hakkari, is particularly noted for its rich livestock potential. Therefore, it is crucial to thoroughly evaluate the biogas production capabilities of the TRB2 Development Region. As of the end of 2023, the region reported a population of 474,114 cattle, 5,759,960 small ruminants, and 1,085,795 poultry [8,9].

In addition, in Türkiye, each province's efforts to meet its energy needs locally by effectively evaluating renewable energy sources will reduce the burden on the country's general energy network and contribute to the economic development of the provinces and the on-site reduction of environmental problems. This study was conducted to reveal the biogas capacity of the TRB2 Development Region. The TRB2 region consists of Van, Muş, Bitlis, and Hakkari provinces, which are classified as the country's 6th least developed socio-economic region [10,11]. It is essential to evaluate the biogas potential of these provinces, which have a predominantly rural population, to meet the daily energy needs of their rural population [12]. Because a large part of the animal manure obtained due to widespread animal husbandry activities is either burned as dung or used as fertilizer. However, obtaining biogas ensures obtaining a cleaner fuel with a high-calorie content. At the same time, biogas production waste is a more useful fertilizer that will lead to the optimal use of animal manure. As an additional benefit to all these, it includes contributing to reducing environmental pollution in rural areas [13–15].

Biogas is an effective method for producing energy from biomass. This process, known as anaerobic digestion, utilizes various organic materials, including agricultural plants, plant waste, animal manure, domestic organic waste, industrial by-products, treatment sludge, and slaughterhouse waste, as raw feedstock for biogas production [16–19]. Under anaerobic (oxygen-free) conditions, bacteria decompose these organic substances through biochemical processes, generating a colorless and clean biogas. The process involves four main stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. However, the ambient temperature within the reactor and the organic waste temperature are critical for maximizing biogas yield. Specifically, the optimal retention times for animal manure at various temperatures significantly enhance biogas production and its overall yield. It is widely acknowledged that a target temperature range of 30-35 °C is desirable for achieving optimal biogas generation. Notably, biogas production ceases when temperatures fall below 10 °C [20]. The calorific value of biogas is

approximately 5,100 kcal/m³ and comprises components such as methane, carbon dioxide, hydrogen sulfide, and water vapor. Notably, biogas' calorific value exceeds that of quality lignite coal [21].

Biogas production is widely utilized in various countries, including China, India, Thailand, the Philippines, Korea, Switzerland, the USA, and Germany [22–25]. Despite Türkiye's significant agricultural capabilities and ample organic waste potential, the country has made limited advancements in harnessing biogas to leverage this potential. Realizing this opportunity would lead to producing environmentally friendly and renewable energy, simultaneously reducing harmful waste and fostering a sustainable environment. This endeavor would also enhance the rural economy. The Eastern Anatolia region, rich in animal husbandry and agricultural prospects, faces challenges that may impede its potential, including traditional pasture-based animal farming and the area's harsh, prolonged winter characteristic [14]. The TRB2 development region, which comprises four provinces in Eastern Anatolia, has not yet capitalized on the energy production potential from cattle and sheep manure. To tap into this underutilized resource, the public sector needs to urgently implement necessary regulatory frameworks and infrastructure, creating an appealing environment for private sector investment. Additionally, a biogas feasibility study specific to the region is needed. This study aims to support the aforementioned objectives and highlights the role of biofertilizers, a by-product of biogas production, in promoting sustainable agriculture. By quantifying this contribution, the study seeks to raise awareness regarding the impact of animal waste on the prosperity of rural areas in the region.

2. Material and Method

This study is of utmost importance as it aims to assess the biogas potential that can be generated from animal manure in the TRB2 region. As one of the least developed areas of Türkiye regarding socio-economic conditions, the TRB2 region comprises provinces characterized by a high rural population density. Evaluating this potential, which could directly enhance the welfare of a community that relies on agriculture and animal husbandry, is highly significant for the region. This study calculated the biogas potential separately for cattle, small ruminants, and poultry farming. Additionally, the volume of liquid biofertilizer produced as a byproduct of biogas generation was estimated. The data used for these calculations were obtained from the TURKSTAT data bank and the TRB2 Regional Development Agency (DAKA).

The quality and quantity of animal manure are influenced by several factors, including the animal species, feed type, live weight, breeding method, the ratio of total to volatile solids, duration of confinement in barns or similar areas, and the living conditions of the animals, all of which affect the waste's usability [26,27]. In order to assess the theoretical biogas potential, wet manure must be calculated based on a certain percentage of the animals' live weight. This requires considering the utilization percentage of the manure, which is linked to the animals' housing and feeding conditions, as well as the solid waste rate values determined based on the type of animal. All these parameters were derived from existing literature, underscoring the reliance of this study on established knowledge. The potential biogas yield from animal manure in the TRB2 development region was determined using the values presented in Table 1.

Table 1. Waste characteristics and biogas yields according to animal species [26,28,29]

Animal species	Live weight (kg)	Amount of fresh waste (Percentage of live weight of animal (%))	TS(%)	VS(%)	Availability or duration of stay in the stable (%)	Biogas yield (l/kg.UK)
Cattle	135-800	5-6	5-25	75-85	65 (milk), 25(meat)	200-350
Small ruminants	30-75	4-5	30	20	13	100-310
Chicken(egg)	1.5-2.0	3-4	10-35	70-75	99	310-620
Chicken(meat)			50-90	60-80		550-650

3. Animal Potential of TRB2 Development Region

The animal population statistics for the provinces within the TRB2 Development Region at the end of 2023 are outlined in Table 2 [8,9]. The proportions of cattle, small ruminants, and poultry across the TRB2 Region are illustrated in Figures 1, 2, and 3. Van province stands out in small ruminant farming, boasting a total of 3,280,145 animals, while Muş province holds the leading position in cattle farming with 235,507 animals. This data underscores the dominance of small ruminant farming throughout the region, attributed primarily to the vast areas of available pastureland.

Table 2. Animal population of TRB2 Region [8,9]

Animal species	Van	Muş	Bitlis	Hakkari	Total
Cattle	133,193	235,507	70,869	34,545	474,114
Small ruminant	3,280,145	1,051,461	739,888	688,466	5,759,960
Poultry	553,716	361,738	94,794	75,547	1,085,795
Total	3,967,054	1,648,706	905,551	798,558	7,319,869

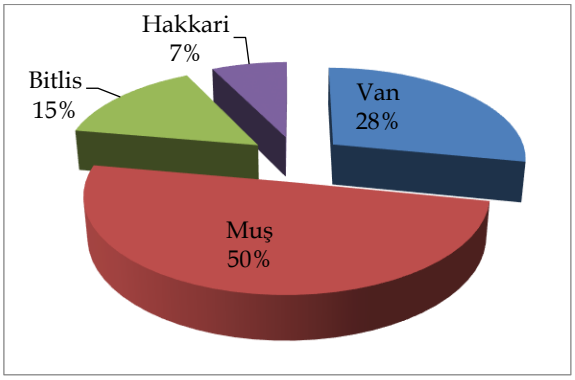

Figure 1. Cattle population of TRB2 Region

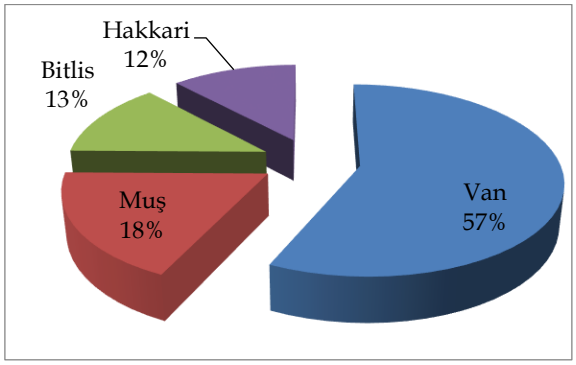

Figure 2. Small ruminant population of TRB2 Region

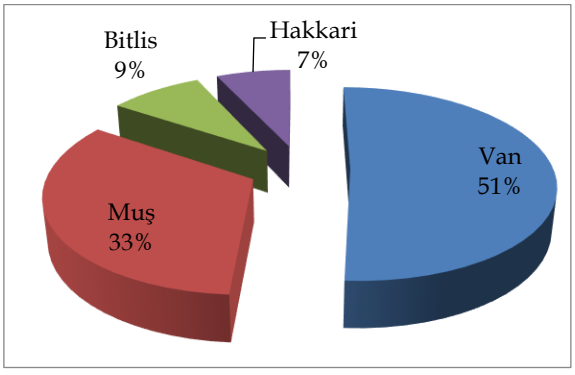

Figure 3. Poultry population of TRB2 Region

4. Estimation of Biogas Energy Potential of TRB2 Development Region

In calculating the amount of waste, Table 3 was created by utilizing the averages specified in Table 1. For this analysis, the live weights were established as follows: cattle at 470 kg, small ruminants at 53 kg, and poultry at 2 kg. The daily wet manure waste was calculated as 5.5% of the live weight for cattle, 4.5% for small ruminants, and 3.5% for poultry. Considering the duration of the animals in the barn, the availability of waste was determined to be 45% for cattle, 13% for small ruminants, and 99% for poultry. Additionally, the biogas yield from 1 ton of solid animal waste was set at 200 m^3, with a calorific value of 22.7 MJ/m^3. Lastly, when converting biogas into electrical energy, we assumed a cogeneration system with 40% electricity efficiency, 50% heat efficiency, and 10% energy loss, which facilitated the calculation of electricity production from biogas [28]. Using the aforementioned parameters and the equations outlined in 1 and 2, the biogas potential for the TRB2 region was assessed. Initial calculations were made for the provinces of Van, Muş, Bitlis, and Hakkari, with the results then aggregated to determine the total potential of the region. To estimate manure production for cattle and sheep, we utilized the year-end 2023 animal population data from TURKSTAT, while poultry data was sourced from the TRB2 region's development agency (DAKA) year-end 2023 report [8,9].

Table 3. Average quantities of waste produced by various animal types

Animal species	Wet manure (kg/gün)	TS (%)	Availability rate (%)	Biogas yield (l/kg.VS)
Cattle	26	15	45	275
Small ruminant	2.4	30	13	205
Poultry	0.07	46	99	533

Total amount of wet manure

$$AM_{year} = NoA * DW * 365/1000 \quad (1)$$

Here;
AM_{year} : Total annual fresh waste (ton/year)
NoA : Number of Animals
DW : Daily Animal Waste (kg/day), for cattle : 26 kg/day,
for small ruminant = 2.4 kg/day, for poultry = 0.07 kg/day

Calculation of total solid

$$ATS_{year} = AM_{year} * TS * Av \quad (2)$$

Here;
ATS_{year} : Total amount of solid waste (ton/year)
AM_{year} : Total annual fresh waste (ton/year)
TS : Rate of solid waste amount, for cattle = 0.15; for small ruminant = 0.30; for poultry = 0.46 average values were used in the calculations.
Av: Availability or the rate of the duration of animals staying in the stable, for cattle = 0.45; for small ruminant = 0.13 and for poultry = 0.99 values were used in the calculations.

The calculations for biogas production in the provinces of Van, Muş, Bitlis, and Hakkari within the TRB2 Region, utilizing Formulas 1 and 2, are detailed in Tables 4-7. Furthermore, the overall biogas production potential for the TRB2 Region is summarized in Table 8.

Table 4. Biogas potential of Van province

Animal species	Animal population	Wet manure (ton/ year)	Solid waste (ton/year)	Biogas yield (m^3/ year)	Heat energy potential (GJ/year)	Electric energy potential (MWh/year)
Cattle	133,193	1,264,002	85,320	17,064,000	387,352,800	43,039
Small ruminant	3,280,145	2,873,407	112,063	22,412,600	508,766,020	56,530
Poultry	553,716	14,148	6,443	1,288,600	29,251,220	3,250
Total	3,967,054	4,151,557	203,826	40,765,200	925,370,040	102,819

Table 5. Biogas potential of Muş province

Animal species	Animal population	Wet manure (ton/year)	Solid waste (ton/year)	Biogas yield (m^3/year)	Heat energy potential (GJ/year)	Electric energy potential (MWh/year)
Cattle	235,507	2,234,962	150,860	30,172,000	684,904,400	76,100
Small ruminant	1,051,461	921,080	35,922	7,184,400	163,085,880	18,121
Poultry	361,738	9,243	4,209	841,800	19,108,860	2,123
Total	1,648,706	3,165,285	190,991	38,198,200	867,099,140	96,344

Table 6. Biogas potential of Bitlis province

Animal species	Animal population	Wet manure (ton/year)	Solid waste (ton/year)	Biogas yield (m^3/year)	Heat energy potential (GJ/year)	Electric energy potential (MWh/year)
Cattle	70,869	672,547	45,397	9,079,400	206,102,380	22,900
Small ruminant	739,888	648,142	25,278	5,055,600	114,762,120	12,752
Poultry	94,794	2,422	1,103	220,600	5,007,620	557
Total	905,551	1,323,111	71,778	14,355,600	325,872,120	36,209

Table 7. Biogas potential of Hakkari province

Animal species	Animal population	Wet manure (ton/year)	Solid waste (ton/year)	Biogas yield (m^3/year)	Heat energy potential (GJ/year)	Electric energy potential (MWh/year)
Cattle	34,545	327,832	22,129	4,425,800	100,465,660	11,163
Small ruminant	688,466	603,096	23,521	4,704,200	106,785,340	11,865
Poultry	75,547	1,930	879	175,800	3,990,660	444
Total	798,558	932,858	46,529	9,305,800	211,241,660	23,472

Tables 4-7 present the calculated values on a provincial scale, indicating that Van province possesses the highest energy potential in the region, quantified at 102,819 MWh per year. Muş province closely follows, with a potential of 96,344 MWh per year. Subsequent in the ranking are Bitlis and Hakkari provinces, which exhibit lower potential values. The total energy potential for the TRB2 region is delineated in Table 8.

Table 8. Biogas potential produced from animal waste at the provincial scale in TRB2 Region.

Province	Animal species	Animal population	Biyogas yield (m^3/year)	Heat energy potential (GJ/year)	Electric energy potential (MWh/year)
Van	Cattle	133,193	17,064,000	387,352,800	43,039
	Small ruminant	3,280,145	22,412,600	508,766,020	56,530
	Poultry	553,716	1,288,600	29,251,220	3,250
Muş	Cattle	235,507	30,172,000	684,904,400	76,100
	Small ruminant	1,051,461	7,184,400	163,085,880	18,121
	Poultry	361,738	841,800	19,108,860	2,123
Bitlis	Cattle	70,869	9,079,400	206,102,380	22,900
	Small ruminant	739,888	5,055,600	114,762,120	12,752
	Poultry	94,794	220,600	5,007,620	557
Hakkari	Cattle	34,545	4,425,800	100,465,660	11,163
	Small ruminant	688,466	4,704,200	106,785,340	11,865
	Poultry	75,547	175,800	3,990,660	444
Total		7,319,869	102,624,800	2,329,582,960	258,844

Table 9 below indicates the quantity of electricity generated from biogas derived from animal waste from provinces in the TRB2 region. Figure 4-5 compares the biogas production potential among the provinces within the TRB2 region. Although Van Province has a notable potential for small cattle, most animals are typically grazed on plateaus.Thus, the utilization rate of their manure is limited to 13%, which results in reduced biogas production. This condition subsequently diminishes the overall biogas potential for Van Province.

Table 9. Biogas potential of provisions of TRB2 Region

Potential of Van (MWh/year)	Potential of Muş (MWh /year)	Potential of Bitlis (MWh /year)	Potential of Hakkari (MWh /year)
102,819	96,344	36,209	23,472

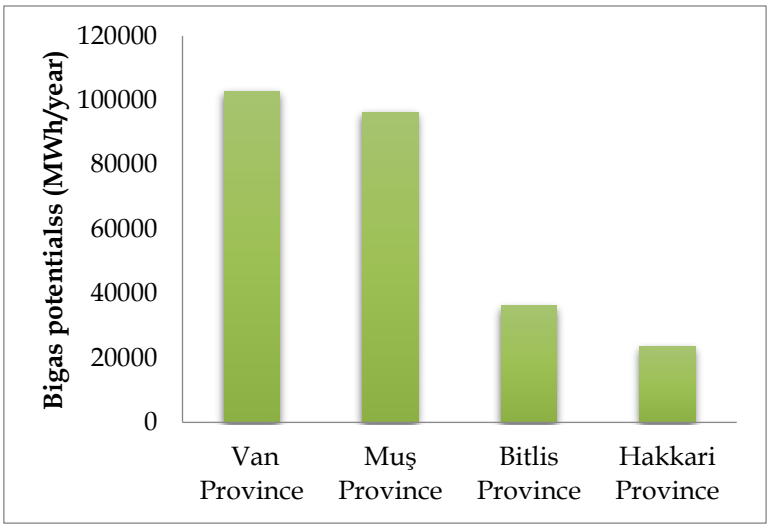

Figure 4. Comparison of biogas potentials of provinces within the TRB2 Region

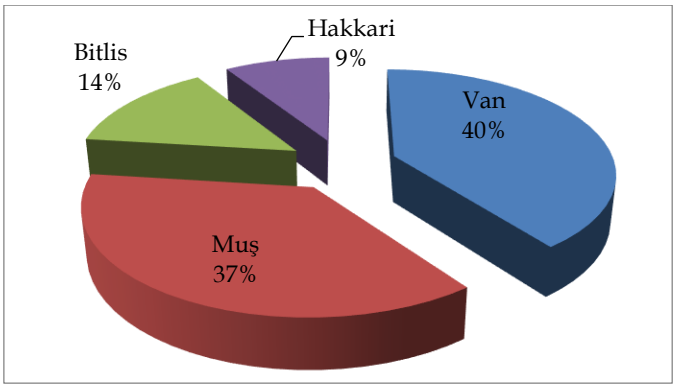

Figure 5. Proportional comparison of biogas energy potential that can be produced from each province in TRB2 region

4.1. Assessment of fermented organic fertilizer production from biogas in the TRB2 Region and its impact on agricultural sustainability

Biogas production results in the generation of fermented organic fertilizer in liquid form. This fertilizer can be employed in agricultural practices either as a liquid, in a granulated state, or can be allowed to dry naturally in concrete or soil pools. It can be utilized in both liquid and granulated forms, and portions may also be applied as solid fertilizer [30,31]. One of the primary advantages of this organic fertilizer is the significant reduction of most disease-causing microorganisms, which occurs due to the anaerobic fermentation process. This fermented fertilizer demonstrates an efficiency that is approximately 20-25% greater than that of non-fermented animal manure [6,7]. As depicted in Figure 6, an analysis of mass balance during anaerobic fermentation reveals that 2-4% of the mass entering the reactor is converted into biogas. The composition of the reactor output consists of 96-98% fresh wet manure, with approximately 7-25% of the fermented fertilizer in solid form and 75-93% in liquid form. This mass balance is illustrated in Figure 6 [28].

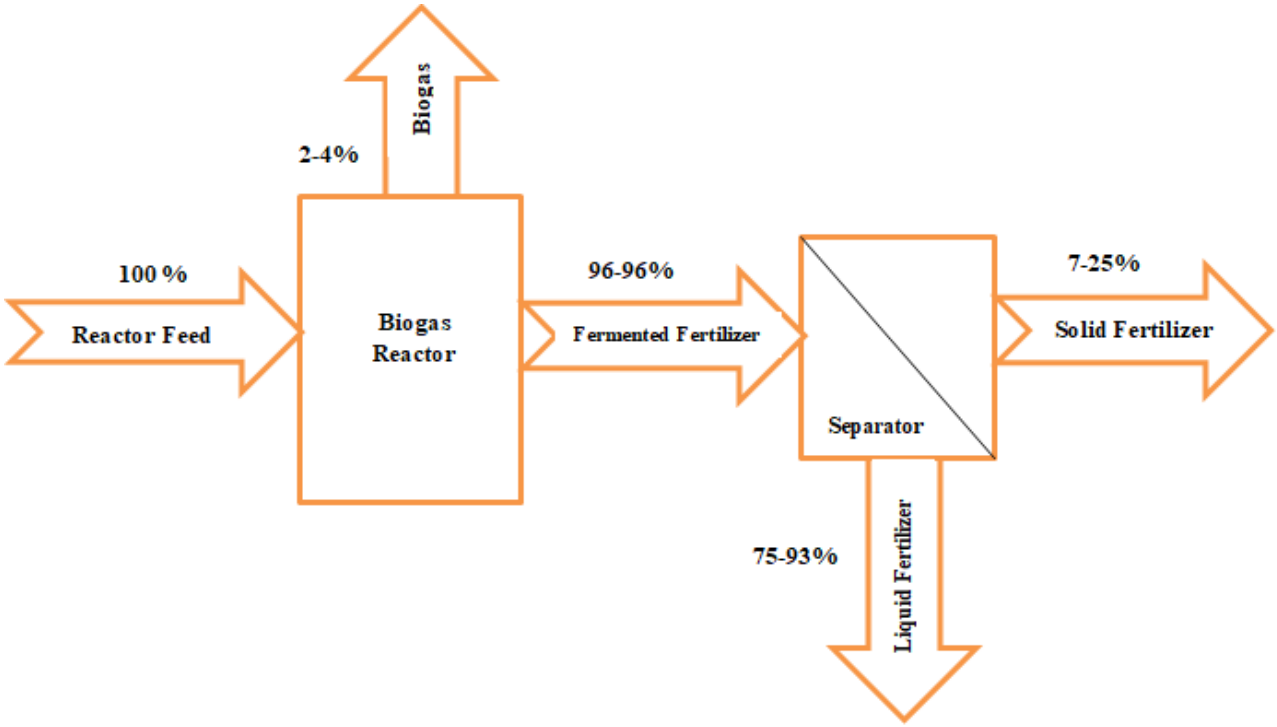

Figure 6. Mass balance diagram in biogas production process [28]

The liquid organic fertilizer for the provinces within the region has been determined by calculating the average values presented in Figure 6, representing a liquid-fermented fertilizer composition of 97%. This analysis is summarized in Table 10, providing a detailed overview of fertilizer distribution throughout the region.

Table 10. Production potential of liquid organic fertilizer in the provinces of the TRB2 Region

Potential of Van (m^3/year)	Potential of Muş (m^3/year)	Potential of Bitlis (m^3/year)	Potential of Hakkari (m^3/year)
39,542,244	37,052,254	13,924,932	9,026,626

5. Results and Discussion

Despite the many disadvantages associated with fossil fuels, their predominant role in ensuring energy supply security remains a key factor in their continued preference for energy production. However, with finite fossil fuel reserves projected to deplete rapidly due to rising demand, it has become essential to rapidly and effectively deploy renewable energy sources. Additionally, the localized nature of these sources can significantly contribute to energy independence, allowing regions and cities to meet their own energy needs, thereby alleviating pressure on the national energy grid. Implementing this energy strategy and planning represents one of the most viable alternatives for achieving sustainable economic development. While countries with limited fossil fuel resources are investing in energy solutions that integrate into the broader energy network—such as nuclear energy and large- to medium-scale hydroelectric power plants—local communities must be encouraged to harness renewable energy sources like wind, solar, and biogas to satisfy their energy requirements. Biogas, in particular, stands out as an important and clean energy source that supports the economic development of rural areas and sustainable agriculture and helps mitigate local environmental issues. Moreover, the biogas production process yields fermented organic fertilizer in liquid form, which proves to be more effective than untreated animal manure, as it effectively destroys many pathogenic microorganisms due to anaerobic fermentation.

Furthermore, Türkiye must assess renewable energy sources that can significantly minimize greenhouse gas and carbon emissions to achieve sustainable economic development while meeting its international environmental obligations. It is crucial for Türkiye to urgently explore its largely untapped biogas potential, which holds considerable promise. Biogas is a vital clean energy source that can enhance the economic development of rural areas and help alleviate local environmental issues. Despite Türkiye's significant agricultural and livestock potential, it lags behind advanced countries in this domain. Therefore, thorough research should be conducted to evaluate the biogas potential in each province and region. The TRB2 development region, comprising four provinces in Eastern Anatolia, boasts a substantial capacity for animal manure owing to its significant small ruminants and cattle population. This study aims to highlight the biogas potential of the TRB2 development region and raise awareness about its benefits.

This study assesses the biogas potential of animal waste within the TRB2 region. The calculated electricity generation potential from this biogas is determined to be 102,819 MWh/year for Van, 96,344 MWh/year for Muş, 36,209 MWh/year for Bitlis, and 23,472 MWh/year for Hakkari, as illustrated in Table 9. Furthermore, Table 11 delineates the projected electricity consumption patterns for the provinces in the TRB2 region by the conclusion of the year 2023 [32].

Table 11. Distribution of electricity consumption by consumer type in the provinces of the TRB2 Region [32]

Province	Lighting (MWh)	Public and commercial services and others (MWh)	Residential (MWh)	Industrial (MWh)	Agricultural activities (MWh)	Total consumption (MWh)
Van	75,141	388,586	542,688	162,098	4,353	1,172,866
Muş	31,333	127,976	177,642	75,886	4,836	417,673
Bitlis	31,253	140,899	165,256	27,178	60,186	424,772
Hakkari	17,404	151,481	139,079	1,997	138	310,099

Table 9 outlines the potential electrical energy from biogas in the TRB2 region, while Table 11 summarizes total electricity consumption for its provinces. Based on this data, Table 12 shows the percentage of each province's electricity consumption that can be met by biogas-generated electricity.

Table 12. Proportion of Electricity Generated from Biogas Meeting Energy Needs in TRB2 Region Provinces

Province	Electricity consumption (MWh)	Calculated electricity production from biogas (MWh)	The ratio of biogas production to cover electricity consumption (%)
Van	1,172,866	102,819	8.7665
Muş	417,673	96,344	23.0668
Bitlis	424,772	36,209	8.5243
Hakkari	310,099	23,472	7.5692

The information presented in Table 12 highlights the percentage of electricity that can be generated from biogas in the TRB2 region to meet the electricity needs of its provinces. Muş leads the pack, supplying 23.07% of its energy consumption through biogas, followed by Van at 8.77%, Bitlis at 8.52%, and Hakkari at 7.57%. Additionally, the fermented fertilizer produced during the biogas generation process can help satisfy some of the fertilizer needs for agricultural activities, particularly in the Muş plain of the TRB2 region. This initiative will significantly enhance sustainable agricultural practices in an area predominantly inhabited by rural communities. To fully capitalize on the potential of biogas production from animal waste in this region, the public sector needs to implement necessary regulatory frameworks and infrastructure improvements. Such measures will create a favorable environment for private sector investments. A cleaner and more energy-efficient fuel can be generated by converting animal waste into biogas. At the same time, the by-product can be processed into high-quality fertilizer, thus promoting the optimal use of animal manure. Beyond these advantages, this approach can reduce environmental pollution in rural areas and improve farmers' livelihoods. In contrast, if the potential of animal manure remains underexploited, it may either be incinerated or utilized as a low-grade fertilizer, leading to a significant wastage of valuable natural resources.

Finally harnessing biogas from animal waste in the TRB2 development region could lead to numerous benefits, including increased energy independence, reduced environmental impacts, and improved agricultural sustainability. Further investment in biogas technology and education for farmers is crucial to realizing this potential.

6. Conclusion and Suggestions for Future Work

The rural population of the TRB2 Region significantly exceeds the national average in Türkiye, with a substantial portion of this demographic relying on agriculture and animal husbandry for their livelihoods. Thus, the potential implementation of village-scale or small-scale home biogas plants presents a crucial opportunity to address the daily energy needs of this economically underdeveloped

region, particularly for heating and cooking purposes. However, given the severe continental climate characteristic of the region, biogas facilities must be engineered to mitigate the adverse effects of external weather conditions. The harsh winters prevalent in the TRB2 provinces, attributable to the region's continental climate, will inevitably lead to increased heating costs due to the necessity of maintaining temperature for both the biogas reactors and the organic waste. To effectively address these challenges, biogas plants within this region must be designed to minimize additional heating expenditures. To achieve the stated objectives, it is imperative to design a village or farm-type biogas reactor that is appropriate for the region's severe continental climate conditions. This undertaking will involve the calculation of both construction and operational costs, in addition to determining the investment's payback period. Such analyses extend beyond the current scope of this article, thereby indicating the necessity for a comprehensive publication that effectively addresses these critical issues. In due course, financial support will be sought from organizations such as the TRB2 Regional Development Agency (DAKA) and the Agriculture and Rural Development Support Institution (TKDK) to facilitate the pilot implementation of this tailored biogas power plant. Ultimately, these initiatives aim to foster genuine biogas production by enabling farmers engaged in animal husbandry and agriculture to recognize and capitalize on the advantages of biogas production.

Statement of Conflict of Interest

The author or authors of the article declare that they have no personal or financial conflict of interest with any institution, organization or person.

References

[1] Wang J, Azam W. Natural resource scarcity, fossil fuel energy consumption, and total greenhouse gas emissions in top emitting countries. Geosci Front 2024;15:101757. https://doi.org/10.1016/J.GSF.2023.101757.
[2] Şenoğlu G, Erden Topal Y, Gürsoy Haksevenler BH. Yenilenebilir enerji kullanımı ve artırılmasına ilişkin politika önerileri: İstanbul örneği. İdealkent 2022;13:171–96.
[3] Bingol A, Arslan O. Effective Utilization of Solar Energy In Sustainable Agricultural Irrigation A Provincial Example from Turkiye. Therm Sci 2023;27:3373–84. https://doi.org/10.2298/TSCI2304373B.
[4] Şenyapar, H. N. D. Çetinkaya Ü, Bayındır R. Renewable energy incentives and future implications for Turkey: A comparative bibliometric analysis. Politek Derg 2024;27:329–42.
[5] Anacleto TM, Oliveira HR, Diniz VL, de Oliveira VP, Abreu F, Enrich-Prast A. Boosting manure biogas production with the application of pretreatments: A meta-analysis. J Clean Prod 2022;362:132292. https://doi.org/10.1016/j.jclepro.2022.132292.
[6] Erkmen J, Özdemir N. Organik gübre kullanımının yaygınlaştırılmasında biogaz üniteli süt ve besi üretim çiftlikleri vasıtası ile sözleşmeli çiftçilik modelinin uygulanabilirliği. Karadeniz Fen Bilim Derg 2012;2:27–38.
[7] Yaldız O. Biyogaz Teknolojisi Ders Kitabı. 1st ed. Antalya: Akdeniz Üniversitesi Yayınları; 2004.
[8] TÜİK. Hayvancılık istatistikleri. Ankara: 2024.
[9] DAKA. TRB2 Kalkınma Bölgesi kümes hayvanları sayısı. 2024.
[10] Yıkın MM. Bölgesel Kalkınma Ajansları ve Yönetişim: Yönetişim Bağlamında DAKA'nın TRB2 Bölgesi'nin Kalkınmasındaki Rolü. Ağrı İbrahim Çeçen Üniversitesi, 2019.
[11] Arslan Ö. Kentin gelişim potansiyelini ortaya çıkarma bağlamında MUŞ İLİ SWOT ANALİZİ. 1st ed. Bursa: Ekin Yayınevi; 2021.
[12] TÜİK. Adrese dayalı nüfus kayıt sistemi. Ankara: 2025.
[13] Arslan Ö. İllere özgü etkin dikey sanayi politikaları geliştirme bağlamında MUŞ SANAYİ MODELİ. 2nd ed. İstanbul: Çizgi Kitabevi; 2022.
[14] Arslan Ö. Kentin yenilenebilir enerji kaynaklarını etkin değerlendirme bağlamında MUŞ ENERJİ MODELİ. 1st ed. Bursa: Ekin Yayınevi; 2023.
[15] Aktan O, Arslan Ö. Determination of Biomass Potential of Muş Province. Bitlis Eren Üniversitesi Fen Bilim Derg 2024;13:939–49. https://doi.org/10.17798/bitlisfen.1472913.
[16] Kurnuç Seyhan A, Badem A. Erzincan İlindeki Hayvansal Atıkların Biyogaz Potansiyelinin Araştırılması. Acad Platform-Journal Eng Sci 2018;6:25–35. https://doi.org/10.21541/apjes.334256.
[17] Kurnuç Seyhan A, Badem A. Erzincan ili hayvansal atık kaynaklı biyogaz potansiyelinin değerlendirilmesine yönelik biyogaz tesisi senaryoları. Gümüşhane Üniversitesi Fen Bilim Enstitüsü Derg 2021;11:245–56. https://doi.org/10.17714/gumusfenbil.743724.

[18] Mercado JP, Ubando AT, Gonzaga JA, Naqvi SR. Life cycle assessment of a biomass based chemical looping combustion. Environ Res 2023;217:114876. https://doi.org/10.1016/j.envres.2022.114876.
[19] Dağlıoğlu ST, Taşkın R, Özteke Nİ, Kandemir Ç, Taşkın T. Reducing Strategies for Carbon Footprint of Livestock in Izmir/Turkiye. Water, Air, Soil Pollut 2024;235:243. https://doi.org/10.1007/s11270-024-07038-z.
[20] Çağlayan GH, Koçer NN. Evaluation of the Potential of Livestock Breeding in the City of Muş for the Research of Biogas Production. Muş Alparslan Univ J Sci 2014;2:215–20.
[21] Afacan H, Kasap A. Küçük ölçekli sürekli beslemeli bir biyogaz tesisinin çalışma şartlarının belirlenmesi. Tarım Makinaları Bilim Derg 2009;5:235–40.
[22] Horváth IS, Tabatabaei M, Karimi K, Kumar R. Recent updates on biogas production: A review. Biofuel Res J 2016;10:394–402.
[23] Torrijos M. State of development of biogas production in Europe. Procedia Environ Sci 2016;35:881–889. https://doi.org/10.1016/j.proenv.2016.07.103.
[24] Theuerl S, Herrmann C, Heiermann M, Grundmann P, Landwehr N, Kreidenweis U, et al. The Future Agricultural Biogas Plant in Germany: A Vision. Energies 2019;12:396–427. https://doi.org/10.3390/en12030396.
[25] Yağlı H, Koç Y. Determination of biogas production potential from animal manure: A case calculation for Adana Province. Çukurova Univ J Fac Eng Archit 2019;34:35–48.
[26] Avcioğlu AO, Türker U. Status and potential of biogas energy from animal wastes in Turkey. Renew Sustain Energy Rev 2012;16:1557–61. https://doi.org/10.1016/j.rser.2011.12.008.
[27] Özer B. Biogas energy opportunity of Ardahan city of Turkey. Energy 2017;139:1144–52.
[28] Yokuş İ. Sivas İlindeki Hayvansal Atıkların Biyogaz Potansiyeli. Ankara Üniversitesi, 2011.
[29] Ilgar R. Hayvan varlığına göre çanakkale biyogaz potansiyelinin tespitine yönelik bir çalışma. Doğu Coğrafya Derg 2016;35:89–106.
[30] Heck P. International flow management lecture notes 2010/11: Sustainable waste management. 2011.
[31] Onurbaş Avcıoğlu A, Türker U, Atasoy Z, Koçtürk D. Tarımsal Kökenli Yenilenebilir Enerjiler-Biyoyakıtlar. 1st ed. Ankara: Nobel Yayınevi; 2011.
[32] EPDK. Elektrik Piyasası 2023 Yılı Piyasa Gelişim Raporu. 2024.