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SECTORAL ANALYSIS OF KEBAN DISTRICT BIOGAS POTENTIAL AND ITS CONTRIBUTION TO DISTRICT ELECTRICITY CONSUMPTION

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ABSTRACT

As a result of the rapid increase in the world's population, non-renewable natural resources have begun to deplete and country administrations are looking for solutions to provide cheap and safe energy supply. At this point, biogas production comes to the fore as an alternative energy source. This study was carried out to determine the biogas production potential of agricultural, animal and industrial wastes in Keban district of Elazığ province and to evaluate the possible contribution of this potential to the electricity consumption of the district. The monthly biogas production capacity and the corresponding amount of electrical energy were calculated on a sectoral basis, taking into account the types and number of animals belonging to the district, agricultural production data and the amount of waste from the aquaculture processing plant. According to the results, the monthly amount of biogas that can be obtained only from these wastes in Keban district is approximately 104.559 m^3 and the corresponding electricity generation capacity is approximately 507.638 kWh. This value is considerably higher than the monthly electricity consumption of Keban Municipality, which varies periodically. Animal wastes in particular offer a stable production potential throughout the year, while agricultural and industrial wastes contribute to production with seasonal fluctuations. The study results show that biogas technology can provide significant benefits not only in terms of energy production, but also in terms of waste management, environmental sustainability and rural development. In this context, an integrated biogas plant to be established in Keban district is thought to contribute to energy independence and environmentally sensitive development by expanding the use of renewable energy at the local scale.

Keywords: Biogas, Renewable energy, Animal waste, Agricultural waste.

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1 INTRODUCTION

The rapid increase in population and the resulting increase in energy demand have brought the world face to face with problems such as climate change, global warming, decreased biodiversity, water scarcity, and the approaching depletion limit of non-renewable natural resources [1], [2]. The energy system struggles with fluctuations in energy prices, climate conditions, supply and demand characteristics and political instabilities [3]. In addition to these problems, socioeconomic progress is also based on energy flow [4]. Significant efforts are needed to increase renewable energy production in line with the Sustainable Development Goals (SDGs) of the United Nations 2030 Agenda [5]. Although the use of renewable energy sources has increased significantly in Turkey in recent years, the majority of energy is provided by traditional energy sources. According to the data of the Ministry of Energy and Natural Resources of the Republic of Turkey for the year 2024, Turkey's electricity was generated from 35.2% coal, 18.9% from natural gas, 21.5% from hydraulic energy, 10.5% from wind, 7.5% from solar, 3.2% from geothermal energy and 3.2% from other sources [6]. According to these data, it is seen that in the past years, our country's dependence on fossil fuels to meet its energy needs has decreased and the use of renewable energy sources for energy production has increased. Sevgili and Koçer [7] stated that energy consumption in the world has increased approximately 17 times in the last hundred years and as a result of this increase, biomass studies have accelerated all over the world. Biomass, a derivative of biological materials, is a renewable resource and any biological material such as forest, agricultural and livestock residues can be used as a biomass source [8], [9], [10]. Biomass energy is also carbon neutral [11]. The main biomass resources in our country are categorized in 4 groups by the Ministry of Energy and Natural Resources. 1. Plant Biomass Resources 2. Biomass Resources from Forest and Forest Products 3. Animal Biomass Resources 4. Biomass Resources from Urban and Industrial Wastes [6]. Biomass energy is produced in two ways, classical and modern. Classical biomass energy is the direct burning of wood, plant and animal residues, while modern biomass is the use of wood, agricultural residues and organic wastes with modern techniques such as fermentation, esterification, gasification and pyrolysis to obtain heat, electricity, liquid and gaseous fuel [12]. Biogas is a gas mixture formed by the digestion of organic wastes in the presence of microorganisms in an oxygen-free environment and contains 54-80% methane (CH_4), 20-46% carbon dioxide (CO_2), 2% hydrogen (H_2) and 2% hydrogen sulfide (H_2S) and the components may vary depending on the organic material used [13], [14], [15]. The biomass conversion process is shown in Figure 1.

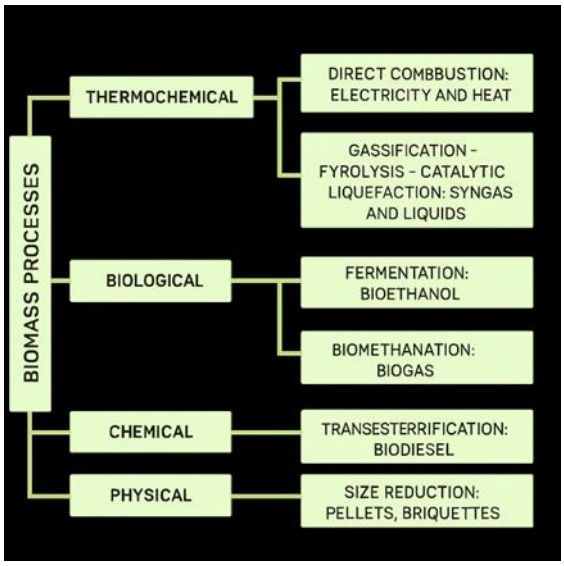


Figure 1. The biomass conversion process

When evaluated from an environmental perspective, the advantages of biogas production are as follows: minimizing disposal problems by ensuring efficient use of wastes, converting methane (CH_4) gas, which is the second most emitted gas contributing to the greenhouse effect, into efficient end products such as electricity and fuel, reducing waste disposal containing pathogens that contribute to changing biodiversity and degrading ecosystems and threatening human health [16], [17]. In addition, biogas production provides great advantages for rural areas as it is independent of geographical location and climate effects [18]. Fuel cells, generators, internal and external combustion engines are used to convert biogas into electricity [19]. Caetano et al. [16] calculated that 50 kWh of electricity would be generated daily from the waste of 26 dairy cows using a Stirling engine. Arshad et al. [4] reported that the biogas potential of 25.000 poultry facilities in Pakistan is 280 MWh/day. Şenol [20] calculated the poultry manure-based biogas potential in Turkey as 3.469 GWh equivalent for 2021 and stated that this value will increase by 72% until 2040. The biogas obtained will contribute greatly to electricity consumption in lighting, industrial, residential, agricultural irrigation and facilities. This study has determined the biogas production capacity of the Keban district and has analyzed the extent to which this energy can meet the district's electricity demand. Studies in the literature have generally focused separately on the amount of biogas that can be obtained from either agricultural or animal biomass in a given region, while industrial waste—which has become a serious issue today—has largely been overlooked. However, the failure to estimate the total amount of biogas that can be produced will not fully reflect the actual potential of the region. Furthermore, focusing solely on the quantity of biogas leads to the neglect of its potential contributions as a source of fuel or electricity to local municipalities, facilities,

industries, and even the residents of the area. In this context, the study aims to clearly reveal the biogas potential of the region by calculating the amount of biogas that can be produced sectorally based on local biomass waste. Furthermore, by determining the amount of electricity that can be generated from biogas, it will be possible to assess the extent to which this energy can contribute to meeting the electricity consumption of the district municipality. The study proposes a sustainable energy model specific to the district. It is expected that the effective use of biogas in energy production will not only promote environmental sustainability but also support rural development.

2 MATERIAL AND METHOD

2.1 Study Area

Keban district is located in the Upper Euphrates section of the Eastern Anatolia Region (38°48′N 38°45′E). It is a district of Elazığ province with a surface area of 543 km^2. Keban Dam, which produces a significant portion of the electricity needs of the Eastern Anatolia region, is located in this district. Although it is generally under the influence of continental climate, the Keban dam has made the climate more temperate. The average temperatures in the district are 17.7 ºC, 32ºC, 20 ºC and 4.7 ºC in spring, summer, autumn and winter, respectively. The average precipitation in the district is 34 mm, 4.2 mm, 23.1 mm and 1.4 mm in spring, summer, autumn and winter seasons, respectively. Although the prevailing average hourly wind direction in the Keban region varies throughout the year, the average wind speed is 10.5 kph [21]. The main source of income in the district is agriculture, animal husbandry and aquaculture. Livestock farming in Keban is primarily practiced as small ruminant husbandry, particularly sheep and goat breeding. Continental climate conditions, the abundance of pastures, and the wide grazing areas available during the summer months are the main factors supporting the development of livestock farming. According to 2024 data from the Turkish Statistical Institute (TÜİK), there are approximately 17 million cattle and 55 million small ruminants in Turkey. Elazığ province ranks among the top 10 provinces in the Eastern Anatolia Region in terms of livestock population, and the Keban district constitutes a significant portion of this potential [22]. Agricultural activities in Keban are mostly carried out in the form of dry farming. The main agricultural products grown include wheat, barley, chickpeas and lentils. In areas where irrigation is possible, vegetables and fruits are produced. In Turkey, the agricultural sector is carried out on an area of approximately 23 million hectares as of 2023, and the Eastern Anatolia Region constitutes 15% of this area [23]. In aquaculture-based production in inland waters,

Elazığ province ranks among the top three in the country, with Keban serving as the center of this success. In particular, trout farming in Keban contributes up to approximately 25% of the country's total inland aquaculture production [24]. The location of Keban district is shown in Figure 2.

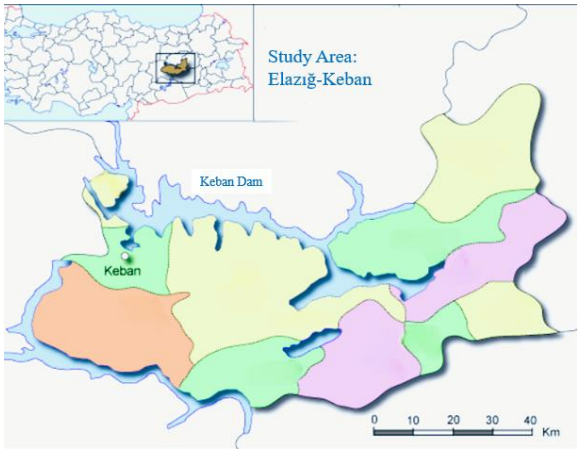


Figure 2. Location of Keban district

2.2 Method

In order to determine the contribution of Keban district to biogas energy potential, the number of animals raised in the district was obtained from Keban District Agriculture and Forestry Directorate and the animal numbers in Keban district for 2025 are given in Table 1.

Table 1. Animal numbers in Keban district in 2025

Animal species fed in the district	Number of Animals
Cattle (Bovine)	1.122
Small Ruminants (Sheep-Goat)	29.518
Poultry (Chicken)	120.000

Data on agricultural support products and their cultivation areas in Keban district were obtained from the Keban District Directorate of Agriculture and Forestry, and the agricultural support products for the year 2025 in Keban district are presented in Table 2.

Table 2. Agricultural support products for 2025 in Keban district

Agricultural Support Products	Period	Cultivated Area (da)
Barley	July	12.455
Wheat	July	3.492

The amount of waste from the Gümüşdoğa aquatic products processing and packaging facility, which plays a major role in the development of the district, was provided by the relevant company and the amount of waste from the aquatic products processing and packaging facility for the 2024-2025 production period is given in Table 3. The most efficient operating period of the facility is May, June, July and August, and these 4 months are indicated as the P1 period in Table 3. In the remaining months, the plant operates at a low production rate and these months are indicated as P2 in Table 3. Biogas from fish waste was calculated based on daily capacity and the number of days per month in P1 (May–August) and P2 (Sep–April), assuming 30 days per month.

Table 3. Amount of waste from the aquaculture processing and packaging plant

Waste Type	Period (P)	Amount (t/d)
Fish Waste P1	May Jun July August	50
Fish Waste P2	September- October- November- December- January-February -March-April	5

To estimate the potential biogas production from agricultural, animal-based, and industrial fishery waste sources, the expected amount of biogas produced per ton of waste is presented in Table 4. In the table, the amount of waste generated from each animal per year is expressed in tonnes. It was assumed that approximately 65% of manure from cattle, 13% from small ruminants, and 99% from poultry was collected, while the remaining portion was considered to be lost in pastures [25]. The mass of animal waste was calculated as the product of the per-animal annual waste (ton/head/year), the assumed source collection rate, and the number of animals. Given year-round continuity in animal-waste generation, the annual waste mass was split evenly over 12 months, and the calculated biogas was allocated equally by month. The amount of agricultural waste was calculated by multiplying the waste per decare (tons/da) by the total cultivated area (da) in Keban district. Since barley and wheat residues are limited to July, the calculated biogas was included only for July. For both crop- and animal-derived wastes, the expected biogas volume was calculated by multiplying the total waste mass (t) by the biogas yields per ton (m^3/t) reported in Table 4. The biogas to be obtained from fish waste was calculated by multiplying the monthly waste mass by the biogas yield per ton of waste.

Table 4. Feedstock Characteristics for Biogas Modeling: Collection Rates and Specific Yields

Waste Type	Annual amount of waste obtained from 1 animal (ton/year)	Usable waste amount per decare area (ton/da)	Assumed source collection rate (%)	Amounts of biogas expected to be obtained per ton of waste (m^3)	References
Barley	-	0.036	100	25	[12], [13]
Wheat	-	0.037	100	25	[12], [13]
Cattle	9.94	-	65	33	[13], [25], [26]
Small Ruminants	0.82	-	13	58	[13], [25], [26]
Poultry	0.033	-	99	78	[21],[25], [26]
Fish Waste	-	-	100	524	[27]

According to the Ministry of Energy and Natural Resources of the Republic of Turkey [6], the energy equivalent of 1 m^3 of biogas is 4.70 kWh. The following formulas were used for calculations.

Biogas amount = Waste mass (ton) x Amount of biogas obtained per ton of waste (m^3)

Energy gained = Amount of biogas (m^3) x 4.70 (kWh)

3 RESULTS AND DISCUSSION

The most important livelihoods of the people in Keban district are agriculture, animal husbandry and industrial activities based on aquaculture. The great potential of the district in terms of aquaculture is promising for biogas production. A biogas plant to be built in the district in the near future is of great importance for the sustainable disposal of waste. According to the data, if the sectoral wastes in the district are systematically collected and converted into biogas, there is an energy production potential that can more than meet the electricity needs of the municipality. The amount of biogas to be obtained from agricultural, animal and industrial wastes in Keban district and the amount of electricity obtained from biogas are given in Table 5.

Table 5. Amount of biogas and electricity to be obtained from agricultural, animal and industrial wastes in Keban district

Waste Type	Biogas quantity (m^3/month)	Electricity quantity (kWh/month)
Cattle	19.935	93.696
Small Ruminants	15.209	71.481
Poultry	25.019	117.591
Barley	5.681	26.700
Wheat	15.897	74.716
P1	26.200	123.140
P2	2.620	12.314

Animal wastes constitute the most stable and continuous component of the biogas potential in Keban district. It has been determined that 282,768 kWh of biogas equivalent electricity can be obtained monthly from animal waste. Especially the high number of poultry farming activities causes poultry farming to have a significant role in biogas production. Due to fluctuations in agricultural waste and industrial waste, animal waste provides energy supply security for biogas production in the district. In addition, the fermented fertilizer remaining after the anaerobic fermentation process of animal waste is expected to contribute to sustainability in agricultural production. Similarly, the establishment of biogas plants in intensive poultry farming areas is encouraged [4], [20]. At this point, it is necessary to enhance coordination between local authorities and farmers to ensure the regular collection and classification of animal waste.

Agricultural wastes, although not constant throughout the year, cause a significant increase in biogas production, especially during harvest periods. It has been estimated that 101,416 kWh of electricity equivalent in biogas can be generated from the residues of barley and wheat harvested in July. This creates an important opportunity for converting agricultural production waste into energy; however, it also reveals that seasonal fluctuations must be taken into account for sustainable energy supply. The stability of agricultural waste will be increased by developing waste collection and storage strategies focused on harvest periods or by applying pre-treatments such as drying and compression.

When evaluated in terms of industrial waste sources, fish waste originating from the aquaculture processing facility operating in the district has a very high biogas efficiency. Especially in the period called P1, between May and August, the production intensity increases, and during this period, 123,140 kWh of electricity can be produced per month. In the other months of the year, defined as P2, this amount is limited to 12,314 kWh. This difference shows

that seasonal production cycles should be taken into account in the utilization of industrial wastes as in agricultural wastes.

Keban Municipality's monthly electricity consumption varies according to the periods of the year. While the average consumption is 58,540 kWh/month in spring and summer due to increased irrigation activities, street lighting and water pumping operations, this value drops to 27,523 kWh/month in winter and spring. These data reveal that the total amount of electricity to be produced from the obtained biogas (approximately 507,638 kWh/month) is considerably more than the electricity needed by the municipality in both summer and winter. This situation shows that a biogas plant to be established in the district will contribute not only to the municipality but also to households, small businesses and even the regional grid. The graph showing the monthly electricity consumption of Keban Municipality against the amount of electricity to be obtained from waste is given in Figure 3. According to the Figure 3, the fact that biogas can be converted into energy in a stable manner throughout the year indicates that it represents a significant alternative in terms of energy supply security. Moreover, from an environmental perspective, the utilization of this potential will provide multifaceted benefits such as reducing greenhouse gas emissions, improving waste management, and alleviating pressure on ecosystems. As emphasized in the literature, biogas plants should be considered not only as a means of energy production, but also as a mechanism for environmental sustainability and rural development [16], [18].

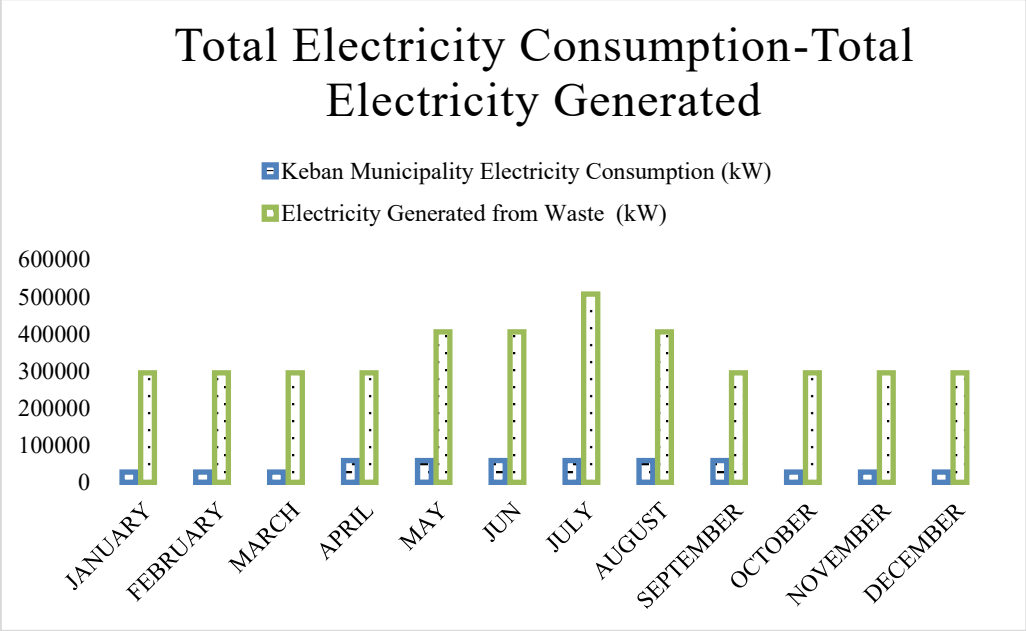


Figure 3. Monthly electricity consumption of Keban Municipality against the amount of electricity to be obtained from waste

4 CONCLUSION AND SUGGESTIONS

This study aimed to determine the biogas production potential of Keban district based on agricultural, animal and industrial waste resources and to evaluate the contribution of this potential to the electricity demand of the district. Based on the obtained data, if the existing waste in the district is efficiently utilized, the electricity generation capacity would significantly exceed the current monthly electricity consumption of Keban Municipality. This not only ensures energy supply security for the district but also offers the potential to transfer surplus energy to the regional grid. Biogas, especially obtained from animal waste, offers a significant advantage in terms of sustainable energy supply by providing stable production throughout the year. Industrial wastes originating from fish processing facilities and post-harvest agricultural wastes were evaluated as dynamic resources that increase production capacity seasonally. The findings of the study show that biogas technology can provide multidimensional benefits in rural areas, not only in energy production but also in waste management, environmental sustainability and local economic development. In this context, the establishment of an integrated biogas facility in the Keban district would contribute to energy independence while simultaneously serving to reduce environmental impacts. In future studies, monitoring the change in biogas potential over time, evaluating the impact of climatic conditions and conducting economic feasibility analyses will serve as a scientific guide in the decision-making processes of local governments and policy makers. In this regard, it is important to integrate biogas-based renewable energy investments into strategic planning at local and national scales.

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Conflict of Interest Statement

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics.

Artificial Intelligence (AI) Contribution Statement

This manuscript was entirely written, edited, analyzed, and prepared without the assistance of any artificial intelligence (AI) tools. All content, including text, data analysis, and figures, was solely generated by the authors.

Contributions of the Authors

Gönül ÖZDEMİR: Provision of data, Calculations;

Meriç YILMAZ SALMAN: Provision of data, Calculations, Theory, Original drafting, Revision and Editing.

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