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Determination of Biomass Potential of Muş Province

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Abstract

Fossil resources currently supply the majority of the world's energy needs. Even if fossil fuel sources are gradually depleted, the need for energy will continue due to population increases and the widespread use of life-improving technology. Biomass is one of these unique and sustainable energy sources. Anywhere there is life- human, animal, or plant-biomass may be a clean, readily available, and sustainable energy source. Furthermore, Türkiye, which depends on foreign energy and should reduce its carbon footprint, must benefit from this energy source to the maximum extent. Since the city of Muş has an economy based on agriculture and animal husbandry, it is a province with high biomass potential. Therefore, it was chosen as the subject of this study. Furthermore, with this study, the biomass potential of Muş province was tried to be determined for the first time in the literature. The theoretical annual amount of energy obtained from plant, animal, forest, and municipal waste in Muş province is 222,066.3 TOE. However, the economically realizable amount of the theoretical potential was calculated to be 8935.20 TOE. It has been estimated that this economical biomass energy can meet 27.15% of the city's electricity consumption. This contributes significantly to the socio-economically underdeveloped city economy and provides the utilization of waste that would harm the city's environment.

1. Introduction

Humans rely on both underground and surface energy resources to meet their energy needs. Among these sources, fossil fuels are the most widely consumed. However, due to the limited and finite nature of fossil fuel reserves and the environmental issues they cause, many countries are turning to renewable energy sources [1-2]. This shift has sparked significant interest among government officials, academic researchers, and industry experts who aim to enhance energy supply. A primary goal of renewable energy production is to reduce anthropogenic greenhouse gas emissions contributing to climate change while promoting social and economic development. It includes improving energy accessibility, enhancing energy security, and achieving better public health outcomes. Biomass, a versatile renewable energy source, plays a crucial role in reducing fossil fuel emissions, particularly in sectors where it is challenging to cut carbon emissions. Solid biomass is any plant matter that can be used directly as fuel or processed into other forms before combustion [3]. The diversity of biomass sources for energy generation such as forest management practices, cultivated biomass crops, animal waste, agricultural residues, and biomass from industrial, municipal, and agricultural solid waste highlights the potential of this resource [4].

Like many fossils fuel-poor countries, Türkiye has started to work hard to meet most of its energy needs from local biomass and other renewable energies. This trend is increasing since biomass energy can be used as thermal energy or converted into electrical energy and is environmentally friendly. About six-percent of the electrical energy produced in

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the world is produced from renewable energy sources. Biomass energy is the most widely used renewable energy type after hydroelectric and wind energy in the production of electrical energy. Especially in OECD and European countries, there has been a significant increase in the evaluation of biomass energy and other renewable energy sources due to the dramatic increase in incentives and grants to encourage using renewable energy sources [5]. In the report titled "Fuels of 2050," announced in 2011 by the European Union, detailed information about the use of different biomass fuels in sea, land, and air vehicles is given. In the Vision 2030 document, the target of a 25% increase in the use of biomass energy until 2030 is stated [6]. Biogas, which is one of the biomass types, is an alternative fuel to natural gas because it is used not only for electricity generation but also for heating purposes. Sweden plans to use biogas as an alternative to natural gas. In Sweden, the use rate of biogas as a fuel in vehicles in the country has increased in the last ten years. In addition, biogas energy has been used in trains in Sweden since 2005 [7].

Muş has been particularly preferred for biomass potential analysis in this study since it is predicted that the city's biomass potential may be attractive for investment due to the agriculture and animal husbandry-based economy of Muş province. Within the scope of this study, the biomass potential of Muş was determined by considering the amount of municipal and domestic waste as well as animal, plant, and forest wastes of Muş. Then, a comparison was made with the values in the literature. In addition, in this study, monthly electricity consumption, natural gas consumption, and petroleum products consumption in Muş province were calculated. Thus, it has been tried to determine how much biomass energy, an alternative to fossil fuels, can meet the energy consumed by the city. As a province of Türkiye, which is foreign-dependent in energy, the contribution that Muş can offer to the country by making maximum use of the biomass energy potential has been tried to be revealed. It is also hoped that this study can serve as a reference guide that can contribute to academic studies and business people who want to invest in renewable energy.

2. Material and Method

The biomass potential of a region is determined by the amount of vegetal, animal, domestic, municipal, and forestry waste belonging to that region. The biomass potential created by the vegetal entity is calculated by taking into account the waste rate of the plants and the unit calorific values of these plants. When looking at animal-derived waste, calculations are made according to the type of animal, the amount of waste it will create, and the amount of energy that can be obtained from these wastes. The amount of domestic and municipal waste is proportional to the size of the city's human population. In forestry assets, the amount of energy obtained from tree species and wastes such as bark and leaves arising from trees is calculated. In this study, the BEPA calculation system was used. Türkiye Biomass Energy Potential Atlas (BEPA) is a GIS application that can dynamically present on a map, graphically and numerically, the potential to produce how much electricity and how much biofuel from which biomass source in Türkiye and in which regions of the country these resources are concentrated. In this study, data regarding the vegetal, animal, forest, and domestic waste potential of Muş province are given in tables to help understand the subject. In addition, all formulas used in BEPA biomass energy potential calculations are given in detail, and an attempt is made to understand the method used in the calculations. In this study, calculations were taken from the BEPA system. In the BEPA system, calculations are updated according to the latest data.

3. Biomass Potential of Muş Province

Muş is a province located in the Eastern Anatolia Region. Its area is 8,196 km^2, corresponding to 1.1% of Türkiye's area. It is located between 39 29' and 38 29' north latitudes and 41 06' and 41 47' east longitudes. Its population is 411,117. It has the Muş Plain, Türkiye's third largest inland plain. It covers an area of approximately 1650 km^2, 30 kilometers wide and 80 kilometers long. Muş province borders the Ahlat and Adilcevaz districts of Bitlis and the Patnos and Tutak districts of Ağrı from the east. It borders Erzurum's Karayazı, Hınıs, Tekman, and Karaçoban districts from the north, Bingöl's Karlıova and Solhan districts, and Diyarbakır's Kulp districts from the west. It borders Batman's Sason and Bitlis' Güroymak and Mutki districts from the south. Muş province was established on the northern slope of Kurtik Mountain [8].

Muş province is an agricultural and animal husbandry city. It includes the Muş Plain, Bulanık, Liz, and Malazgirt plains within the borders of Muş province and is a city with a high animal population as it has large-scale pasture areas. Therefore, the city's agriculture and livestock potential are high. This section will discuss the city's plant, animal, forest assets, and domestic and municipal waste potential. Not all plant and animal wastes can be used to obtain biomass energy. Only a certain percentage of this waste is used.

This section will discuss the city's plant, animal, forest assets, and domestic and municipal waste potential.

3.1. Animal Biomass Potential of Muş Province

Eastern Anatolia is one of the regions with high livestock breeding potential in Türkiye, and Muş is one of the provinces with high livestock breeding potential in this region. Since the amount of animal waste increases directly proportional to the number of animals, biomass energy potential also increases. Due to the advantage of having large pasture lands in Muş province, farmers mainly engage in pasture livestock farming.

The number of sheep, goats, and cattle in Muş province is over 2 million. Data on animal numbers are shared in Table 1. Due to the large capacity of pasture lands in Muş province, sheep and goats are widely bred.

Table 1. Animal population of Muş Province between 2018-2022 [9]-[10].

Animal species	2018	2019	2020	2021	2022
Small ruminant	1,041,102	1.084.591	1,235,552	1,250,000	1.205.000
Cattle	306,542	325,067	331,881	335,798	301.000
Buffalo	7,341	7,078	7,031	7,591	-
Horse	2,629	2,619	2,430	2,171	-
Donkey	2,601	2,625	2,327	2,091	-
Mule	342	348	347	311	-
Poultry (total)	511,128	503,169	732,592	467,007	346.773
Chicken	305,462	300,908	422,591	277,047	-
Turkey	76,484	72,615	110,227	64,234	-
Duck	36,428	35,610	43,472	23,268	-
Goose	92,754	94,036	156,302	102,458	-

The animal population of Muş Province as of the end of 2022 is illustrated in Figure 1.

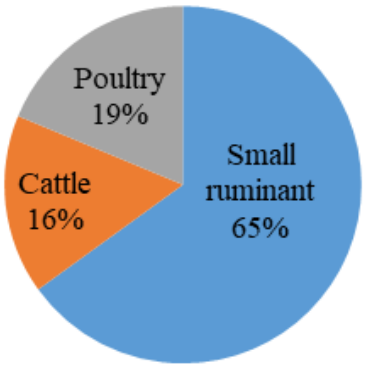

Figure 1. Animal population of Muş Province at the end of 2022 [10].

Table 2 analyzes the changes in the animal population within Muş Province from 2010 to 2023, with corresponding data illustrated in Figure 2. Figure 2 depicts variations in the animal population, demonstrating fluctuations rather than a consistent trend of either growth or decline.

Table 2. Animal population change in Muş Province between 2010-2023 [10].

Years	Cattle	Small ruminant
2010	236,330	1,004,831
2011	247,302	1,016,089
2012	276,507	1,001,228
2013	294,998	925,551
2014	285,146	1,085,197
2015	290,521	984,070
2016	302,215	1,021,142
2017	306,508	1,049,367
2018	306,542	1,041,102
2019	325,067	1,084,591
2020	331,881	1,235,552
2021	335,798	1,250,000
2022	301,000	1,205,000
2023	235,507	1,051,461

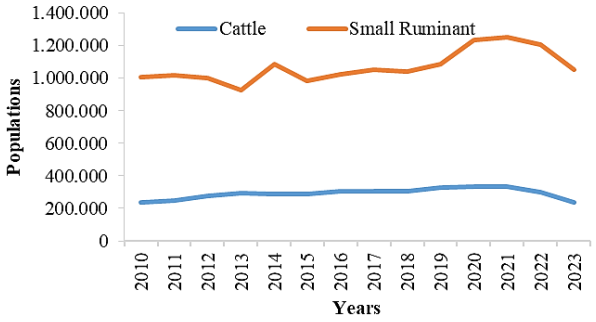

Figure 2. Changes in cattle and small ruminant populations between 2010-2023 years in Muş Province

When calculating the amount of animal waste, the waste yield for cattle is taken as 10-20 kilograms per day. However, the daily waste amount of goats and sheep is accepted as 2 kg. As can be seen in Table 3, animal biogas potential was calculated by taking into account animal species, waste collection rate, and biogas yield [8].

Table 3. Animal species and biomass (biogas) energy yield [11].

Animal species	Live weight (kg)	Amount of fresh waste		TS(%)	VS(%)	Availability duration of stay in the stable (%)	Biogas yield (L/kg.UK)
		Percentage of weight (%)	Manure (kg/day)				
Cattle	135-800	5-6	10-20	5-25	75-85	65 (milk), 25(meat)	200-350
Small ruminants	30-75	4-5	2	30	20	13	100-310
Chicken(egg) Chicken(meat)	1.5-2.0	3-4	0.08-1.00	10-35 50-90	70-75 60-80	99	310-620 550-650

Formulas (1) and (2) below were used to calculate animal waste.

$$\sum AM_{yıllık} = AMx\ HS \quad (1)$$

$$\sum Q_{top.yanma} = \sum AM_{yıllık}\ x\ Hu \quad (2)$$

Here;

$Q_{top.yanma}$ = Energy obtained from total combustion

$AM_{yıllık}$ = Annual waste amount

HS = Number of Animals

Hu = Lower calorific value of animal waste

3.2. Crop Production Potential of Muş Province

As seen in Table 4, Muş province has a land area of 866,833 hectares. The proportion of agricultural lands among these lands is 357,342 ha. 278,500 ha of agricultural land is suitable for the use of agricultural machinery. The non-arable area of Muş province is 21,331 ha [9].

Table 4. Land types and ratios in Muş Province [12].

Land type	Area (ha)	Percentage in land (%)
Farmland	357,342	41.2
Meadow	56,985	6.6
Pasture	351,176	40.5
Forest	79,999	9.2
Unsuitable for agriculture	21,331	2.5
Total	866,833	100

As seen in Table 5, grain and plant products rank first in the use of agricultural lands in Muş province, with an area of 2,095,225 decares. Fruit beverages, spices, and vegetable plants follow these. The table shows that there is not ornamental plant cultivation in Muş province. Additionally, the land left fallow is 281,530 decares

Table 5. Usage status of agricultural lands in Muş Province [13]

Agricultural areas (decare)	
Fruits, beverage and spice plants	13,415
Fallow	281,530
Vegetables	41,088
Ornamental plants	0
Cereals and other plant products	2,095,225

Table 6 shows the crop production data of Muş province, covering the years 2020-2022. Wheat is the most significant grain production in Muş. The wheat production area corresponds to 1,115,402 decares. Then, alfalfa, barley, sugar beet, sainfoin, vetch, silage corn, safflower seeds, chickpeas, dry beans, oil sunflower seeds, tobacco, and potatoes are produced, respectively. Besides grains and other plant products, mostly vegetables are produced in Muş. We can list these vegetables, from highest production to lowest, as watermelon, table tomato, melon, cucumber, white cabbage, green beans, bell pepper,

green pepper, tomato paste, onion, eggplant, onion, and zucchini. When the fruits, beverages, and spice plants produced in Muş province are examined, table grapes take the first place with an area of 3,848 decares. These are followed by walnuts, apples, pears, and cherries [11].

Table 6. Crop production amounts in Muş Province [14].

	2020		2021		2022	
Products	**Cultivation area(ha)**	**Production (ton)**	**Cultivation area(ha)**	**Production (ton)**	**Cultivation area(ha)**	**Production (ton)**
Clover	49,427	1,234,224	49,599	1,077,623	46,590	965,447
Sugar beet	6,603	372,670	5,581	277,558	7,313	406,612
Wheat (other)	111,540	222,970	124,254	199,798	125,000	431,061
Sainfoin-(green herb)	5,438	106,200	82,964	82,964	3,695	49,695
Corn-slage	2,315	114,190	2,008	96,994	2,299	125,685
Vetch (green grass)	3,578	60,634	3,452	50,107	2,877	36,467
Barley	24,710	56,107	26,923	33,069	34,897	97,706
Sunflower(oil)	777	1,712	2,936	4,085	3,517	7,934
Haricot bean	1,236	2,087	1,521	2,575	1,995	3,812
Chickpeas	1,797	2,633	1,736	1,361	14	1,742
Potatoes	129	3,904	145	4,087	33	967
Red lentil	7	10	7	6	76	114
Corn-grain	54	308	145	961	162	1,942
Onion	61	513	64	996	23	582

The biomass energy potential obtained from agricultural wastes was calculated using the formula (3). Thus, the total biomass potential that can be obtained from the plant products of Muş province has been revealed.

$$\sum Q_{top.yanma} = \sum AM_{yıllık}\ x\ Hu\ x\ AK\ x\ KO. \quad (3)$$

Here;

$Q_{top.yanma}$ = Energy obtained from total combustion

$AM_{yıllık}$ = Annual waste amount

AK = Literature waste coefficient

KO = Availability rate

Hu = Lower calorific values of agricultural wastes

While calculating the biomass potential from plant products, the usability and unit heat values of the products shown in Table 7 were considered.

Table 7. Unit calorific values of some plant products [11]

Products	Wastes	Utilization (%)	Unit calorific value (MJ/kg)
Wheat	Straw	15	17.9
Barley	Straw	15	17.5
Rye	Straw	15	17.5
Oat	Straw	15	17.4
Corn	Stalk	60	18.5
	Somek	60	18.4
Rice	Straw	60	16.7
	Shell	80	12.98
Tabacco	Stalk	60	16.1
Cotton	Stalk	60	18.2
	Crispy waste	80	15.65
Sunflower	Straw	60	14.2
Peanut	Straw	80	20.74
	Shell	80	20.74
Soya	Straw	60	19.4

3.3. Municipal Waste Biomass Potential of Muş Province

Waste such as leaves from parks and gardens, grass, sewage waste, waste from municipalities, garbage from houses, urban waste, and waste from industrial facilities are evaluated within this scope. While conducting biomass potential analysis, domestic and municipal wastes were included.

The biomass potential of municipal waste was calculated using the formula (4).

$$\sum Q_{top.yanma} = \sum AM_{yıllık}\ x\ H_u\ x\ AO. \quad (4)$$

Here;

$Q_{top.yanma}$ = Energy obtained from total combustion

$AM_{yıllık}$ = Annual waste amount

AO = Proportion of organic waste in municipal waste

H_u = Lower calorific value of municipal wastes

3.4. Waste Biomass Potential of Muş Province

Due to the continental climate structure of the city, biomass potential based on forest products is low. There is a total of 78,426 ha of forest area within the borders of Muş, including 48,775 ha of degraded forest area and 29,651 ha of normal forest area. Fuelwood generated from production activities in the forests in these limited areas can be evaluated as forest waste, such as abandoned roots, thin branches, trees disintegrated during transportation, and dried cones and leaves [15].

The biomass energy potential obtained from forest waste can be calculated using the formula (5).

$$\sum Q_{top.yanma} = AM_{yıllık}\ \text{x}\ H_u\ x\ AO \quad (5)$$

Here;

$Q_{top.yanma}$ = Energy obtained from total combustion

$AM_{yıllık}$ = Annual waste amount

AO = Proportion of forest organic waste

H_u = Lower calorific value of forest wastes

4. Theoretical Biomass Energy Potential of Muş Province

In order to calculate the realistic amount of biomass energy in plant production, it is necessary to collect the waste left over as a result of plant production. Because when full access to the waste generated in plant production is not provided, less biomass energy can be obtained compared to plant production.

As seen in Table 8, the theoretical biomass energy potential of Muş province was 222,067.3 TOE/year. Of this biomass energy potential, 189,412 TOE/year consists of plant wastes 23,125.9 TOE/year animal wastes, 9,175 TOE/year municipal wastes, and 354.4 TOE/year forest product wastes. In addition, Figure 3 graphically shows the proportional comparison of the theoretical biomass energy potential that can be produced from different waste sources in the city. The economically applicable energy potential of this total is calculated as 8,935.20 TEP per year (Table 9) and Figure 4 shows the economically feasible biomass potential from waste at district scale (TOE/year).

Table 8. Theoretical biomass energy potential to be obtained from waste in Muş Province [16].

Vegetable waste (TOE/year)	Animal waste (TOE/year)	Municipal waste (TOE/year)	Forest waste (TOE/year)	Total (TOE/year)
189,412	23,125.90	9,175	354.40	222,067.30

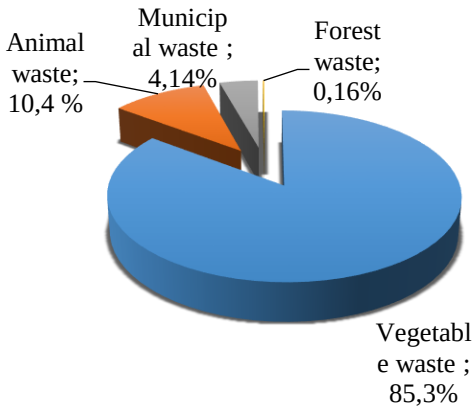

Figure 3. Proportional comparison of theoretical biomass energy potential that can be produced from different waste sources in Muş Province.

Table 9. Economically feasible biogas potential that can be produced from waste at the district scale in Muş Province [16].

Province/District	Type	Animal population (quantity) Amount of crop production (Ton)	Amount of waste (Ton)	Economic energy equivalent (TOE/Year)
Central District	Cattle	65,508	461,803.5	888.2
	Small ruminant	481,750	486,212.9	88.4
	Poultry	156,063	8,604	522.8
	Vegetable waste	1,064,876	140,182	758.1
	Forest waste	291.67		59.07
	Municipal waste	25,412		163.9
Bulanık	Cattle	104,298	684,234	1,235.6
	Small ruminant	143,186	148,284.2	27.5
	Poultry	95,748	4,649.4	282.5
	Vegetable waste	335,225	108,918.3	775.6
	Forest waste	291.67		59.07
	Municipal waste	10,583		68.3
Hasköy	Cattle	24,245	169,703.1	324.7
	Small ruminant	42,420	41,077.1	7.2
	Poultry	37.80	1,969.9	119.7
	Vegetable waste	147,814	4,787.2	2.7
	Forest waste	291.67		59.07
	Municipal waste	3,383.4		78.2
Korkut	Cattle	25,164	172,226.8	324.6
	Small ruminant	109,174	109,621.2	19.9
	Poultry	10,195	489.1	29.7
	Vegetable waste	257,114	30,179.6	20.3
	Forest waste	291.67		59.07
	Municipal waste	3,392.4		78.4
Malazgirt	Cattle	65,230	465,905.8	900.2
	Small ruminant	41,394	43,224.7	8
	Poultry	114,958	5,555.8	337.6
	Vegetable waste	393,973.63	114,088.1	571.9
	Forest wste	291.67		59.07
	Municipal waste	6,743.8		155.8
Varto	Cattle	27,369	179,551.6	324.6
	Small ruminant	223,178	234,462.9	43.9
	Poultry	76,184	4,369.7	265.6
	Vegetable waste	193,334	9,992	62.3
	Forest waste	291.67		59.07
	Municipal waste	4,095.6	461,803.5	94.6
Total				8,935.2

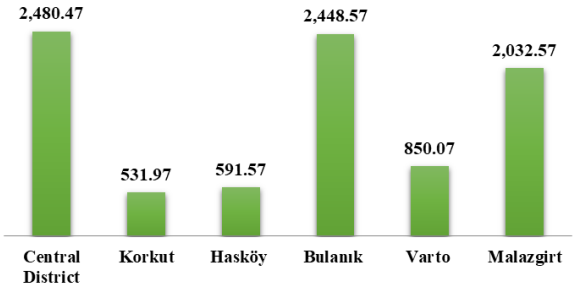

Figure 4. The economically feasible biomass potential from waste at district scale (TOE/year).

4.1 Comparison of the Biomass Potential of the Provinces in the TRB2 Region (Van, Mus, Bitlis, Hakkari)

This section analyzes the economically viable biomass potential derived from waste in the TRB2 region. Among the provinces in the TRB2 region, Muş has the highest biomass production potential, with an economically viable capacity of 8,935.2 tons of oil equivalent (TOE) annually, as illustrated in Table 10 and Figure 5. Following Muş, the provinces of Van, Bitlis, and Hakkari rank sequentially in terms of their respective biomass potentials.

Table 10. The Economically feasible biomass potential from waste in the TRB2 Region [16].

Potential of Van (TOE/year)	Potential of Muş (TOE/year)	Potential of Bitlis (TOE/year)	Potential of Hakkari (TOE/year)
6735.40	8935.20	4512.90	1744.30

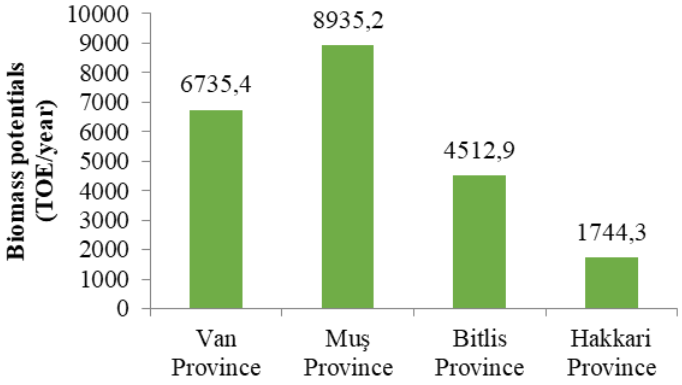

Figure 5. Comparison of the economically feasible biomass potentials (TOE/year) of provinces within the TRB2 Region

5. Energy Consumption Data for Muş Province

As seen in Table 11, the total electrical energy consumption in Muş province in 2022 was 381,772 MWh [17].

Table 11. Distribution of electricity consumption by area in Muş Province [17].

Province	Lighting (MWh)	Public and commercial services and others (MWh)	Residential (MWh)	Industrial (MWh)	Agricultural activities (MWh)	Total (MWh)
Muş	29,841	121,624	161,038	66,086	3,182	381,772

Table 12 shows the natural gas consumption of Muş province. The city's total natural gas consumption in 2022 was 183,672 million sm^3 [18].

Table 12. Natural gas Consumption of Muş Province [18].

Pipe gas	LNG	CNG	Other products	Total
182,433	0,933	0,305	0	183,672

As seen in Table 13, the consumption of petroleum products in Muş province was 56,246.072 tons [19].

Table 13. Petroleum products consumption of Muş Province [19].

Petrol (Ton)	Diesel (Ton)	Fuel oil (Ton)	Aviation fuels (Ton)	Other products (Ton)	Total (Ton)
3,727	48,024	177.94	4,317.146	0	56,246.086

Muş province energy production and consumption data are expressed in different units according to the usage area and sector. Expressing these data in the same unit will provide a clearer understanding of energy consumption and production potential. The unit commonly used for these different energy units is the tonne equivalent unit of oil. According to the definition of the International Energy Agency/Organization for Economic Co-operation and Development (IEA/OECD), it is the amount of energy produced by burning one ton of crude oil. The equivalent of one ton of oil in standard units is 10 Gcal, or 41.868 GJ, or 11.625 MWh. Since crude oil has different origins, different amounts of heat are obtained when burned. Conversion coefficients to TOE, depending on the calorific values of all energy resources in Türkiye, were determined by the regulation on Increasing Efficiency in the Use of Energy Resources and Energy dated October 25, 2008. The approximate equivalent of 1 TOE in other types of energy is given below [20].

1 TOE corresponds approximately to the following values in practice.

- 11600 kWh electrical energy
- 1200 m3 natural gas
- 3 tons of lignite
- 1 ton of fuel oil
- 1.6 tons of hard coal

Energy consumption data for Muş province is converted into tons of oil equivalent (TOE), as shown in Table 14. According to Table 14, 381,772 MWh of electrical energy was consumed annually in Muş province, which corresponds to 32,911.38 TOE. As for natural gas, 183,672 million sm3 was consumed annually, which corresponds to 153,060.00 TOE. Petroleum products were consumed annually at 56,246,090 tons, which corresponds to 56,246,090 TOE. The total energy consumed in the city is 242,217.47 TOE.

Table 14. Annual energy consumption in Muş Province by energy types.

Energy type	Amount/Unit	TOE equivalent
Petroleum	54,246.090/Ton	56,246.090
Natural gas	183,672/ million sm^3	153,060.00
Electricity	381,772 MWh	32,911.38
Total		242,217.47

The energy consumption data of Muş province, given in the table above, is also shown graphically in Figure 6.

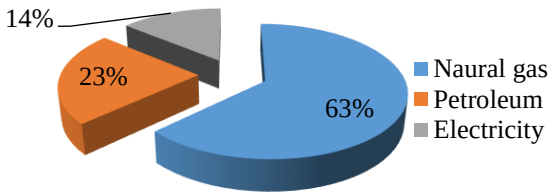

Figure 6. Energy consumption rates in Muş Province by energy types.

The theoretical annual amount of energy obtained from plant, animal, forest, and municipal waste in Muş province is 222,066.3 TOE. The economically feasible amount of this potential is 8935.20 TOE.

6. Conclusion and Evaluation

Since Türkiye is a developing country with a rapidly increasing population, energy demand also increases in parallel with this increase. On the other hand, since it is a country dependent on foreign energy, the burden of energy costs increases on the budget. Therefore, the country needs to make maximum efforts to utilize local energy resources. In addition, the fact that these local energy sources are renewable will greatly contribute to the country's fulfillment of its carbon emission obligations and prevent energy-related environmental pollution on-site. Biomass energy sources, which have a significant potential among renewable energy sources, are increasingly used worldwide and in our country. With this thesis study, the biomass energy potential of Muş province was tried to be revealed.

Muş has the potential for animal, vegetable, forest, and municipal waste that can be used as biomass energy. The city of Muş has a significant population in cattle and sheep farming. While Muş ranks 15th in Türkiye regarding cattle population, it ranks 12th in the country regarding sheep farming [8]. It also promises great potential in terms of agricultural production. Muş Plain, the third largest interior plain of Türkiye, Bulanık, Liz, and Malazgirt plains confirm the existence of this potential. With the implementation of the Alparslan II irrigation project shortly, it will be possible to utilize this potential on a larger scale.

This study calculated the theoretical annual amount of energy obtained from plant, animal, forest, and municipal waste in Muş as 222,066.3 TOE. However, the economically feasible amount was determined as 8,935.20 TOE. The ratios of this economic energy potential to meet the energy consumption of different sectors of the city are shown in Figure 7. As can be seen in Figure 7, it meets

27.15% of the electrical energy needs of Muş province, 5.84% of its natural gas needs, and 15.89% of petroleum fuel products. It covers 3.69% of the city's total energy consumption.

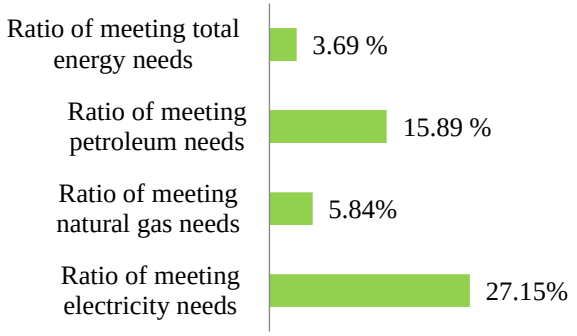

Figure 7. The capacity of Muş's biomass potential to meet the city's energy consumption

There are currently no biogas, bioethanol, or biodiesel facilities in Muş province. Considering the production possibilities and climatic conditions of Muş province, constructing biomass facilities with low investment costs and high efficiency and whose installation is publicly supported will accelerate the establishment of these facilities in the city. By increasing the number of these facilities, a certain amount of Muş's energy needs will be met from local renewable energy sources. Utilizing the biomass potential of Muş province will contribute significantly to both the economic development of the city and the supply of energy needs without harming the environment. Therefore, it is thought that intense efforts are needed to inform and encourage potential entrepreneurs about incentives and grant support for biomass energies. It is hoped that this study will help support this effort.

7. Suggestions for Future Work

The production of biogas from organic waste has the potential to significantly benefit the economy of the rural area of Muş while addressing environmental issues related to waste. However, despite this potential, no biomass facility has been established in Muş province due to a lack of interest and support from the public and relevant stakeholders. With the support of the TRB2 region development agency (Eastern Anatolia Development Agency, DAKA) and the Agricultural and Rural Development Support Institution (TKDK), conducting research, feasibility studies, and pilot projects on a local scale can help increase interest among farmers and the energy sector in this initiative.

Muş province has considerable potential for utilizing animal waste. Currently, animal dung is often burned as a low-calorie fuel or left to decompose in open areas for use as a low-nutrient fertilizer. However, converting animal manure into biogas can produce fuel with significantly higher energy content, along with high-nutrient biofertilizer as a valuable byproduct. This approach not only adds more value but also addresses environmental issues associated with outdoor manure storage. To maximize this potential, it is essential to raise awareness among farmers about the benefits of biogas and to secure support and incentives from relevant authorities. Establishing pilot biogas facilities in select villages or towns, funded by rural development grants, could serve as an exemplary initiative. Such pilot programs could also encourage broader adoption of biogas facilities across the TRB2 region.

Finally, local manufacturing of the equipment and units used in biogas facilities can significantly reduce installation costs. This would promote the widespread use of these facilities and ensure their economic feasibility, thereby boosting confidence in the potential for biogas production in Muş.

Contributions of the authors

Ö. Arslan: Methodology, Formal analysis, visualization, data curation, writing & editing and resources. O. Aktan: Investigation and resources.

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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 complies with research and publication ethics.

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