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Biomass for efficiency and sustainability energy utilization in Turkey

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Abstract
Turkey's renewable sources are the second largest source for energy production after coal. Energy supply and use is a national priority and a major focus of national, state, and local policy makers across the country. The impacts of climate change and the need to increase energy efficiency, reduce reliance on foreign oil, and address related international security threats are some of the issues driving the need for a new national energy policy and practice. Biomass energy, harvested from the nation's lands and forests, has the potential to provide an important source of renewable, sustainable energy for the country. The yearly amount of usable biomass potential of Turkey is between 15-18 Mtoe. Since biomass energy will be used more and more in the future, its current potential, usage, and assessment in Turkey is the focus of the present study.

Keywords: Climate change; energy issues; biomass; renewable energy; sustainability

1. Introduction

Biomass combustion is carbon neutral compared with fossil fuel combustion because the biomass combustion is simply releasing the CO2 that was sequestered by growing the biomass in the beginning is certainly true [1-3]. It may be argued that such thinking completely ignores the fact that fossil fuel combustion is also CO2 neutral for exactly the same reason; however, it should be noted that the obvious difference lies in the elapsed time between the sequestration from the atmosphere and the return of the CO2 to the atmosphere [4-6]. Also, biomass is the term used for all organic material originating from plants, trees and crops and is essentially the collection and storage of the sun's energy through photosynthesis [7-10]. Biomass can be either obtained directly from plants or indirectly from industrial, domestic, agricultural and animal wastes [11-13]. The examples of biomass energy sources include wood and wood wastes, agricultural crops and their waste byproducts, municipal solid waste, animal wastes, waste from food processing, and aquatic plants, algae, energy crops such as trees and sugarcane that can be grown specifically for conversion to energy [14-23]. Bioenergy is the conversion of biomass into useful forms of energy such as heat, electricity and liquid fuels [1-4]. Figure 1 shows the bioenergy conversion possibilities [5]. Bioenergy, the energy from biomass, has been used for thousands of years, ever since people started burning wood to cook food or to keep warm [5]. Biomass is used to meet a variety of energy needs, including generating electricity, heating homes, fueling vehicles and providing process heat for industrial facilities [6]. Today, worldwide, biomass is in the fourth place as an energy source and provides about 10% of the world's energy needs as given in Table 1[2]; it also accounts for about 37% of the primary energy consumption in developing countries and it often makes up more than 90% of the total rural energy supplies in those countries. The average majority of biomass energy is produced from wood and wood wastes (64%), followed by municipal solid waste (24%), agricultural waste (5%) and landfill gases (5%) [2, 4, 7].

2. Biomass energy for efficiency, scale and sustainability

Energy supply and use is a national priority and a major focus of national, state, and local policy makers across the country [8]. The impacts of climate change and the need to increase energy efficiency, reduce reliance on foreign oil, and address related international security threats are some of the

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issues driving the need for a new national energy policy and practice. Biomass energy, harvested from the nation's lands and forests, has the potential to provide an important source of renewable, sustainable energy for Turkey [5, 7, 8].

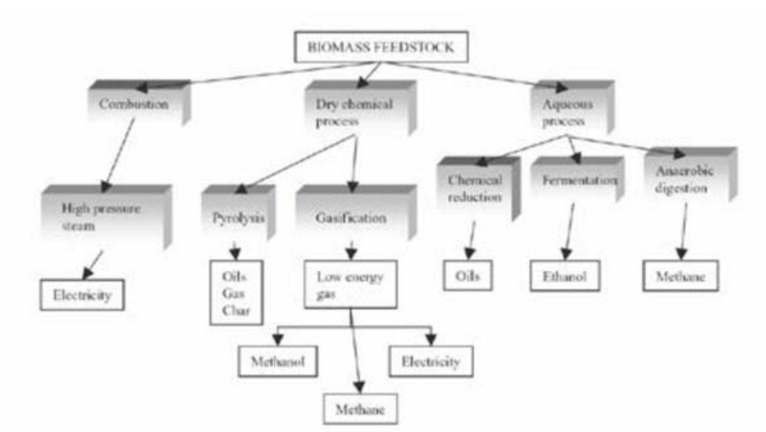

Figure 1. Bioenergy conversion possibilities [4].

To develop this important energy sector successfully, however, public policy can play a critical role in addressing issues of scale, efficiency, biomass supply, environmental impacts, local economics, harvesting capability, and investment and financing. Using biomass for energy in ways that sustain the health of the nation's lands and forests and creates robust and resilient energy economies depends on several critical factors [1, 3, 6]:

2.1. Efficiency

Used for heat or combined heat and power (CHP), biomass energy is approximately 75-80% efficient, while generation of electricity is only 20-25% efficient, and conversion to liquid fuels for transportation applications are even less efficient overall [1]. This is true regardless of the type of fuel used but is a critically important factor when considering the sustainability of using biomass for fuel [3]. Nevertheless, to date, national renewable energy policies have ignored thermal energy and focused on directing biomass energy into electric generation and transportation fuels, a direction that has the potential to overtax the energy potential of our country's wood resource, while diminishing its potential benefit, and raising issues of sustainable supply [6].

2.2. Scale

Biomass is a diffuse resource, growing over dispersed areas [1]. Use in large central facilities requires consolidation and transportation of fuel over greater distances that can reduce the overall efficiency of the resource [3]. The most energy efficient use for biomass in general is thermal energy at the community scale, where local wood resources are produced and used to provide local energy, fueling the local economy, and at heat-led CHP operations of a scale that can be accommodated by the resource [6]. Directing biomass into appropriately scaled applications such as heat (or CHP) for schools, hospitals, office buildings, college campuses, and district heating systems is essential for creating a wood-energy economy that is flexible and resilient over time. Biomass also has the potential for high efficiency use at industrial applications that are large heat and electricity users. Producing biomass through an array of appropriately scaled and local chip and pellet plants is also a critical component of a wood-energy supply chain and a dynamic and resilient local wood-energy economy [6].

2.3. Sustainability

Sustainability of the biomass resource depends on wood and agricultural supplies on a macro level as well as harvesting methods and infrastructure. It is also must be advanced in the context of air quality and climate change objectives [1, 3, 6, 9, 13]:

- Wood Supply: Sustainable development of the country's biomass resource for energy depends on understanding the capacity of our forests and agricultural lands to supply biomass while preventing over-harvesting and associated ecological and economic consequences [1]. It is essential to provide an accurate and ongoing assessment of the amount of low-quality woody biomass available from forests for energy on a sustainable basis that supports long-term forest health, soil productivity, water quality, wildlife habitat, and biodiversity [6].
- Sustainable Harvesting: In many instances, previously developed best management

practices did not anticipate the increased removal of biomass associated with the expanded biomass energy industry and offer mixed guidance on the amount of removal that is consistent with long- term forest health and productivity. A review and update of harvesting standards is important to ensure sufficient post-harvest retention of fine and course crop and woody debris, standing and down dead wood for wildlife, biodiversity, and site productivity. In addition to harvesting standards, biomass fuel procurement guidelines for public and private facilities are important to ensure a sustainable supply chain [6].

- Harvesting Infrastructure and Capacity: While there are concerns about the ecological sustainability of biomass harvesting, there are also concerns about the sustainability of the harvesting infrastructure and workforce that will be needed to reliably supply wood fuels to markets. Strong, reliable, and local markets for low-grade wood such as wood fuel are essential to help keep a reliable supply chain intact [6].
- Emissions: Energy derived from biomass energy must minimize emissions and meet or surpass stringent public health and air-quality standards. Biomass energy projects should implement efficient combustion technologies and best management practices for emission control technologies, fuel quality, and operating conditions [1].
- Climate Change: Use of biomass for energy-efficient and appropriately scaled applications has tremendous potential to displace fossil fuels and, over the long term, lower atmospheric CO2 emissions. Biomass energy used in this manner is a “low-carbon fuel,” and, integrated with the sustainable fuel supply, has the potential to be a net carbon sequestering option, even when considering the fossil fuels used in production and transportation of wood fuel and agricultural production. The degree to which biomass energy systems can reduce carbon emissions compared to fossil fuels is directly related to establishment and management of harvesting regimes, forest types, fuel transport, and efficiency. National carbon sequestration and reduction policies such as carbon cap and trade regulations and voluntary carbon standards will also have an impact on forest management and agricultural decisions regarding carbon storage, forest adaptation, production of biomass for energy, and harvesting of traditional wood products. Policies must be put in place to optimize carbon storage, adaptation potential, biomass used for energy, and the harvest of traditional products.

3. Global biomass potential and resources

The world’s energy demand in 2012 amounted to about 13,361 Million tons of oil equivalent (Mtoe) and was made up of about 82% fossil fuels (oil, gas and coal), about 9% biomass, about 6% nuclear and about 2.4 and 0.6% hydropower and other energy respectively as shown in Table 1 [2]. The annual global primary production of biomass is equivalent to the 108 000 Mtoe of solar energy captured each year. About 6% of this energy, or 6 681 Mtoe, would have covered almost 50% of the world’s total primary energy demand in 2012, as shown in Table 1. These 5 400 Mtoe are in line with other estimates based on models which assume an annual sustainable bioenergy market of 6480 [1]. On the other hand, the future potential for energy from biomass depends to a great extent on land availability. Currently, the amount of land devoted to growing biofuels is only 0.025 billion hectares or 0.19% of the world’s total land area of 13.2 billion hectares and 0.5-1.7% of global agricultural land [2, 3, 6, 13]. There are many scenarios that predict a future potential in biomass. There are also many studies performed during the past decades which attempt to estimate the future demand and supply of bioenergy. For a detailed analysis and comparison of studies on global biomass production potentials are given in the literature [1-3]. However, published estimates of the total global bioenergy production potential in 2050 ranged from 792 to 27240 Mtoe annually, from which 100 to 8592 Mtoe annually came from woody biomass. Energy crops from surplus agricultural land have the largest potential contribution of 100-23712 Mtoe [10]. This large range of estimates was the result of: differences in the type of biomass included; differences in the theoretical, technical, economic, or ecologic limitations related to the supply of woody biomass for energy use; differences in data on key parameters, such as the consumption of wood fuel, the annual growth of forests, and the efficiency of conversion; differences in scope whereby most of the existing bioenergy potential assessments focused on either the demand [11] or the supply of bioenergy and consequently ignored demand-supply interactions [10, 13, 14]. Most of the studies they reviewed ignored existing studies on the demand and supply of wood, despite the extensive literature and data on the subject. Overall, differences between the various scenarios are due to large differences in demand and energy mix, as a result of variations in population dynamics, and economic and technological development [3, 6, 10].

Table 1. Global hydropower market in 2014

Region	Cumulated Installed Capacity (GW)	Installed Capacity (GW)	Estimated Electricity Generation (TWh/yr)
North America	173.4	0.9	708.2
South America	147.9	1.4	675.8
Europe	186.0	1.0	576.8
Asia	509.6	35.5	1694.1
Oceania	13.4	0.0	37.4
Africa	28.0	0.2	122.5
World Total	1059	39.0	3815

4. Current status of biomass energy in Turkey

4.1. Current energy production and consumption

The Turkish economy has been growing very fast during the last two decades [24]. Despite limitations in domestic resource availabilities, primary energy demand in Turkey is growing very rapidly, parallel with the industrialization efforts. The annual rate of increase is around 6–8% [24]. On the other hand, Turkey's domestic fossil energy sources especially oil and gas are very limited [25]. Therefore Turkey is heavily dependent on imported energy resources that place a big burden on the economy [26, 27]. Air pollution is also becoming a great environmental concern in the country. In this regard, renewable energy resources appear to be one of the most efficient and effective solutions for clean and sustainable energy development in Turkey. Turkey's renewable sources are the second largest source for energy production after coal [24, 30].

Turkish coal and lignite are largely inappropriate for the purposes of sustainable development as their usage is cost-ineffective and responsible for air pollution in urban centers during the 1970s and 1980s [28]. This is because Turkish lignite has low calorific value and high sulfur, dust and ash content whereas Turkish hard coal is low grade [29]. Also, Turkey has huge reserves of renewable energy sources. Turkey's renewable energy sources are abundant and extensive. Renewable energy production makes up approximately 14.4% of the total primary energy supply (TPES) [30].

In 2013, primary energy production and consumption has reached 31.94 and 120.29 million tons oil equivalents (Mtoe) respectively as shown in Table 2 [24]. The most significant developments in production are observed in hydropower, geothermal, solar energy and coal production [30]. Turkey's use of hydropower, geothermal and solar thermal energy has increased since 1990. However, the total share of renewable energy sources in TPES has declined, owing to the declining use of non-commercial biomass and the growing role of natural gas in the system [24]. Turkey has recently announced that it will reopen its nuclear program in order to respond to the growing electricity demand while avoiding increasing dependence on energy imports [24-30].

The TPES in Turkey grew by 3.2% per year between 1990 and 2013. Hard coal and lignite is the dominant fuel, accounting for 27.1% of TPES in 2013. Oil (34.8%) and gas (27.2%) also contributed significantly [24]. Renewable energy, mostly biomass, waste and hydropower, accounted for 10.9%. Hydropower represented 3.8% of TPES in 2013. Biomass, primarily fuel wood consumed by households, represented almost 5.9% [24]. The economic downturn in Turkey in 2008–2013 caused TPES to decline by 5.0%. But energy demand is expected to increase according to Turkish government sources [27]. On the other hand, gas accounted for 46.4% of total electricity generation in 2013, coal 26.58% and oil at about 5%. Hydropower is the main indigenous source for electricity production. Hydropower declined significantly relative to 2000 due to lower electricity demand and to take-or-pay contracts in the natural gas market [29].

Table 2. Total final energy production and consumption in Turkey (Mtoe)

	Production		Consumption	
Energy sources	2008	2013	2008	2013
Coal and lignite	16.41	14.96	29.18	30.87
Oil	2.69	2.49	31.78	33.90
Natural gas	0.93	0.44	33.81	37.63
Biomass and wastes	4.81	4.38	4.81	4.38
Hydropower	2.86	5.11	2.86	5.11
Geothermal	0.80	2.64	0.80	2.64
Solar and wind	0.44	1.45	0.44	1.45
Total	29.24	31.94	106.34	120.29

Mtoe: Million tons of oil equivalent

4.2. Biomass energy potential and utilization

Biomass energy is the term used for all organic material originating from plants, trees and crops and is essentially the collection and storage of the sun's energy through photosynthesis. Biomass energy is the conversion of biomass into useful forms of energy such as heat, electricity and liquid fuels. Biomass for bioenergy comes either directly from the land, as dedicated energy crops, or from residues generated in the processing of crops for food or other products such as pulp and paper from the wood industry [1, 4]. Another important contribution is from consumer residue streams such as construction and demolition wood, pallets used in transportation, and the clean fraction of municipal solid waste [9].

Direct burning in Turkey for many years has used fuelwood, animal wastes, agricultural crop residues, and logging wastes [25, 26]. These sources are often called non-commercial energy sources, but in Turkey, fuelwood is a tradable community since it is the primary fuel in rural and urban poor districts. Fuelwood is the fourth largest source of energy in Turkey. Wood is the major source of energy in rural Turkey (Figure 2 and 3). An average consumer in a year burns 0.80 m3 fuelwood. The total forests potential of Turkey is around 930 million m3 with an annual growth of about 26 million m3 [27].

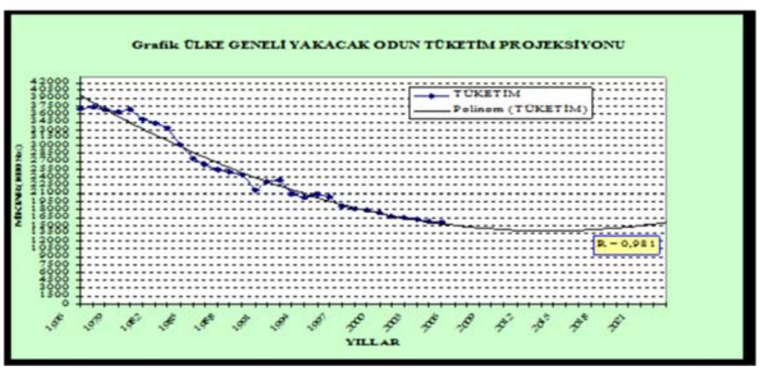

Figure 2. The projection of fuelwood consumption in Turkey [5].

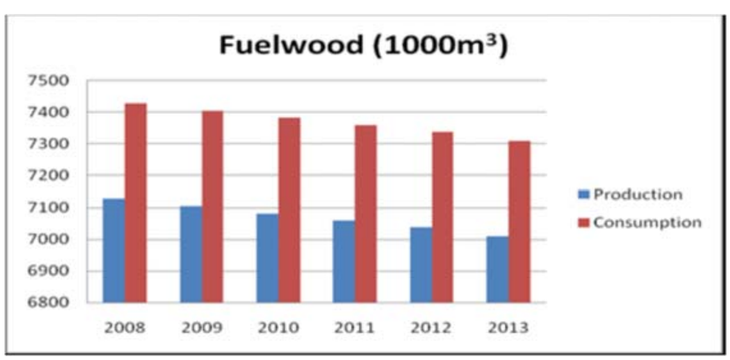

Figure 3. Production and consumption projections of the fuelwood in Turkey [5].

The total forest area in Turkey occupies 26% of the country's territory [5]. Traditional fuels predominate in rural areas; almost all biomass energy is consumed in the household sector for heating, cleaning, and cooking needs of rural people. The lumber, pulp and paper industries burn their own wood wastes in large furnaces and boilers to supply 60% of the energy needed to run factories. In their homes, Turkish people burn wood in stoves and fireplaces to cook meals and warm their residences. Wood is the primary heating fuel in 6.0 million homes in Turkey [24, 27].

Biogas energy is also derived from biomass, which is combusted as a gas comprising primarily methane [7]. Biogas is commonly generated from biomass waste products at sewage treatment plants, solid waste landfills, through forest sector activities, and agricultural operations [8]. The composition of Turkish municipal solid wastes shows that there is important potential for biogas production [5].

The biomass products are converted to a gaseous fuel. Biogas is then combusted in a boiler to produce steam for power generation through a steam turbine or through a combustion turbine directly. In both instances, under cogeneration applications, the residual heat is used as energy for other applications [5, 7, 8]. In the coming years, these energy sources will play an increasingly significant role for producing green power [16]. Biogas production potential in Turkey has been estimated at 1.0–1.5 million tons of oil equivalent (Mtoe) but only three small units are in operation and one new facility (1.5 MW) has been licensed [11]. Around 85% of the total biogas potential is from dung gas, while the remainder comes from landfill gas. The use of animal wastes as biofuel is limited because they are mostly used in agriculture as fertilizers [18, 19].

4.3. Case study in Black Sea Region

In the present study, the biomass potentials of some selected provinces in the Black Sea Region of Turkey were computed and given in Table 3. These provinces are Trabzon, Ordu, Giresun, Rize and Gümüşhane. As shown in Table 3, total bioenergy potential of Trabzon, Ordu, Giresun, Rize and gümüşhane are 239 365, 287 472, 281 891, 5832 and 389 969 tons of oil equivalent (toe), respectively.

Figure 4 shows the biogas potential as (toe) of five provinces in the Black Sea Region of Turkey. As shown in Figure 4, the Trabzon province has highest value of biogas potential such as 9710 toe. The Ordu province has second higher value of biogas potential as 4740 toe while province Rize was lowest gas potential such as 847 toe. On the other hand, Figure 5 shows the share of biomass potentials for five provinces in Black Sea Region of Turkey.

Table 3. Bioenergy potential some selected provinces of Black Sea Region in Turkey (toe)

Provinces	Biogas	Waste gas	Vegetable waste	Total
Trabzon	9710,195525	5,582209803	229649,4099	239365,1877
Ordu	4740,446256	6,23055009	282725,5749	287472,2517
Giresun	3132,38744	4,714511005	278753,537	281890,639
Rize	847,815696	2,387503954	4982,102661	5832,305861
Gümüşhane	1604,08976	1,264049468	388363,8	389969,1538

toe: tons of oil equivalent

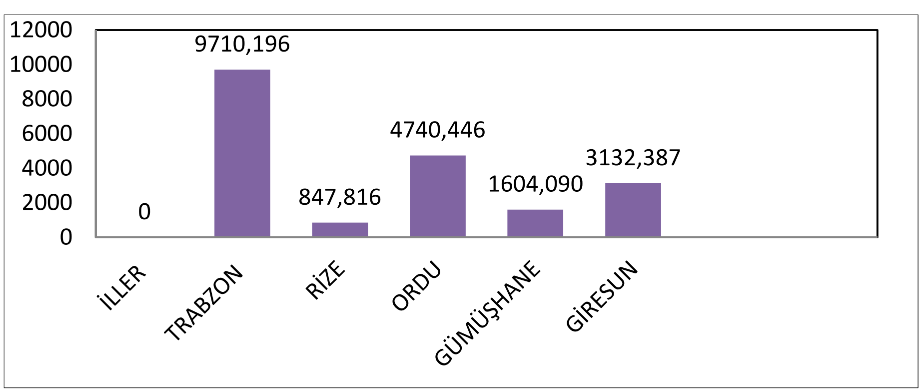

Figure 4. Biogas potential of some provinces in Black Sea Region of Turkey (toe).

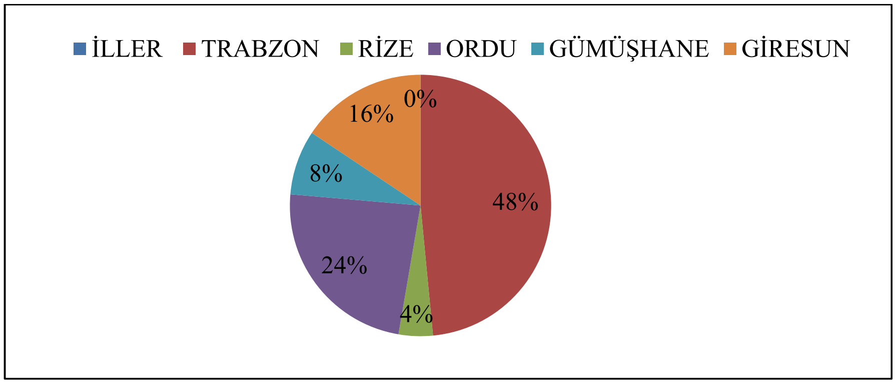

Figure 5. The share of biomass potential for five provinces in Black Sea region of Turkey.

Figure 6 shows the vegetable waste energy values for five provinces in the Black Sea Region of Turkey. As shown in Figure 6, the Gümüşhane province has highest value of vegetable waste energy potential such as 388 364 toe. The Ordu province has second higher value of vegetable waste energy potential as 282 726 toe while province Rize was lowest value of 4982 toe. On the other hand, Figure 7 shows the percent of vegetable waste energy values for five provinces in Black Sea Region of Turkey.

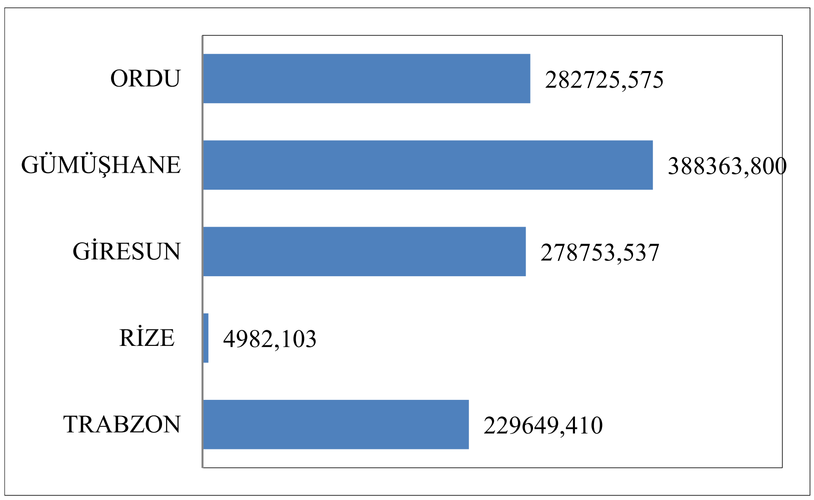

Figure 6. Vegetable waste energy of some provinces in Black Sea Region of Turkey (toe)

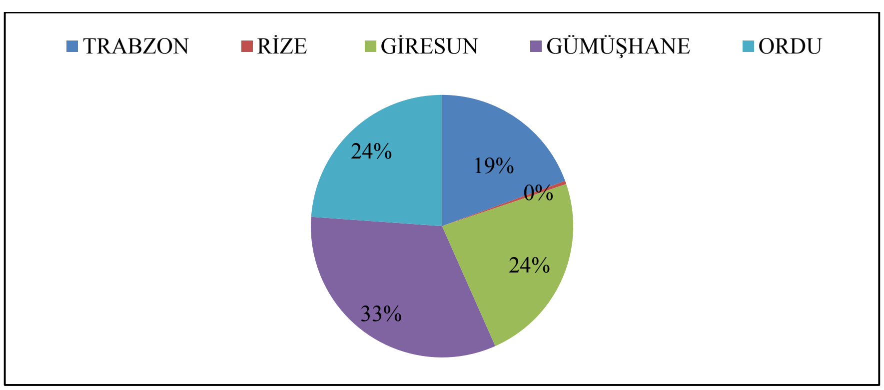

Figure 7. The share of vegetable waste energy potential for five provinces in Black Sea region of Turkey.

Figure 8 also shows the waste gas energy values for five provinces in the Black Sea Region of Turkey. As shown in Figure 8, the Ordu province has highest value of waste gas energy potential such as 6.23 toe. The Trabzon province has second higher value of waste gas energy potential as 5.82 toe while province

Gümüşhane was lowest value of 1.26 toe. On the other hand, Figure 9 shows the percent of waste gas energy values for five provinces in Black Sea Region of Turkey.

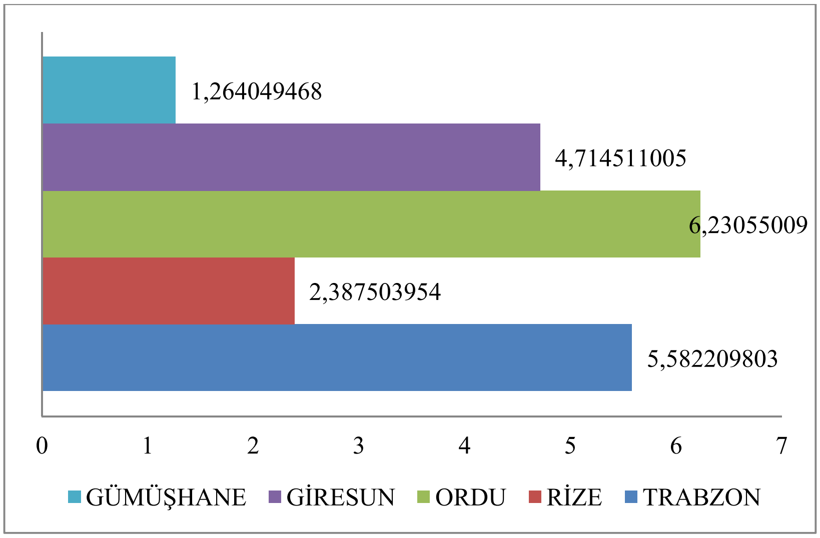

Figure 8. The amount of waste gas energy for five provinces in Black Sea Region of Turkey (toe).

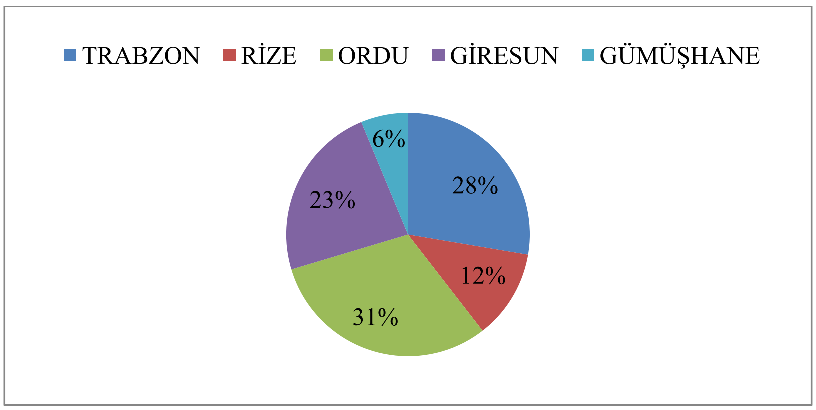

Figure 9. The share of waste gas energy values for five provinces in Black Sea region of Turkey.

5. Conclusions

The increasing importance of biomass as a renewable energy source has led to an acute need for reliable and detailed information and researches for sustainable energy development. Biomass energy is readily obtained from wood, twigs, straw, dung, agricultural residues, etc. Biomass is burnt either directly for heat, or to generate electricity, or can be fermented to alcohol fuels, anaerobically digested to biogas, or gasified to produce high-energy gas.

Turkey has great opportunities for using biomass and bioenergy has been traditionally used for heating and cooking in the country. Today there is a need to reconsider the status of bioenergy usage and to examine the ways forward to modern biomass energy production. Thus, firstly the government should analyze the capacity and potential on bioenergy. This analysis should conclude with the long term and short term strategies on bioenergy and then political and financial frameworks should be created. Turkey has always been one of the major agricultural countries of the world. The importance of agriculture is increasing due to biomass energy being a major resource of Turkey. Like many developing countries, Turkey relies on biomass to satisfy much of its energy requirements.

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