

Sustainable bioenergy policies in Turkey

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Abstract

Turkey is heavily dependent on imported energy resources that place a big burden on the economy. 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. About two-thirds of the renewable energy produced is obtained from forest biomass and other bioenergy sources, which is used to meet a variety of energy needs, including generating electricity, heating homes, fueling vehicles and providing process heat for industrial facilities. 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, bioenergy, renewable energy, sustainability

1. Introduction

The Republic of Turkey, located in Southeastern Europe and Southwestern Asia, has an area of about 780,580 km² and a population of over 70 million [1]. With its young population, growing energy demand per person, fast growing urbanization and economic development; Turkey has been one of the fast growing power markets of the world for the last two decades. Turkey is an energy-importing country; more than half of the energy requirement has been supplied by imports.

Biomass combustion is carbon or carbon dioxide neutral compared with fossil fuel combustion because the biomass combustion is simply releasing the carbon or carbon dioxide that was sequestered by growing the biomass in the beginning is certainly true. It may be argued that such thinking completely ignores the fact that fossil fuel combustion is also carbon or carbon dioxide 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 carbon or carbon dioxide to the atmosphere [2-7].

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. Biomass can be either obtained directly from plants or indirectly from industrial, domestic, agricultural and animal wastes. 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 [3]. Biomass energy, or bioenergy, is the conversion of biomass into useful forms of energy such as heat, electricity and liquid fuels. Figure 1 shows the bioenergy conversion possibilities.

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. Biomass is used to meet a variety of energy needs, including generating electricity, heating homes, fueling vehicles and providing process heat for industrial facilities. Today, worldwide, biomass is in the fourth place as an energy source and provides about 14% of the world's energy needs [6-9]; it also accounts for about 38% of the primary energy consumption in developing countries and it often makes up more than 90% of the total rural energy supplies in those

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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%) [4-7]. Table 1 presents renewable energy indicators in the world [10].

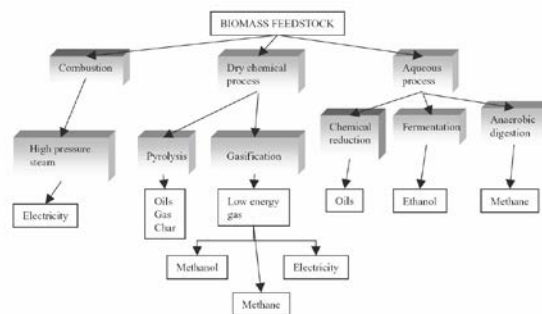


Figure 1. Bioenergy conversion possibilities

Table 1 Renewable energy added and existing capacities in 2008

	Existing at end of 2008
Wind power	159
Small hydropower <10 MW	60
Biomass power	54
Solar PV, grid-connected	21
Geothermal power	11
Concentrating solar power (CSP)	0.6
Ocean power	0.3
Hydropower (all size)	980
Biomass heating	270
Solar hot water/space heating	180
Geothermal heating	60
Ethanol production	76
Biodiesel production	17

2. Turkish economy and energy sector

The Republic of Turkey, located in Southeastern Europe and Southwestern Asia, has an area of about 780,580 km² and a population of over 73 million [1]. With its young population, growing energy demand per person, fast growing urbanization and economic development; Turkey has been one of the fast growing power markets of the world for the last two decades. Turkey is an energy importing country; more than two thirds of the energy requirement has been supplied by imports [10-13].

Turkey's dynamic economy is a complex mix of modern industry and commerce along with a traditional agriculture sector that still accounts for more than 35% of employment. It has a strong and rapidly growing private sector, yet the state still plays

a major role in basic industry, banking, transport, and communication. Real GNP growth has exceeded 6% in many

years, but this strong expansion has been interrupted by sharp declines in output in 2001. The economy is turning around with the implementation of economic reforms, and 2006 GDP growth reached 10%, followed by roughly 5% annual growth from 2005-08. Inflation fell to 7.7% in 2005 but climbed back to 8.5% in 2007. Despite the strong economic gains from 2002-08, which were largely due to renewed investor interest in emerging markets, IMF backing, and tighter fiscal policy, the economy is still burdened by a high current account deficit and high external debt. In short, the economic fundamentals of Turkey are sound, marked by strong economic growth and foreign direct investment [1].

Turkey's population of more than 72 million is growing at an annual rate of 1.01% and expected to grow to 85 million in 2030. In response to the growth rates of population and consumption, Turkey's total final energy consumption (TFC) grew at an average

annual rate of 9.6% over the last three decades. This average annual growth rate of TFC is projected to decrease to 6.4% between 2010 and 2020 and 8% between 2020 and 2030. Table 2 presents some important selected Indicators for Turkey [1, 8].

Table 2 Some important indicators for Turkey in 2010

Indicator	Value
Population (millions)	73
Population growth rate	1.01%
GDP (purchasing power parity, billion 2000 USD)	376
GDP (official exchange rate, billion USD)	664
GDP real growth rate	4.1%
GDP per capita (purchasing power parity, USD)	12,000
GDP per capita (official exchange rate, USD)	9,000
Electricity production (GWh)	200
Electricity consumption/population (kWh/capita)	2,650
Energy-related CO ₂ emissions (Mt CO ₂)	263.1

Turkey's primary energy sources include hydropower, geothermal, lignite, hard coal, oil, natural gas, wood, animal and plant wastes, solar and wind energy [11]. In 2008, primary energy production and consumption has reached 29 and 98.55 Mtoe, respectively as shown in Table 3. Fossil fuels provided about 90.5% of the total energy consumption of the year 2008, with natural gas (30.62%) in first place, followed by oil (25.98%) and coal (29.89%). Turkey has not utilized nuclear energy yet [8, 9]. The Turkish coal sector, which includes hard coal as well as lignite, accounts

for nearly one half of the country's total primary energy production (57.5%). The renewables collectively provided 9.5% of the primary energy consumption, mostly in the form of combustible renewables and wastes (4.95%), hydropower (about 3%) and other renewable energy resources (1.3%) [11-13]. As can be seen in Table 3, the general equilibrium of energy use and supply indicators shows that Turkey is dependent on imported resources very heavily. In 2008, 70.5% of the total energy supply was met by imports [9].

Table 3 Energy production and consumption in Turkey

Energy source	1990	2000	2008
Coal	12.37	12.49	16.68
Oil	3.61	2.73	2.13
Gas	0.17	0.53	0.84
Wood & Waste	7.21	6.51	4.88
Hydropower	1.99	2.66	2.86
Wind	-	0.0	0.07
Geothermal	0.43	0.68	1.15
Solar	0.03	0.26	0.42
Total production	25.82	25.86	29.03
Coal	16.91	22.91	29.46
Oil	23.40	30.40	29.55
Gas	2.86	12.63	30.18
Wood & Waste	7.21	6.51	4.88
Hydropower	1.99	2.66	2.86
Wind	-	0.0	0.07
Geothermal	0.43	0.68	1.15
Solar	0.03	0.26	0.42
Total consumption	52.76	76.35	98.55

Turkey's total electricity production and installed capacity were 191.6 GWh and 41.7 GW, respectively, in 2007. The distribution of the produced electricity

energy according to primary energy sources was as follows: natural gas 49.6%, coal 27.9%, hydropower 18.7%, oil 3.4%, geothermal 0.08% and wind 0.2%.

Table 4 reflects the increasing reliance on natural gas and natural gas had the largest share in gross electricity output in 2007 [8]. The share of natural gas power plants in installed capacity was about 31.6% in 2007

Table 4 Installed capacity and electricity generation in Turkey (2008)

Fuel type	Installed capacity (MW)	Share of total (%)	Electricity generation (GWh)	Share of total (%)
Natural gas	12 007.7	28.68	98 685	49.72
Hydropower	13 828.7	33.03	33 270	16.76
Coal	10 190.9	24.34	57 716	29.08
Oil	1 998.6	4.77	7 519	3.78
Geothermal	30.00	0.07	162	0.08
Wind	847.0	2.02	847	0.42
Others	2961.3	7.07	250	0.13
Total	41 864.2	100.00	198 450	100.00

3. Bioenergy in Turkey

3.1. Bioenergy potential in Turkey

Bioenergy 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, or bioenergy, is the conversion of biomass into useful forms of energy such as heat, electricity and liquid fuels [14-23]. 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. Another important contribution is from post consumer residue streams such as construction and demolition wood, pallets used in

transportation, and the clean fraction of municipal solid waste.

Biomass is the oldest form of renewable energy exploited by mankind, mainly in the form of wood burnt to provide heat and light for domestic and productive activities [21]. The main biomass resources are agricultural residues and wastes, organic fractions of municipal solid waste and refuse, sewage sludge, industrial residues, short-rotation forests, herbaceous lingo-cellulosic crops, sugar crops, starch crops, oil crops, wood wastes. In the long term, energy crops could be a very important biomass fuel source. At present, however, wastes are the major biomass sources [20-23].

Table 5. Production of crop residues in Turkey (2005)

Crop	Residue	Theoretical Production (tons)	Actual Production (tons)	Available Residue (tons)	Heating Value (MJ/kg)	Total Heating Value (x10 ⁵ GJ)
Wheat	Straw	29,170,755	23,429,907	3,514,486	17.9	629.2
Barley	Straw	9,992,948	8,963,012	1,344,452	17.5	235.3
Rye	Straw	405,188	358,040	53,706	17.5	9.4
Oats	Straw	419,678	321,236	48,185	17.4	8.4
Maize	Stalk	5,911,902	4,970,259	2,982,155	18.5	551.7
Rice	Straw	582,555	209,532	125,719	16.7	21.0
Tobacco	Stalk	362,763	410,778	246,467	16.1	39.7
Cotton	Stalk	6,317,181	2,520,281	1,512,169	18.2	275.2
Sunflower	Stalk	2,341,554	2,259,121	1,355,472	14.2	192.5
Groundnut	Shell	27,621	28,638	22,910	20.8	4.8
Soybean	Straw	60,468	21,872	13,123	19.4	2.5

Table 5 shows the production of crop residues in Turkey. As shown in Table 5, total heating value obtained from crop residues is about 2280.1×10^5 Gigajoul (GJ) and total available residue was about 12,950,232 tons in 2006. The production of fruit and fruit tree residues in Turkey is given in Table 6. As shown in Table 6, total heating value obtained from fruit residues is about 754×10^5 GJ and total available

residue was about 3,250,212 tons in 2006. Table 7 also shows the total amount of animal wastes, available dry manure and biogas in Turkey. As shown in Table 7, available yearly amount of biogas is 2,650 billion m^3 and total heating value was 551.5×10^5 GJ in 2008. All these tables show that there is an important bioenergy potential for Turkey excluding fuelwood in 2008 [24-26].

Table 6. Production of fruit and fruit tree residues in Turkey (2005)

Crop	Residue	Theoretical Production (tons)	Actual Production (tons)	Available Residue (tons)	Heating Value (MJ/kg)	Total Heating Value ($\times 10^5$ GJ)
Apricots	Tree pruning	1,328,846	86,964	69,571	19.3	13.4
Olive	Cake	673,484	829,816	746,834	20.69	154.5
Pistachio	Shell	-	14,008	4,202	19.26	8.2
Walnut	Shell	173,546	75,792	60,633	20.18	12.2
Almond	Shell	44,366	25,784	23,205	19.38	4.6
Hazelnut	Shell	698,499	566,437	453,510	19.3	87.5
Orange	Tree pruning	3,424,439	237,686	190,148	17.6	33.5
Mandarin	Tree pruning	981,970	1,093,430	82,744	17.6	14.6

Table 7. Total amount of animal wastes, available dry manure and biogas in Turkey (2005)

Animal Waste	Waste quantity (tons/year)	Total dry manure (tons/year)	Available dry manure (tons/year)	Available Biogas (m^3 /year)	Heating Value (MJ/kg)	Total Heating value ($\times 10^5$ GJ)
Cow	27,654,932	16,211,033	10,535,172	2,107,434,345	22.7	478.4
Sheep	24,558,323	6,139,581	758,146	159,629,101	22.7	36.2
Poultry	7,731,694	1,932,924	1,913,594	382,718,866	22.7	36.9

Direct burning in Turkey for many years has used fuelwood, animal wastes, agricultural crop residues, and logging wastes [25-27]. These sources are often called non-commercial energy sources, but in Turkey, fuelwood is a tradable commodity 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 (see Figs. 2-4). An average consumer in a year burns $0.80 m^3$ fuelwood. The total forest potential of Turkey is around 930 million m^3 with an annual growth of about 26 million m^3 . The total forest

area in Turkey occupies 26% of the country's territory [1, 15]. 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 [8, 11, 12].

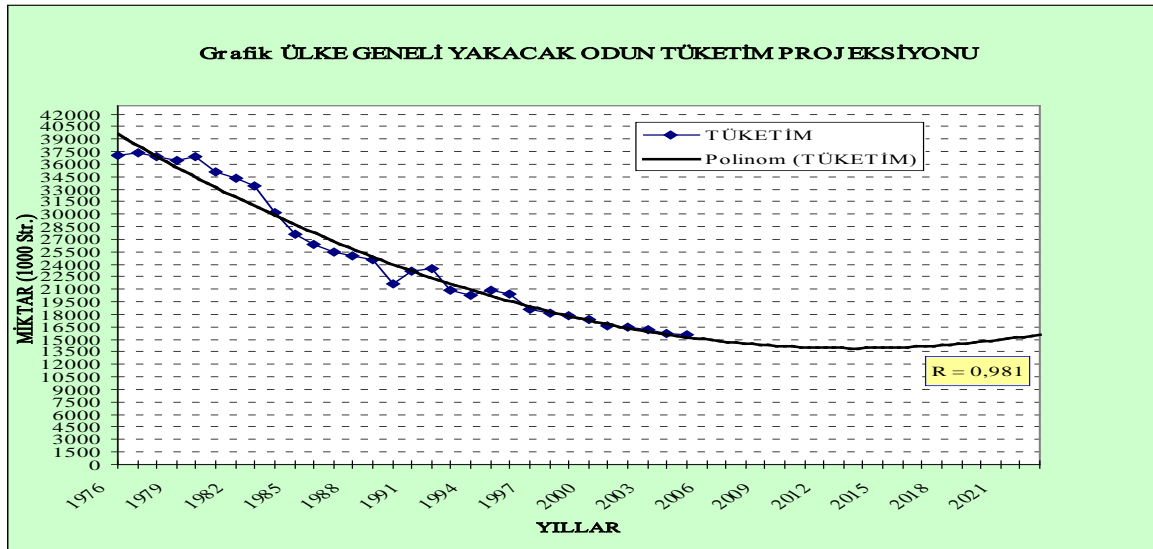


Figure 2. The projection of fuelwood consumption in Turkey.

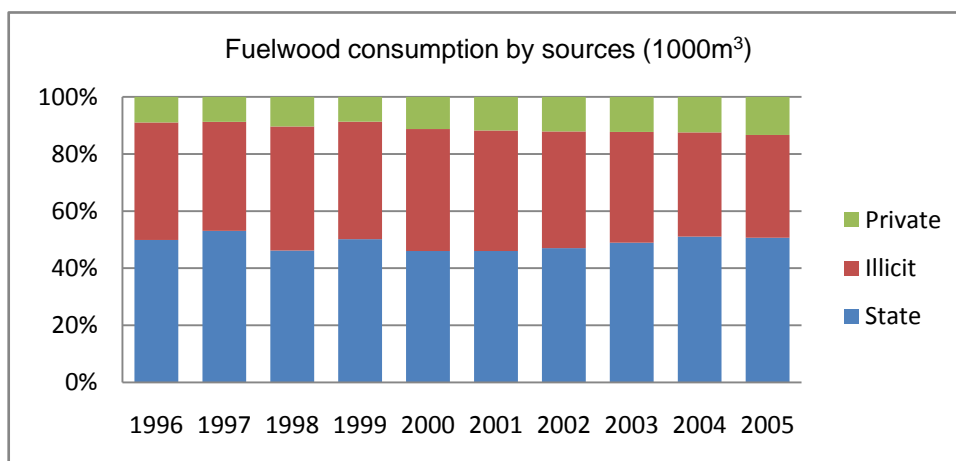


Figure 3. Fuelwood consumption by sources in Turkey.

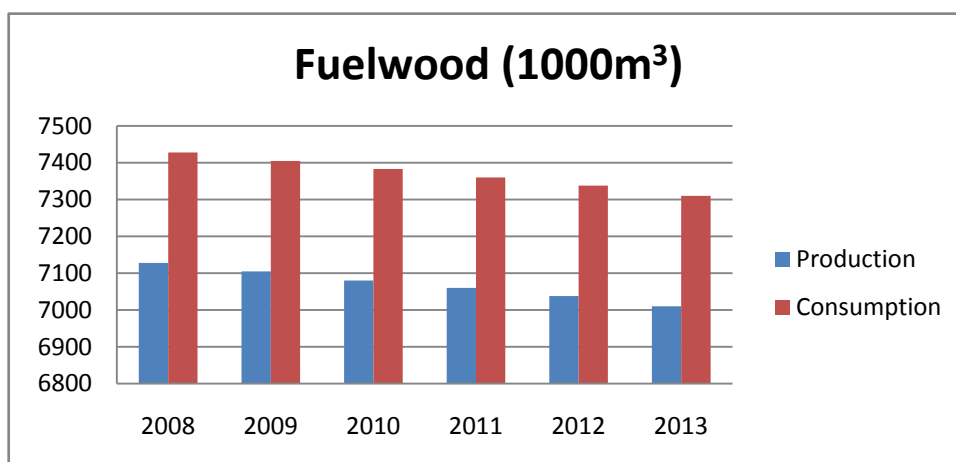


Figure 4. Production and consumption projections of the fuelwood in Turkey.

Biogas energy is also derived from biomass, which is combusted as a gas comprising primarily methane [12]. Biogas is commonly generated from biomass waste products at sewage treatment plants, solid waste landfills, through forest sector activities, and agricultural operations [13]. The composition of Turkish municipal solid wastes shows that there is important potential for biogas production. 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 [11, 12]. In the coming years, these energy sources will play an increasingly significant role for producing green power [8]. 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 [8, 9, 26]. Table 9 shows Turkey's biogas plant inventory.

3.2. Turkish legislation on bioenergy

Existing Turkish law and regulation with relevance to the use of renewable energy sources is limited to two pieces of legislation. One piece of legislation is the Electricity Market Licensing Regulation, and the second is the Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy (Law no. 5346). As indicated by the titles, this legislation has been developed for the electricity sector. In both regulations, biomass is included in the definition of renewable energy resource. There is no legislation currently existing for biomass alone [8, 9, 11, 12].

According to the Electricity Market Licensing Regulation, promotion of renewable energy sources in the electricity market has been assigned to the Energy Market Regulatory Authority (EMRA). With regard to the environmental effects of the electricity generation operations, to take necessary measures for encouraging the utilization of renewable and domestic energy resources and to initiate actions with relevant agencies for provision and implementation of incentives in this field. In this context, there are some incentives and regulations related to renewable energy sources [8, 11].

Generating Electrical Energy is to increase the use of renewable energy sources for generating electrical energy, as well as to diversify energy resources, reduce greenhouse gas emissions, assess waste products, protect the environment and develop the necessary manufacturing sector for realizing these objectives. In this law, the biomass definition given as: the fuels in solid, liquid or gaseous phase obtained from organic wastes and from the agricultural and forestry products including the waste products of agricultural harvesting and oil extraction from plants as well as from the byproducts formed after their processing.

3.3. International aspect

Rising concern for global environmental degradation have led to wide acceptance of sustainable development concept. Following its initial popularization, the concept of the sustainability has appeared in a wide range of forms in recent literature. Although different authors have given it a variety of meanings, sustainable development is best defined as meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. In this context, sustainability is used to characterize the desired balance between economic growth and environmental preservation [8, 11].

The Kyoto Protocol to the United Nations Framework Convention on Climate Change, agreed to in December 1997, marks an important turning point in efforts to promote the use of renewable energy worldwide [28]. Since the original Framework Convention was signed at the Earth Summit in Rio de Janeiro in 1992, evidences of climate change have spurred many countries to increase their support of renewable energy. Even more ambitious efforts to promote renewables can be expected as a result of the Kyoto pact, which includes legally binding emissions limits for industrial countries, and for the first time, specially identifies promotion of renewable energy as a key-strategy for reducing greenhouse gas emissions.

In contrast to fossil fuels, biomass fuels are characterized by their low density, and sources of biomass are small, dispersed, disparate and seasonal. Biomass fuels may be collected from, for example, individual farms covering a wide geographic area. Sources are very small in comparison to fossil fuel extraction industries, with the possible exception of the largest pulp and paper or wood processing units. These issues all contribute to potentially raised fuel costs-via logistics, contracting, transport, fuel

preparation, and storage. On the other hand, a unique aspect of many agricultural waste materials is their seasonality. The seasonality of agriculture is seen to be a key risk, for both establishing viable fuel supply businesses and for maintaining year-round fuel supplies for potential energy plants [4].

The high capital cost of agricultural waste or biomass power plants is a major disincentive to investors. Further, the upper size limit of biomass plants is lower than fossil fuel-fired plants, because long-distance transport of low-density biomass fuels is generally not considered feasible due to financial reasons. There are limited opportunities to achieve economies of scale with bioenergy. Thus, to achieve favorable power and heat generation costs, technology with high fuel conversion efficiency is selected. While improved technology may be able to battle some of the elevated investment costs of bioenergy, technology risks remain. Some relevant technology is proven, however, a lot of technology remains in research, development and demonstration phases. This technology risk is considered unacceptable to most investors.

4. Evaluation of bioenergy use

4.1. Benefits of bioenergy use

Bioenergy appears to have formidably positive environmental properties, resulting in no net releases of carbon dioxide and very low sulfur content. The most important gain of bioenergy utilization is the environmental benefit of displacing fossil fuel usage and a reduction in any adverse environmental impacts that are caused by fossil fuel consumption.

Bioenergy can contribute to the generation of new jobs especially in rural and farming communities, which in turn may result in an improvement of income distribution. Bioenergy has the potential to provide millions of households with incomes, livelihood activities and employment. A number of studies have now concluded that the development of bioenergy systems is a generator of jobs.

In Turkey, there are also substantial areas of abandoned agricultural land that are not managed and are becoming overgrown. Creating demand for biomass fuel would help to bring these areas back into economic exploitation. Furthermore, development of new dedicated energy crops and/or an energy market for residues from existing crops would help farm income and reduce the rate of land abandonment [3, 9]. Furthermore,

provided that fossil fuel prices increase in the future, bioenergy appears to have significant economic potential.

Sustainable energy can be developed by laying more emphasis on domestic resources in the energy mix. In recent years, Turkey has begun to ignore the importance of energy usage based mainly on domestic sources. Today, about 78% of the Turkey's energy consumption is met by imports. The reliance on import resources to such an extent threatens the essentials of the sustainable development model seriously.

The abundant fossil fuels, such as coal, are often damaging to the environment throughout the fuel cycle, from mining to processing to consumption. Fossil fuels also carry the threat of global climate modification through increased discharge of carbon dioxide, particulates and other materials. Nuclear energy, while imposing no threat of climate modification, is associated with serious problems, such as waste disposal, accidents and weapons proliferation. The substitution of fossil fuels and their derivatives by biomass and biofuels helps to conserve depletable fossil fuels. Bioenergy may replace petroleum fuels. Biofuels are obtained from biomass and can be used as a substitute for transportation fuels and to generate heat, power and chemicals. Because biomass can be converted directly into a liquid fuel, it could someday supply much of our transportation fuel needs for cars, trucks, buses, airplanes and trains. In addition, the use of a fossil fuel and biomass together in certain applications, such as electric power generation with coal and wood, can result in reduction of undesirable emissions.

4.2. Drawbacks of bioenergy use

Generally speaking, biofuel production cost is currently higher than that of the classic fuels; sometimes the critical factor is the raw material cost. Collecting, transporting and storing biomass is expensive. There are also significant costs of marketing, distribution and service. At the moment, biofuels are about 2.3 times more expensive than fossil fuels. For bioethanol, this figure ranges between 2.6 and 2.8 as compared with petrol. However, cost comparisons are highly dependent on the fluctuations in the international market for crude oil and refined products and in biofuel feedstock. On the other hand, the continuous efforts for the increase in the raw material yields as well as the advances in production technologies may make this cost relationship more favorable for biofuels [8, 20, 22].

The large volumes of water required to produce biomass constitute another point to consider. Also, water and soil nutrients are finite and may easily be degraded. Besides, the abundant use of fertilizers and manure for bioenergy production may result in considerable environmental problems in various regions: nitrification of groundwater, saturation of soils with phosphate and so on. In sum, there are numerous considerations that hint at the unsustainable nature of bioenergy. In case of an increase in bioenergy utilization, the demand for agricultural land could increase; growing amounts of virgin rainforest could be cleared for farmland and greater soil degradation ensues [21-29].

5. Conclusions

Though Turkey has great opportunities for using bioenergy, biomass energy 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. Forest villagers, living in terribly hard economic conditions, should also be considered in those analyses. Because they have some legal rights on forests that could be used for bioenergy production, they might feel reluctant to conducting of these operations. Employment creation possibilities for forest villagers may provide an important base for awareness raising activities in those villagers. Total welfare effect of the energy plants needs to be determined regarding the social costs and alternative costs of potential lands.

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