An Expose of Bioenergy and its Potential and Utilization in Turkey

Erdogdu, Erkan

Energy Market Regulatory Authority, Republic of Turkey

2008

An Expose of Bioenergy and Its Potential & Utilization in Turkey

Erkan Erdogdu[a,b,*]

[a]*Energy Market Regulatory Authority, Ziyabey Cad. No:19 06520 Balgat/ANKARA TURKEY*

Abstract

Turkey is heavily dependent on expensive imported energy resources (oil, gas and coal) 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 bioenergy, 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 amount of usable bioenergy potential of Turkey is approximately 17 Mtoe. This article not only presents a review of the potential and utilization of the bioenergy in Turkey but also provides some guidelines for policy makers.

Keywords: *Bioenergy, Biomass, Turkey*

[*] Corresponding author. Tel.: +90-312-2872560 Fax: +90-312-2878819
E-mail: erkan@erdogdu.net
URL: http://erkan.erdogdu.net

[b] The author is working as an Energy Expert in Energy Market Regulatory Authority of the Republic of Turkey. In October 2005, the author is awarded an "MSc with Distinction in Energy Economics and Policy" by the Department of Economics, University of Surrey (UK). The views, findings and conclusions expressed in this article are entirely those of the author and do not represent in any way the views of any institution he is affiliated with.

1. Introduction

The Republic of Turkey, located in Southeastern Europe and Southwestern Asia (that portion of Turkey west of the Bosporus is geographically part of Europe), has an area of about 780,580 sq km and a population of over 70 million (CIA, 2007). 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.

The energy sources can be split into three categories: fossil fuels, renewable sources, and nuclear sources. In this paper, the focus will be on renewable sources, specifically bioenergy, in Turkey. However, before getting into details of bioenergy use in Turkey, let me concentrate on the definition of “renewable source”. In this paper, an energy source is regarded as renewable if it has the following two distinctive qualifications:

- carbon neutral,
- derived from those natural, mechanical, thermal and growth processes that repeat themselves within our lifetime.

Based on this definition, examples of renewable energy sources include bioenergy, hydro, solar, wind and geothermal sources.

Biomass combustion is carbon or carbon dioxide neutral compared to 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[1]. 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].

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. 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 flow (Akpinar et al., 2007).

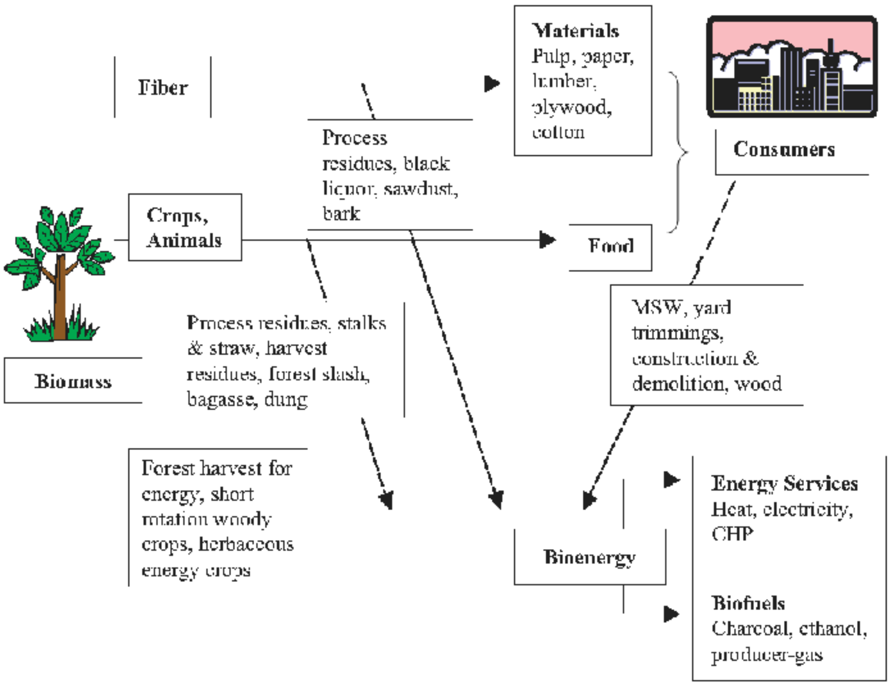

Figure 1. Bioenergy flow chart

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 (Dumanli et al., 2007, p. 2064); 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 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%) (Demirbas et al., 2007). Table 1 presents renewable energy indicators in the world (Bilgen et al., 2007).

[Table 1 goes here]

The rest of the study is organized as follows. Section 2 introduces the key indicators of Turkish economy and her energy sector. Section 3 describes the current status of bioenergy in Turkey, while Section 4 deals with evaluation of bioenergy use in general. Then, some guidelines for policy makers are provided based on the findings of the study. Finally, Section 6 gathers the main conclusions derived from the paper.

2. Key indicators of Turkish economy and energy sector

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 (Gross National Product) growth has exceeded 6% in many years, but this strong expansion has been interrupted by sharp declines in output in 1994, 1999 and 2001 due to economic crisis. The economy is turning around with the implementation of economic reforms and 2004 GDP (Gross Domestic Product) growth reached 9%, followed by roughly 5% annual growth from 2005-06. Inflation fell to 7.7% in 2005, a 30-year low, but climbed back to 9.8% in 2006. Despite the strong economic gains from 2002-06, 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 debt. Prior to 2005, foreign direct investment (FDI) in Turkey averaged less than $1 billion annually, but further economic and judicial reforms and prospective EU membership[3] are expected to boost FDI. Privatization sales are currently approaching $21 billion (CIA, 2007).

Turkey's population of more than 70 million is growing at an annual rate of 1.04% and expected to grow to 83.4 million in 2022. 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 5.4% between 2005 and 2010 and 7% between 2010 and 2020 (Evrendilek et al., 2003). Table 2 presents some important selected Indicators for Turkey as of 2004 (CIA, 2007).

[Table 2 goes here]

Turkey's primary energy sources include hydropower, geothermal, lignite, hard coal, oil, natural gas, wood, animal and plant wastes, solar and wind energy. In 2004, primary energy production and consumption has reached 24.1 million tonnes (Mt) of oil equivalent (Mtoe) and 87.8 Mtoe, respectively. Table 3 shows the Turkey's energy balance table in 2004. Fossil fuels provided about 86.9% of the total energy consumption of the year 2004, with oil (31.5%) in first place, followed by coal (27.3%) and natural gas (22.8%). Turkey has not utilized nuclear energy yet[4]. 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 (%43.7). The renewables collectively provided 13.2% of the primary energy, mostly in the form of combustible renewables and wastes (6.8%), hydropower (about 4.8%) and other renewable energy resources (approximately 1.6%) (IEA, 2007).

[Table 3 goes here]

As can be seen in Table 3, the general equilibrium of energy use and supply indicators shows that Turkey is dependent on import resources very heavily. In 2004, 77.6% of the total energy supply was met by imports, and the rest was domestically produced.

Turkey's total electricity production and installed capacity were 162.5 GWh and 38.8 MW, respectively, in 2005 (Erdogdu, 2007a). The distribution of the produced electricity energy according to primary energy sources was as follows: natural gas 44.74%, hydropower 25.11%, coal 25.05%, oil 4.92%, biomass 0.09%, geothermal 0.06% and wind 0.04% (Kone et al., 2007). Table 4 reflects the increasing reliance on natural gas[5] in the power sector. The share of natural gas power plants in installed capacity was about 37% in 2005. Likewise, natural gas had the largest share in gross electricity output in 2005.

[Table 4 goes here]

3. Current status of bioenergy in Turkey

3.1. Bioenergy potential in Turkey

Turkey has a considerably high level of renewable energy resources that can be a part of the total energy network of the country. 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 biomass. Various agricultural residues such as grain dust, wheat straw and hazelnut shell are available in Turkey as the sources of biomass energy. The annual biomass potential of Turkey is approximately 32 million tonnes oil equivalents (Mtoe). The total recoverable bioenergy potential is estimated to be about 17.2 Mtoe[6] (Balat et al., 2005). Turkey's present and planned biomass energy production is presented in Table 5 (Yuksel et al., 2007).

[Table 5 goes here]

The importance of agriculture is increasing due to biomass energy being one of the major resources in Turkey. Table 6 shows the production of crop, fruit and fruit tree residues and the total amount of animal wastes available for production of bioenergy in Turkey (Ozturk and Bascetincelik, 2006).

[Table 6 goes here]

In Turkey, almost all biomass energy is consumed in the household sector for heating, cleaning, and cooking needs of rural people. 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 6.5 million homes in Turkey. 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. The use of animal wastes as biofuel is limited because they are mostly used in agriculture as fertilizers. The only waste power plant, built in 1991, of the country is in Adana (Akpinar et al., 2007).

3.2. Current 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 Number 5346, dated May 10, 2005). 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.

In Turkey, market based policies for renewables started in 1984 with third-party financing, excise and sales tax exemptions. Capital grants were offered in 2001. The Turkish government's approach to the deployment of renewables reveals its priorities to develop indigenous and renewable resources in conjunction with the expansion of privately owned and operated power generation from renewable sources. The build-own-transfer (BOT) and the build-own-operate (BOO) schemes were put in place in 1984 and financed major power projects (not limited to renewables) with the main objective of attracting private investors. BOT projects were granted a treasury guarantee. Although BOT and BOO approaches attracted significant investment, they also created large public obligations with the government covering the market risk through take-or-pay contracts. The BOT and BOO financing schemes ended in 2000 and were replaced in 2001 by financial incentives within the framework of the Electricity Market Law (Law Number 4628)[7].

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). Specifically, the Regulation states that the issues assigned to the Energy Market Regulatory Authority are “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. The incentives brought into existence based on the Electricity Market Licensing Regulation are given below:

- Entities applying for licenses for construction of facilities based on domestic natural resources and renewable energy resources shall pay only 1% of the total licensing fee.
- The generation facilities based on renewable energy resources shall not pay annual license fees for the first 8 years following the facility completion date indicated on their respective licenses.

- Turkish Electricity Transmission Company (TEIAS) and/or distribution companies shall assign priority for system connection of generation facilities based on domestic natural resources and renewable resources.

The aim of the Law on Utilization of Renewable Energy Resources for the Purpose of 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. The biomass definition given in this law reads: "*Biomass: 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 by products formed after their processing*". Specific incentives introduced in the law that are applicable to the use of biomass include:

- Obligation to purchase electricity from renewable energy sources: Each legal entity possessing a retail sale license shall be required to purchase renewable energy source-certified (RES-certified) electricity in an amount declared by EMRA.
- Purchasing of electricity from renewable energy sources with a higher price: Until the end of 2011, the applicable price for the electricity to be purchased in pursuance with the law within each calendar year shall be the Turkish average wholesale electricity price in the previous year determined by EMRA. The Council of Ministers is entitled to raise this price up to 20% at the beginning of each year.

- Acquisition of land: In the case of utilization of property which is under the possession of Forestry or Treasury or under the sovereignty of the State for the purpose of generating electricity from the renewable energy resources included in the law, these territories are permitted on the basis of its sale price, rented, given right of access, or usage permission by the Ministry of Environment and Forestry or the Ministry of Finance. A 50% deduction shall be implemented for permission, rent, right of access, and usage permission in the investment period.

3.3. International aspect

Since the 1970s, 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* (WCED, 1987). In this context, sustainability is used to characterize the desired balance between economic growth and environmental preservation.

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. 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 October 2005, European Union (EU) opened accession negotiations with Turkey, who has been an associate member of the EU since 1963 and an official candidate since 1999. There are many policies, directives, standards and norms in the EU designed to stimulate and support the biofuels industry. The Renewable Fuels Directive defines targets for 2% of petrol and diesel for transport by the end of 2005 and 5.75% by the end of 2010 (Directive, 2003/30/EC). To support the biofuels industry, the Energy Taxation Directive allows exemptions or reductions from energy taxation for biofuels (Directive, 2003/96/EC). The recently released Biomass Action Plan (BAP) outlines more than 20 actions to stimulate the development and diffusion of bioenergy in Europe. Many of the actions in the BAP are focused on meeting the targets in the Renewable Fuels Directive. Finally, there are a range of fuel standards and emission norms in the EU for petrol, diesel, bioethanol and biodiesel. Currently, Turkey is not required to comply with the EU norms but in the near future she will be obliged to do so in the course of accession negotiations[8].

3.4. Barriers to bioenergy exploitation in Turkey

The barriers holding back biomass exploitation in Turkey can be divided into two main groups: (1) barriers in the institutional, legal, and administrative framework and (2) real and perceived risks and other inherent difficulties associated with promoting biomass energy (Kaya et al., 2007).

3.4.1. Barriers in the institutional, legal, and administrative framework

The most important barriers in the institutional, legal, and administrative framework for the exploitation of biomass in Turkey are summarized below:

- establishment of a responsibilities structure and organization at the institutional level, which requires a higher level of coordination and cooperation within and between institutions, agencies, institutes, and other stakeholders,
- insufficient available information about existing and possible future costs of biomass utilization,
- insufficient detailed biomass energy resource assessments and data banks pertaining to Turkey,
- insufficient credit facilities, particularly for small-scale projects,
- administrative and time-consuming obstacles for foreign investors,
- need for support for infrastructure and management know-how at a local level,
- insufficient participation by the private sector,
- need for staff with sufficient technical information,
- difficulties possibly encountered in planning, project feasibility, and project control activities,
- insufficient policy and market instruments (including available subsidies) in the environmental, agricultural, and energy sectors,
- need for public acceptance and willingness.

3.4.2. Real and perceived risks and other inherent difficulties

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, storage, etc.

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.

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 (for financial and environmental reasons). There are limited opportunities to achieve economies of scale with bio-energy. 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 bio-energy, 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.

A further important consideration is that the core business for the wood or agro-industry plant owners and managers is not energy-based. If a capital sum is available for investment, improvements to their core business are likely to take precedence over any potential energy-related business expansion.

4. Evaluation of bioenergy use

4.1. Benefits of bioenergy use

4.1.1. Lower emissions to the environment

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.

4.1.2. Economic development and growth in the agricultural sector

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 (Bilen et al., 2007).

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

4.1.3. Contribution to security of supply and sustainability

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—particularly on natural gas—to such an extent threatens the essentials of the sustainable development model seriously.

Not only bioenergy contributes to Turkey's energy diversification strategy but also substitution of current energy imports, mainly gasoline and diesel, with bioenergy is important for economic and national security reasons.

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. We must also recognize that all fossil fuels and nuclear energy from fission are ultimately exhaustible. The substitution of fossil fuels and their derivatives by biomass and biofuels helps to conserve depletable fossil fuels. Bioenergy may replace petroleum fuels. Biofuels (mainly bioethanol, hydrogen and biodiesel) are obtained from biomass and can be used as a substitute for transportation fuels and to generate heat, power and/or 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.

4.1.4. Development of competition in energy market

Bioenergy presents an opportunity to move towards more decentralized forms of electricity generation, where a plant is designed to meet the needs of local customers, avoiding transmission losses and increasing flexibility in system use; which in turn provides an opportunity to increase the diversity of power generation plants, and competition in electricity generation.

4.2. Drawbacks of bioenergy use

4.2.1. High cost of bioenergy production

Generally speaking, biofuel production cost is currently higher than that of the classic fuels; sometimes the critical factor is the raw material cost[9]. 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 to 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 (Kondilia et al., 2007).

4.2.2. Soil degradation and run-off

The large volumes of water required to produce biomass (much of which is often derived from aquifers that might not continue to yield water indefinitely) 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. Furthermore, deforestation, especially of high conservation value (HCV) forests, could lead to a considerable loss of biodiversity and the extinction of an incalculable number of species, some as yet undiscovered. On a global scale, deforestation has generally been assumed to be a key factor in altered weather patterns, soil degradation and erosion.

4.2.3. Inefficiency in the production process

The most significant concern about bioenergy relates to inefficiency in its production process. For instance, bioenergy production, in the case of corn and wheat, rely on starch from the kernels of the plant or, in the case of sugar cane and sugar beet, on the sucrose produced (McCormick-Brennan et al., 2007). The remainder, at least for the purpose of fuel production, goes to waste. The same holds true for the seeds used to extract vegetable oil for biodiesel production. Thus, a large amount of energy is expended on cultivating, harvesting and processing the biomass, even though only a relatively small proportion is used to derive energy. The result is an arguably high level of inefficiency and a poor allocation of energy resources throughout.

Crops used for bioenergy production also have lower energy content than conventional petroleum products. Problematic, too, is that fossil fuels are generally required in the production of biofuels.

4.2.4. Technical concerns

It is important to understand that biofuels have a limited application. From a business perspective, current technology militates against these fuels. Biomass fuels cannot replace conventional fuels on a one-for-one basis in unmodified vehicles. This means that the demand for hydrocarbon-based fuels is unlikely to tail off to any significant degree in the immediate future.

4.2.5. Practical limitations

Systems capacity proves a practical limitation. A clear understanding is required to assess what impact an increasing use of bioenergy will have on the world's current fossil-fuel reliance. If the United States, along with Canada and the EU, were to replace only 10 per cent of their current transport fuels with biofuels, it would require an investment of between 30-70 per cent of their national crop areas, at least with current production and crop-yield levels. Furthermore, in order to replace just under 6 per cent of petrol and diesel, the EU would have to convert 19 per cent of its arable land from food crops to fuel crops (Von Lampe, 2005). Even the EU's modest target of 20 per cent reliance on alternative fuels (including biofuels) by 2020 would consume the majority of its cropland.

5. Guidelines for policy makers

The overall objective of energy-related policies should be ensuring sufficient, reliable and affordable energy supplies to support economic and social development, while protecting the environment. Therefore, when choosing energy fuels, it is essential to take into account economic, social and environmental consequences. In the past, environmental impacts of energy resources were ignored or not foreseen, while energy policies focused on adequate supply of energy to assure high rates of economic growth. Today, besides the economic issues, particular importance should be assigned to environmental factors associated with the choice of energy sources.

In Turkish case, as fossil fuel energy becomes scarcer, Turkey will face energy shortages, significantly increasing energy prices, and energy insecurity within the next few decades. In addition, Turkey's continued reliance on fossil fuel consumption will contribute to accelerating the rates of domestic environmental quality and global warming. For these reasons, the development and use of renewable energy sources and technologies are increasingly becoming vital for sustainable economic development of Turkey (Bilen et al., 2007).

Potential policy instruments appropriate for Turkey concerning bioenergy utilization may include:

- A program to encourage alternative, beneficial uses of agricultural residues and wastes, in particular for biomass energy production.
- A rural development policy that considers renewable energy source exploitation in general, including agricultural waste exploitation and dedicated energy crops[10], i.e. fast growing grasses and trees grown especially for energy production.
- Development and compliance of existing Turkish legislation on bioenergy with EC directives.
- Utilization of market instruments[11] appropriate for Turkey that could include financial incentives, by means of direct grants and/or loans, which would support better use of agricultural by-products (including residues and wastes) in a manner that promotes environmental protection, renewable energy, and overall performance efficiency. Existing legislation, in itself, is not expected to be sufficient to overcome the high investment cost, risk and lack of security associated with the entrance of renewable power plants into the electricity market.
- Exemption or reductions in the level of taxation to electricity, heat, and/or transport fuels produced with biomass sources.

- Other financial support mechanisms such as soft loans, low-interest loans, credit guarantees, start-up subsidies and/or grants, and discounts for consumers willing to purchase bioenergy.
- A legislation establishing a target (e.g., 10%) for the penetration of renewable energy sources into the domestic energy consumption by a given year. It could also include a separate but integrated target for biomass alone.
- A legislation establishing a target for the penetration of biofuels into the gasoline and diesel transport fuel market by a given year, potentially with interim targets to ensure the country stays on track with the goal.
- Development of markets for bioenergy and bio-based products. It is not enough to support the development of renewable energy technologies. They must also support their commercial application in the country. Even with significant gains in the areas of research, development, and education, the biomass industry will not be successful without a market outlet to utilize the final product.
- A program to support the advancement in technology with regard to both the supply and demand sides of bioenergy[12].
- Encouragement of co-generation of biomass with coal. This will reduce the emissions of those existing power generation systems and make a considerable contribution to greenhouse gas emission reductions.
- An effort to control the emissions from waste plants to the air while burning. Necessary controls should be taken over by the Ministry of

Environment for these emissions to be under standards foreseen by the European Union.

These recommended policy instruments are not only energy sector-specific, but agricultural and environmental, as well. These three areas are interrelated and must be considered both individually and collectively.

6. Conclusion

Bioenergy provides a clean, renewable energy source that could dramatically improve our environment, economy and energy security. Biomass energy generates far less air emissions than fossil fuels, reduces the amount of waste sent to landfills and decreases our reliance on foreign oil. Biomass energy also creates thousands of jobs and helps revitalize rural communities.

Turkey is an energy-importing country. In order to be less dependent on other countries, Turkey needs to use its sustainable sources. From this point of view, bioenergy is a very attractive choice, since it is economical, sustainable, environmental friendly and a familiar energy source in Turkey. Furthermore, Turkey has several advantages for the use of bioenergy in terms of its climate. However, today, in Turkey, the domestic consumption of biofuels is lagging, mainly due to economic barriers, lack of legislative and regulatory framework and poor infrastructure.

While specific policies and regulations are recommended here, it is also important for efficiency and effectiveness that communication and mechanisms for coordination/cooperation between ministries (i.e. energy, agricultural, and environmental) and other related institutions (e.g. EMRA) be improved.

The private sector, which has the capacity to mobilize needed funds, must be motivated to participate in biomass and other renewable energy development. The process of liberalization, restructuring, and privatization in the Turkish energy sector[13] is also vital. It should be continued without any delays in the introduction of competition. This will assist in creating a favorable environment for investment in bioenergy.

Acknowledgements

I would like to thank anonymous referees for their very helpful comments on an earlier draft of the paper. Their constructive comments are gratefully acknowledged. The author is, of course, responsible for all errors and omissions.

References

Akpinar, A., Komurcu, M.I., Kankal, M., Ozolcer, I.H., Kaygusuz, K., 2007. Energy situation and renewables in Turkey and environmental effects of energy use. Renew Sust Energ Rev, doi:10.1016/j.rser.2007.04.011.

Balat, M., 2005. Use of biomass sources for energy in Turkey and a view to biomass potential. Biomass Bioenerg 29: 32–41.

Bilen, K., Ozyurt, O., Bakirci,, K., Karsli, S., Erdogan, S., Yilmaz, M., Comakli, O., 2007. Energy production, consumption, and environmental pollution for sustainable development: A case study in Turkey. Renew Sust Energ Rev, doi:10.1016/j.rser.2007.03.003.

Bilgen, S., Keles, S., Kaygusuz, A., Sari, A., Kaygusuz, K., 2006. Global warming and renewable energy sources for sustainable development: A case study in Turkey. Renew Sust Energ Rev, doi:10.1016/j.rser.2006.07.016.

CIA (Central Intelligence Agency), 2007. The World Factbook. Accessed from http://www.cia.gov on 26.12.2007 at 15:56.

Demirbas, A.H., Demirbas, I., 2007. Importance of rural bioenergy for developing countries. Energ Convers Manage 48: 2386–2398.

Dumanli, A.G., Gulyurtlu, I., Yurum, Y., 2007. Fuel supply chain analysis of Turkey. Renew Sust Energ Rev 11: 2058–2082.

Ediger, V.S., Kentel, E., 1999. Renewable energy potential as an alternative to fossil fuels in Turkey. Energ Convers Manage 40: 743-755.

Erdogdu, Erkan, 2002. Turkey and Europe: Undivided but Not United. Middle East Review of International Affairs (MERIA) 6(2): 40-51, (available online: http://meria.idc.ac.il/journal/2002/issue2/jvol6no2in.html).

Erdogdu, Erkan, 2005. Energy Market Reforms in Turkey: An economic analysis. MSc Dissertation, Department of Economics, Surrey University, Surrey, UK, September 2005.

Erdogdu, Erkan, 2007a. Electricity demand analysis using cointegration and ARIMA modelling: A case study of Turkey. Energ Policy 35(2): 1129-1146.

Erdogdu, Erkan 2007b. Regulatory reform in Turkish energy industry: An analysis. Energ Policy 35(2): 984-993.

Erdogdu, Erkan 2007c. Nuclear power in open energy markets: A case study of Turkey. Energ Policy 35(5): 3061-3073.

Evrendilek, F., Ertekin, C., 2003. Assessing the potential of renewable energy sources in Turkey. Renew Energ 28: 2303–2315.

IEA (International Energy Agency), 2007. 2004 Energy Balances for Turkey, accessed from http://www.iea.org on 30.12.2007 at 18:02.

Kaya, D., Kılıc, F.C., Baban, A., Dikec, S., 2006. Administrative, institutional and legislative issues on agricultural waste exploitation in Turkey. Renew Sust Energ Rev, doi:10.1016/j.rser.2006.07.007.

Kondilia, E.M., Kaldellis, J.K., 2007. Biofuel implementation in East Europe: Current status and future prospects. Renew Sust Energ Rev 11: 2137–2151.

Kone, A.C., Buke, T., 2007. An Analytical Network Process (ANP) evaluation of alternative fuels for electricity generation in Turkey. Energ Policy 35: 5220–5228.

McCormick-Brennan, K., Bomb, C., Deurwaarder, E., Kaberger, T., 2007. Biofuels for transport in Europe: lessons from Germany and the UK. Energ Policy 35 (4): 2256–2267.

Ozturk, H.H., Bascetincelik, A., 2006. Energy exploitation of agricultural biomass potential in Turkey. Energy Exploration & Explotation 24: 313–330.

WCED (World Commission on Environment and Development), 1987. Our Common Future. Oxford University Press, Oxford, 1987.

Von Lampe, M., 2005. Agricultural Market Impacts of Future Growth in the Production of Biofuels. Working Policy on Agricultural Policies and Markets, OECD Directorate for Food, Agriculture and Fisheries. Accessed from http://www.oecd.org/dataoecd/58/62/36074135.pdf on 07.01.2008 at 16:43.

Yuksel, I., 2007. Global warming and renewable energy sources for sustainable development in Turkey. Renew Energ, doi:10.1016/j.renene.2007.05.040.

Further Reading

Atiyas, I., Dutz, M., 2003. Competition and regulatory reform in the Turkish electricity industry. Prepared for presentation at the Conference on EU Accession, Turkey, May 10–11 2003, Bilkent Hotel, Ankara.

Bomb, C., McCormick, K., Deurwaarder, E., Kaberger, T., 2007. Biofuels for transport in Europe: Lessons from Germany and the UK. Energ Policy 35: 2256–2267.

Cowie, A.L., Gardner, W.D., 2007. Competition for the biomass resource: Greenhouse impacts and implications for renewable energy incentive schemes. Biomass Bioenerg 31: 601–607.

Demirbas, A., 2007. Progress and recent trends in biofuels. Prog Energ Combust 33: 1–18.

Demirbas, A., Pehlivan, E., Altun, T., 2006. Potential evolution of Turkish agricultural residues as bio-gas, bio-char and bio-oil sources. Int J Hydrogen Energ 31: 613–620.

EMRA (Energy Market Regulatory Authority), 2003. Electricity Market Implementation Manual. Ankara, 2003, accessed from http://www.epdk.org.tr/english/reports/electric/manualapril2003.pdf on 19.08.2005 at 15:24.

Ericsson, K., Huttunen, S., Nilsson, L.J., Svenningsson, P., 2004. Bioenergy policy and market development in Finland and Sweden. Energ Policy 32: 1707–1721.

Fischer, G., Schrattenholzer, L., 2001. Global bioenergy potentials through 2050. Biomass Bioenerg 20: 151–159.

Hepbasli, A., 2005. Development and Restructuring of Turkey’s Electricity Sector: A review. Renew Sust Energ Rev 9(4): 311-343.

IEA (International Energy Agency), 2004. Renewable energy: market and policy trends in IEA countries. Paris: IEA; 2004.

IEA (International Energy Agency), 2005. Energy Policies of IEA Countries: Turkey, 2005 Review. IEA, Paris, France.

Kaltschmitt, M., Weber, M., 2006. Markets for solid biofuels within the EU-15. Biomass Bioenerg 30: 897–907.

Kaya, D., 2006. Renewable energy policies in Turkey. Renew Sust Energ Rev 10: 152–163.

Kaygusuz, K., 2002. Sustainable development of hydropower and biomass energy in Turkey. Energ Convers Manage 43: 1099–1120.

Kaygusuz, K., Sari, A., 2003. Renewable energy potential and utilization in Turkey. Energ Convers Manage 44: 459–478.

Kaygusuz, K., Turker, M.F., 2002. Biomass energy potential in Turkey. Renew Energ 26: 661–678.

Krishnaswamy, V., Stuggins, G., 2003. Private Sector Participation in the Power Sector in Europe and Central Asia: Lessons from the Last Decade. World Bank Working Paper No: 8, The World Bank, Washington DC, USA.

McCormick, K., Kaberger, T., 2007. Key barriers for bioenergy in Europe: Economic conditions, know-how and institutional capacity, and supply chain co-ordination. Biomass Bioenerg 31: 443–452.

Ocak, M., Ocak, Z., Bilgen, S., Keles, S., Kaygusuz, K., 2004. Energy utilization, environmental pollution and renewable energy sources in Turkey. Energ Convers Manage 45: 845–864.

OECD (The Organisation for Economic Co-operation and Development), 2002. Regulatory Reform in Turkey: Regulatory Reform in Electricity, Gas and Road Freight Transport. OECD Reviews of Regulatory Reform.

Roos, A., Graham, R.L., Hektor, B., Rakos, C., 1999. Critical factors to bioenergy implementation. Biomass Bioenerg 17: 113-126.

Rowe, R.L., Street, N.R., Taylor, G., 2007. Identifying potential environmental impacts of large-scale deployment of dedicated bioenergy crops in the UK. Renew Sust Energ Rev, doi:10.1016/j.rser.2007.07.008.

Ryan, L., Convery, F., Ferreira, S., 2006. Stimulating the use of biofuels in the European Union: Implications for climate change policy. Energ Policy 34: 3184–3194.

Skytte, K., Meibom, P., Henriksen, T.C., 2006. Electricity from biomass in the European union—With or without biomass import. Biomass Bioenerg 30: 385–392.

Wrigh, L., 2006. Worldwide commercial development of bioenergy with a focus on energy crop-based projects. Biomass Bioenerg 30: 706–714.

Captions to Tables

Captions to Illustrations

Footnotes

[1] If biomass is utilized in a closed-loop process, the entire process, planting, harvesting, transportation, conversion to electricity via combustion then release into the atmosphere, can be considered as there is no net gain of carbon dioxide in the atmosphere.

[2] Although fossil fuels have their origin in ancient biomass, they are not considered biomass by the generally accepted definition because they contain carbon that has been "out" of the carbon cycle for a very long time. Their combustion therefore disturbs the carbon dioxide content in the atmosphere.

[3] In October 2005, accession negotiations are opened with Turkey, who has been an associate member of the EU since 1963 and an official candidate since 1999. For a more detailed discussion of EU-Turkey relations, see Erdogdu (2002).

[4] For a more in depth discussion of nuclear energy in Turkey, see Erdogdu (2007c).

[5] Turkey imports 96.9% of her natural gas consumption.

[6] This estimate is based on the recoverable energy potential from the main agricultural residues, livestock farming wastes, forestry, wood processing residues and municipal wastes that given in the literature.

[7] Before the Electricity Market Law, the price of energy was decided as a result of negotiations between the energy production companies and the state, which is the buyer. For more information on the subject, see Erdogdu (2005).

[8] For a more detailed discussion of EU-Turkey relations, see Erdogdu (2002).

[9] Almost 80% of the total production cost resides on the raw material cost in bioenergy production (Kondilia et al., 2007).

[10] Energy forests seem to be the best solution, and it has been estimated that 5 million hectares of productive forest land is available to be used as energy forests in Turkey (Ediger et al., 1999).

[11] The potential market instruments would not necessarily need to continue indefinitely. It may only be essential during periods of development and transition to obtain and maintain investor confidence.

[12] Existing approaches are inefficient, uneconomical, and environmentally undesirable because they are essentially just open burning.

[13] For more details on the subject, see Erdogdu (2007b).

Table 1. Renewable energy indicators

Renewable energy indicator	**Existing capacity (end of 2004)**	**%**
Power generation (GW, excluding large hydropower)	**161,6**	**100**
Small hydropower	61,0	37,7
Wind turbines	48,0	29,7
Biomass power	**39,0**	**24,1**
Geothermal power	8,9	5,5
Solar PV, off-grid	2,2	1,4
Solar PV, grid-connected	1,8	1,1
Solar thermal power	0,4	0,2
Ocean (tidal) power	0,3	0,2
Hot water/space heating (GWth)	**325**	**100**
Biomass heating	**220**	**67,7**
Solar collectors for hot water, Heating (glazed)	77	23,7
Geothermal direct heating	13	4,0
Geothermal heat pump	15	4,6
Households with solar hot water	40 million	
Buildings with geothermal heat pumps	2 million	
Transport fuels (billion lt/yr)		
Ethanol production	31	

Biodiesel production	2,2
Rural (off-grid) energy (million)	
Household-scale biogas digesters	16
Small-scale biomass gasifiers	NA
Household-scale solar PV systems	2
Solar cookers	1

Table 2. Selected indicators for Turkey (2004)

Indicator	Value
Population (million)	71,158,647 (July 2007 est.)
Population growth rate	1.04% (2007 est.)
GDP (purchasing power parity)	$640.4 billion (2006 est.)
GDP (official exchange rate)	$361.1 billion (2006 est.)
GDP real growth rate	6.1% (2006 est.)
GDP per capita (PPP)	$9,100 (2006 est.)
Electricity production	154.2 billion kWh (2005)
Electricity consumption	129 billion kWh (2005)
Electricity Consumption / Population (kWh/capita)	1766.00
CO_2 Emissions[a] (Mt of CO_2)	209.45

[a] CO2 Emissions from fuel combustion only. Emissions are calculated using IEA's energy balances and the Revised 1996 IPCC Guidelines.

Table 3. Energy balances for Turkey (2004)

Supply and Consumption	Coal	Crude Oil	Petroleum Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	Combustibles Renewables and Waste	Electricity	Heat	Total[a]
Production	10531	2224	0	566	0	3963	1271	5557	0	0	24111
Imports	11200	23748	10481	18117	0	0	0	0	40	0	63587
Exports	0	0	-5289	0	0	0	0	0	-98	0	-5387
International Marine Bunkers[b]	0	0	-1005	0	0	0	0	0	0	0	-1005
Stock Changes	648	-183	115	20	0	0	0	0	0	0	599
TPES	**22379**	**25789**	**4302**	**18704**	**0**	**3963**	**1271**	**5557**	**-59**	**0**	**81905**
Transfers	0	0	0	0	0	0	0	0	0	0	0
Statistical Differences	-64	191	0	0	0	0	0	0	0	0	126
Electricity Plants	-8701	0	-764	-7964	0	-3963	-85	-21	12436	0	-9063
CHP Plants	-75	0	-1131	-3028	0	0	0	-5	524	450	-3265
Heat Plants	-532	0	0	0	0	0	0	0	0	0	-532
Gas Works	0	0	0	0	0	0	0	0	0	0	0
Petroleum Refineries	0	-26065	26534	0	0	0	0	0	0	0	469
Coal Transformation	-1910	0	0	0	0	0	0	0	0	0	-1910
Liquefaction Plants	0	0	0	0	0	0	0	0	0	0	0
Other Transformation	0	85	-85	0	0	0	0	0	0	0	0
Own Use	-302	0	-1706	-100	0	0	0	0	-615	0	-2724
Distribution Losses	-27	0	0	-19	0	0	0	0	-1999	0	-2045

TFC	**10766**	**0**	**27150**	**7594**	**0**	**0**	**1186**	**5530**	**10287**	**450**	**62962**
Industry sector	**8361**	**0**	**4460**	**2178**	**0**	**0**	**121**	**0**	**4992**	**0**	**20112**
Transport sector	**0**	**0**	**13079**	**105**	**0**	**0**	**0**	**0**	**63**	**0**	**13246**
Other sectors	**2405**	**0**	**5858**	**4881**	**0**	**0**	**1065**	**5530**	**5233**	**450**	**25420**
Residential	2405	0	2879	3640	0	0	1065	5530	2375	0	17894
Commercial and Public Services	0	0	0	1240	0	0	0	0	2522	0	3763
Agriculture / Forestry	0	0	2979	0	0	0	0	0	318	0	3297
Fishing	0	0	0	0	0	0	0	0	17	0	17
Non-Specified	0	0	0	0	0	0	0	0	0	450	450
Non-Energy Use	**0**	**0**	**3754**	**430**	**0**	**0**	**0**	**0**	**0**	**0**	**4184**
- of which Petrochemical Feedstocks	*0*	*0*	*1406*	*430*	*0*	*0*	*0*	*0*	*0*	*0*	*1836*

(in thousand tonnes of oil equivalent (ktoe) on a net calorific value basis)

[a] Totals may not add up due to rounding.

[b] International marine bunkers are not subtracted out of the total primary energy supply for world totals.

Table 4. Installed capacity and electricity generation in Turkey (2005)

Fuel Type	**Installed Capacity (MW)**	**%**	**Electricity Generation (GWh)**	**%**
Natural Gas	14199	36.58	72700	44.74
Hydropower	12906	33.25	40800	25.11
Coal	9117	23.49	40700	25.05
Oil	2527	6.51	8000	4.92
Biomass	**28**	**0.07**	**150**	**0.09**
Geothermal	23	0.06	90	0.06
Wind	20	0.05	60	0.04
Total	**38820**	**100**	**162500**	**100**

Table 5. Present and planned biomass energy production in Turkey

Years	**Total Biomass Production (ktoe)**
2000	6982
2005	7260
2010	7414
2015	7320
2020	7520
2025	7810
2030	8205

Table 6. Production of bioenergy resources in Turkey

Crop/Animal	Residue	Theoretic Production (tons/year)	Actual Production (tons/year)	Available residue manure (tons/year)
Crop residues				
Wheat	Straw	29,170,755	23,429,907	3,514,486
Barley	Straw	9,992,948	8,963,012	1,344,452
Rye	Straw	405,188	358,04	53,706
Oats	Straw	419,678	321,236	48,185
Maize	Stalk	5,911,902	4,970,259	2,982,155
	Cob	596,592	1,907,307	1,144,384
Rice	Straw	582,555	209,532	125,719
	Husk	88,527	77,742	62,198
Tobacco	Stalk	362,763	410,778	246,467
Cotton	Stalk	6,317,181	2,520,281	1.512,17
	Ginning	481,527	732,22	585,776
Sunflower	Stalk	2,341,554	2,259,121	1,355,472
Groundnut	Straw	127,054		
	Shell	27,621	28,638	22,91
Soybean	Straw	60,468	21,872	13,123
Fruit and fruit tree residues				
Apricots	Shell		154,573	
	Tree pruning	1,328,846	86,964	69,571
Sour cherries	Shell		39,916	
	Tree pruning	137,359	21,4	17,12
Olive	Cake	673,484	829,816	746,834
	Tree pruning		441,254	220,627
Pistachio	Shell		14,007	4,202
	Tree pruning		209,611	167,88
Walnut	Shell	173,546	75,792	60,633
	Tree pruning		50,48	25,24
Almond	Shell	44,366	25,784	23,205
	Tree pruning	13,076	28,5	22,8
Hazelnut	Shell	698,499	566,437	453,15
	Tree pruning		2,177,986	1,742,389
	Tree pruning	236,852	88,465	70,772
Orange	Tree pruning	3,424,439	237,686	190,148
Mandarin	Tree pruning	981,97	1,093,430	82,744
Grapefruit	Tree pruning		14,309	11,447
Animal wastes, available dry manure and biogas				
Cow	Waste	16,211,033	10,535,172	10,535,172
Sheep	Waste	6,139,581	758,146	758,146
Poultry	Waste	1,932,924	1,913,594	1,913,594

Figure 1. Bioenergy flow chart