The Challenges Associated with Lignocellulosic Bioethanol Production and Consumption Considering Renewable Energy Policies in Turkey

Yildirim, H.[1,2], Izbul, E.[1,2] Buyukbay, B.[1,2], Ciliz, N.[1,2]

[1]*Bogazici University Institute of Environmental Sciences, 34342 Bebek, Istanbul – Turkey*

Tel: +90 212 359 6947, Fax: +90 212 257 5033, e-mail: cilizn@boun.edu.tr

[2]*Bogazici University, Sustainable Development and Cleaner Production Center 34342 Bebek, Istanbul – Turkey*

**cilizn@boun.edu.tr*

Abstract

Bioethanol is an attractive alternative as a transportation fuel due to increasing energy demand against decreasing fossil fuel sources which cause greenhouse gas (GHG) emissions. Many countries have implemented support programs for fuel bioethanol consumption to decrease dependency on oil such as ProAlcool in Brazil, Clean Cities in U.S. and many incentives and tax exemptions. Turkey has a high potential for bioethanol production from agricultural wastes such as wheat straw and corn stover which have the highest annual production rates with $4x10^{-6}$ and $3.5x10^{-6}$ tons/yr. However, bioethanol production and consumption has not yet been widely applied due to lack of regulatory support. This paper evaluates the challenges about bioethanol production and consumption in Turkey such as difficulties in storage and distribution systems, insufficient taxes and legislation on renewable energy. It is concluded that improvement of tax incentives and development of governmental programs should be considered to increase bioethanol fuel use in Turkey.

Keywords: lignocellulosic bioethanol, transportation, storage, renewable energy regulations

1. 1. Introduction

The energy demand of the world has been increasing steadily for the last several decades, and estimations point that it will continue and accelerate in the coming decades. Interest in renewable biofuels has been increasing world-wide owing to alarming reports on environmental issues as well as the limited oil resources.

Combustion of fossil fuels causes to increase in greenhouse gases (GHG), primarily carbon dioxide (CO_2), and local emissions concentrations such as particulates, sulfur, and lead in the atmosphere. Renewable liquid biofuels for transportation have recently attracted huge attention in different countries all over the world because of its renewability, sustainability, storability, common availability, biodegradability, contribution to regional development and success in reduction of GHG emissions [1].

As bioethanol has the most equivalent properties with fuel gasoline, it is supposed to have the biggest share in energy and transportation market [2]. With the implemented bio-fuel programs set down by governments, biofuels have been drawing attention around the world. The U.S, Brazil, and several EU member states have developed programs promoting use of biofuels in the world. Ethanol production from cornstarch has increased by reducing motor fuel excise taxes on fuels derived from ethanol to reduce air pollutants in response to the Clean Air Act in U.S. In South America, Brazil government made it mandatory to blend anhydrous ethanol with gasoline since 1976 to encourage the use of vehicles that use bioethanol to replace gasoline. Since July, 2007 the mandatory blend is 25% anhydrous ethanol with 75% gasoline or E25 blend [3].

Turkey with important amounts of agricultural facilities has a high potential for second generation bioethanol from lignocellulosic wastes such as corn stover and wheat straw. Despite that, bioethanol production and consumption has not yet been widely applied due to lack of challenges of regulatory support mechanisms and difficulties in its storage and distribution systems.

1. Current Energy Situation in the World

Researches and statistics show that fossil fuel resources are depleting while the energy demand is increasing. According to World Bank 2010 data, the energy consumption per capita in world was 1802.57 kg of oil equivalent per capita in 2009 and 1638.3 kg in 2000, which equals a rise of 10%. Despite that, the total proven reserves of world for oil, natural gas and coal was reported as 188.8 billion tons, 187.1 trillion m^3 and 860.9 billion tons by the end of 2010, respectively [4]. With current consumption trends, the reserves-to-production (R/P) ratio of world proven reserves was also reported as 41.6 years for oil, 60.3 years for natural gas and 133 years for coal by 2010 [5]. Moreover, in New Policies Scenario mentioned in World Energy Outlook (WEO) 2011 report, the global primary energy demand is supposed to increase by 1/3 fold of the demand in 2010 by 2035 [6].

Concurrently, transportation sector is 95% dependent on fossil fuel and responsible for 61% of the world oil consumption [7]. Furthermore, it is a significant contributor to GHG emission, accounting for about 23% of global CO_2 emissions [8]. According to New Policies Scenario, energy-related CO_2 emissions will increase by 20% following a trajectory consistent with a long-term rise in the average global temperature in excess of 3.5°C between 2010 and 2035 [9]. The adverse effects of GHG emissions on the environment, together with declining petroleum reserves have brought an interest for production of bioethanol from renewable resources as a potential alternative to petroleum-derived transportation fuels. As seen in Table 2.1, wheat straw ethanol has a high percentage of GHG emission saving of 87% which will later directly affect the reduction of global warming potential.

Table 2.1. Estimated typical GHG emission saving values for future bioethanol fuels produced from different feedstocks [10]

Biofuel Production Pathway	Typical GHG Emission Saving
Wheat ethanol (lignite as process fuel in CHP plant)	32 %
Wheat ethanol (straw as process fuel in CHP plant)	69 %
Wheat Straw Ethanol	87%
Waste Wood Ethanol	80%
Farmed Wood Ethanol	76%

2. Bioethanol as a Renewable Fuel

Bioethanol (ethyl alcohol, grain alcohol, CH_3–CH_2–OH or ETOH) is an attractive alternative fuel because it is a renewable bio-based resource and contains 35% oxygen thereby provides potential to reduce particulate and sulfur emissions in compression–ignition engines. Bioethanol has a higher octane number (108), broader flammability limits, higher flame speeds and higher heats of vaporization than gasoline. These properties of bioethanol fuel lead to theoretical efficiency advantages over gasoline in an internal combustion engine since its consumption provides a higher compression ratio, shorter ignition time, leaner burn engine and a reasonable antiknock value [11].

Bioethanol can be produced from sucrose-containing feedstocks (e.g. sugar cane, sugar beet, sweet sorghum and fruits), starch materials (e.g. corn, wheat, rice, potatoes, cassava, sweet potatoes and barley) and lignocellulosic materials (e.g. wood, straw and grasses). The conversion of lignocellulosic feedstock that composed of mainly cellulose and hemicellulose to monomeric sugars is harder than the conversion of starch and sugar containing feedstocks, resulting in lower ethanol yield [12]. Although feedstocks such as sugarcane or cereal grain have recently been used for bioethanol production; lignocellulosic feedstock has gained popularity since it is a cheaper and abundant alternative and does not compete with the food sector [13].

3. World Bioethanol Production

In 2009, global production of bioethanol reached 74 billion litters from 51.1 billion liters (2006) which signify an increase of about 45% [14]. Brazil and the United States (U.S) are the world leaders that exploit sugar cane and corn, respectively, accounting for about 70% of the world bioethanol production. The potential bioethanol production could replace 353 billion liters of gasoline (32% of the global gasoline consumption) when bioethanol is used as E85 fuel for a midsize passenger vehicle. On a well to wheel basis, bioethanol gives a 70% CO_2 reduction versus petroleum. This means that a 5% blend produces 3.5% less carbon emissions, whilst an 85% blend would achieve a 50% reduction [15]. Furthermore, lignin-rich fermentation residue, which is the co-product of bioethanol made from lignocellulosic residue, can potentially generate both 458 terawatt hours (TWh) of electricity (about 3.6% of world electricity production) and 2.6 EJ of steam [16].

Table 4.1. Bioethanol yields from different energy crops [1], [14]

Country	Energy Crop	Bioethanol Yield (l/ha)	Bioethanol Production in 2011 (billion liter)
Brazil	Sugarcane, 100%	6641	18.93
U.S	Corn, 98% Sweet sorghum, 2%	3370 1365	53
China	Corn, 70% Wheat, 30%	2011 1730	2.1
EU-27	Wheat, 48% Sugar beet, 29%	1702 5145	3.79
Canada	Corn, 70% Wheat, 30%	3460 1075	1.75

Brazil and U.S are the world's largest producer of ethanol. In 2011, European Union (EU) has an ethanol production of about 3.8 billion liter while U.S and Brazil have about 53 and 19 billion liter, respectively (Table 4.1). Brazil utilizes sugarcane for bioethanol production while the U.S and EU mainly use starch from corn, wheat and barley, respectively. Brazil is the largest single producer of sugarcane with about 31% of global production [1].

4. Bioethanol Incentive Program and Policy Examples

In 1975, the National Alcohol Fuel Program (ProAlcool) which aims to increase production of bioethanol was initiated in Brazil. Since 2007, the mandatory blend has been 25% of anhydrous ethanol [(96 bio-ethanol + 4 water)/100]. More than 80% of Brazil's current automobile production has flexible-fuel capability, up from 30% in 2004. Bioethanol is widely available at almost all of Brazil's 32,000 gas stations [3].

In the United States, U.S Department of Energy created Clean Cities whose mission is to advance the energy, economic, and environmental security of the U.S. by supporting local decisions to reduce the petroleum consumption in the transportation sector. It provides informational, technical, and financial resources to EPAct-regulated fleets and voluntary adopters of alternative fuels and vehicles. Clean Cities has saved more than 3 billion gallons of petroleum since its inception in 1993. To achieve this goal, Clean Cities employs three strategies; a) replace petroleum with alternative and renewable fuels, b) reduce petroleum consumption through smarter driving practices and fuel economy improvements and c) eliminate petroleum use through idle reduction and other fuel-saving technologies and practices [17].

In the U.S, bioethanol use is promoted by several legislations set by the government. Energy Policy Act of 2005 (EPAct 2005) sets a target of 28.4 billion liters consumption of bio-ethanol by 2012. Production incentive of 10 cents per gallon is applied for the first 15 million gallons of ethanol produced each year for small ethanol producer and a 30% tax credit for installation of alternative fuel stations, up to $30,000 by infrastructure tax credit, is also defined by the this regulation. Energy Independence and Security Act of 2007 (EISA) requires the production of 34 billion liters of biofuels (mainly bioethanol) in 2008, increasing steadily to 57.5 billion liters in 2012 and to 136 billion liters in 2022. Volumetric Ethanol Excise Tax Credit (VEETC) of 2010 aims to subsidize the production of ethanol in U.S. A 45-cent/gallon tax credit for gasoline blenders, a 54-cent/gallon tariff on imports, a $1.01/gallon credit to cellulosic ethanol producers, and a 10-cent/gallon small-producer tax credit for ethanol are included in the policy which covers a duration until 2016 [17].

In 2007, the EU agreed amendment of the Fuel Quality Directive (Directive 2009/30/EC) to allow adequate levels of blending. "EU directive 2009/28/EC on the promotion of the use of energy from renewable sources" envisages a 20% share of all renewable energy sources in total energy consumption by 2020.The European Commission White Paper European Transport Policy for 2010 (COM/2001/0370) calls for dependence on oil in the transport sector (which is currently 98%) to be reduced by using alternative fuels such as biofuels [18].

5. Lignocellulosic Feedstock and Second Generation Bioethanol Production Potential in Turkey

Taking into account that 90% of Turkey's petroleum requirement was imported, bioethanol seems to be one of the most reasonable alternatives for conventional transportation fuels for Turkey. When considering the agriculture based lignocellulosic feedstocks in Turkey, it can be deduced that they are feasible for bioethanol production with their promising capacity (Table 6.1). The annual production capacity of wheat is 22,439,042 tons in Turkey resulting in 3,514,486 tons of straw residue. Also, corn production capacity is 2,209,601 tons/year which makes it fourth largest field crops after wheat, barley and cotton. 4,126,539 tons of corn stover was produced annually as lignocellulosic residue.

Table 6.1. Total field crops production and residues in Turkey [19]

Crops	Residue	Production (ton)	Area (ha)	Yield (kg/ha)	Available Residue (ton)	Calorific value (MJ/kg)
Corn	Stalk	2,209,601	565,109	3,910	2,982,155	18.5
	Cob				1,144,384	18.4
Wheat	Straw	22,439,042	9,424,785	2,381	3,514,486	17.9
Rice	Straw	331,563	59,879	5,537	125,719	16.7
	Husk				62,198	12.98

The regions having the highest production rates for the selected residues are given in Table 6.2. Mediterranean Region (1,957,834 tons corn stover), Central Anatolian Region (1,022,608 tons wheat straw) and Marmara region (78,185 tons rice straw) have the highest production rates for the selected feedstocks [19]. The maximum theoretical bioethanol yield is about 431 L/ton for wheat straw, 427 L/ton for corn stover, and 417 L/ton dry feedstock for rice straw [20]. When the aforementioned theoretical bioethanol yields are assessed with the regions having the highest production rates, it is indicated that the potential bioethanol production from wheat straw, corn stover and rice straw will be 440, 835 and 32 million liters in Turkey, respectively. So the total bioethanol production capacity is evaluated as 1,307 million liters. Despite this potential, currently the installed bioethanol capacity in Turkey is 160,000 tons [21].

Table 6.2. Selected field crops production and residues in Turkey [19]

<table>
<tr><th rowspan="2">Region</th><th rowspan="2">Production (ton)</th><th rowspan="2">Area (ha)</th><th rowspan="2">Yield (kg/ha)</th><th colspan="2">Available residue (ton)</th><th colspan="2">Calorific Value (Mj/kg)</th></tr>
<tr></tr>
<tr><td rowspan="2">Mediterranean Region (Corn)</td><td rowspan="2">758,458</td><td rowspan="2">205,058</td><td rowspan="2">3,699</td><td>Stalk</td><td>Cob</td><td>Stalk</td><td>Cob</td></tr>
<tr><td>1,379,988</td><td>577,846</td><td>18.5</td><td>18.4</td></tr>
<tr><td>Central Anatolian Region (Wheat)</td><td>6,269,294</td><td>3,124,326</td><td>2,007</td><td colspan="2">1,022,608</td><td colspan="2">17.9</td></tr>
<tr><td rowspan="2">Marmara Region (Rice)</td><td rowspan="2">209,094</td><td rowspan="2">37,459</td><td rowspan="2">5,582</td><td>Straw</td><td>Husk</td><td>Straw</td><td>Husk</td></tr>
<tr><td>78,185</td><td>36,116</td><td>16.7</td><td>12.98</td></tr>
</table>

6. Turkey's Renewable Energy Policies for Bioethanol

On September 2006, The Republic of Turkey, Tobacco and Alcohol Market Regulatory Authority (TAPDK) published “Communication Related to Market Supply of Fuel Bioethanol Addition to Gasoline Classes” which has enforced denaturalization of bioethanol to the gasoline to be at least 1% as volumetric ratio prior to market. Another legal authority is Energy Market Regulatory Authority (EPDK) of Republic of Turkey. According to the Amendment Regarding the Communication of Technical Regulation of Gasoline Types of EPDK 2011, the blending ratio of bioethanol produced from national agricultural products to the petroleum based products serving on market as liquid fuel must be minimum 2% for January 2013 and by January 2014 this ratio will be minimum 3%. Regarding this fact, as the establishment of bioethanol plants will be disseminated; bioethanol production will accelerate in Turkey.

7. Challenges in Turkey

Although Turkey has a high potential for bioethanol production, its use as vehicle fuel is not extensively used in Turkey due to the challenges such as difficulties in bioethanol storage and distribution systems, insufficient applications of taxes, legislation and financial support on renewable energy resources.

7.1. Storage and Distribution

Biofuels are quite efficient for storage and distribution when compared with other products of renewable energy technology applications. Biofuel distribution can be easily integrated to existing petroleum and natural gas infrastructure without any need for modification. This contributes to attractiveness of the biofuels since construction cost is reduced seriously. However as ethanol is relatively corrosive, special and licensed vehicles and containers should be used for storage and distribution [2].

Ethanol blends must be specially handled because they are sensitive to water in the normal gasoline distribution system, and underground storage tanks must be thoroughly dried to handle ethanol blends. Water is immiscible in gasoline but fully miscible in ethanol; thus, if ethanol blends contact with water, the phases may separate, causing the ethanol to enter the water phase in pipelines or large storage tanks [22].

7.2. Taxes

Despite the fact that the installed bioethanol capacity is about 160,000 tons which compensates about 8% of current gasoline demand of Turkey; application of bioethanol as vehicle fuel is very inefficient in transportation market. There are no financial supports or any kind of economic incentives for investments for ethanol fuel station installation [23]. In Turkey, just for 2 % tax exemption is applied for bioethanol-gas blend which is a very low value when compared with other EU countries [24].

7.3. Legislation

Although 2% blending by 2013 and 3% blending by 2014 is obligated by the related amendment of EPDK, tax exemption has been just applied for 2% addition of bioethanol to gasoline with regarding to the exemption formulation in the Private Consumption Tax Bulletin in Turkey. The application of 2% blending is implemented by only one company; Petrol Ofisi Inc. This regulation has been released late compare to similar laws of EU member countries and the goals set by the regulation are lower compared to other OECD countries.

8. Conclusion and Recommendations

Bioethanol is the most widely used biofuel for transportation worldwide since most of its properties are closer to gasoline. In 2009, global production of bioethanol reached 74 billion litters from 51.1 billion litters in 2006. Total global fuel bioethanol demand will grow definitely with the continual support of worldwide governmental programs. Bioethanol can be produced from sucrose-containing feedstocks, starch materials and lignocellulosic materials. Lignocellulosic materials are attracting feedstock since they are available around the year, especially found in agricultural wastes, and do not compete with other sectors such as agriculture and food. In this context, corn stover and wheat straw having the highest annual production rate are the most appropriate lignocellulosic feedstocks for fuel bioethanol production in Turkey. On the other hand, there are challenges preventing the extend use of bioethanol, such as difficulties in storage and distribution systems and insufficient application of taxes and legislation. In order to implement the renewable energy schemes successfully in Turkey, concrete roadmaps should be developed from the point of political and legislative approaches.

Strong political support should be provided through adoption of policies in favor of bioethanol use in Turkey. Specific targets with well defined deadlines must be set for share of renewables in the fuel market and CO_2 emission levels. The proposed legislations should ensure that the energy market is accessible to independent bioethanol producers by providing support for a guaranteed market, tax intensives/exclusives, subventions and incentives for bioethanol producers, and obligation of higher blends for vehicle fuel users. The blending and sale of bioethanol blends should be performed by private fuel distribution companies like in the Petrol Ofisi case.

The economic incentives defined by the Government should also encourage both producer and consumer regarding production and use of bioethanol. Considering this fact, tax exemption applied for 2% blends should be raised to 5% blends in Turkey. As the installed bioethanol capacity is sufficient for meeting the current demand, bioethanol production projects should have an easy access to financial support for facilitating investments, grants, loans, subsidies, etc. Provided financial support must cover all costs associated with bioethanol in order to keep the prices competitive with fossil based fuels, particularly through the use of energy taxation.

Moreover, Turkish Public authorities should be active in the set up and implementation part of bioethanol projects. An action plan may be developed for this purpose. It may cover increase of awareness addressing information dissemination campaigns and benefits of bioethanol use. Bioethanol production from lignocellulosics will lead to socio-economic development for rural communities which obviously will prevent the immigration, improvement of relevant sectors such as agriculture, industry, transportation and banking and increasing employment.

REFERENCES

[1] Balat, M., 2011. Production of Bioethanol from Lignocellulosic Materials via The Biochemical Pathway: A review, Energy Conversion and Management, 52 (2011) 858–875.

[2] Melikoğlu, M., and Albostan, A., 2011. Bioethanol Production and Potential of Turkey, Journal of gazi University Engineering and Architecture Faculty, Vol 26, No 1, 151-160, 2011.

[3] Balat, M.,and Balat, H., 2009. Recent Trends in Global Production and Utilization of Bioethanol Fuel, Applied Energy 86 (2009) 2273–2282.

[4] World Bank 2010, World Bank, "Energy Use (kg of oil equivalent per capita) Table" in api.worldbank.org/datafiles/EG.USE.PCAP.KG.OE_Indicator_MetaData_en_EXCEL.xls, accessed on 6 May 2012.

[5]BP Statistical Review of World Energy, 2011 in www.bp.com/assets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2011/STAGING/local_assets/pdf/statistical_review_of_world_energy_full_report_2011.pdf, accessed on 6 May 2012

[6]International Energy Agency, "World Energy Outlook 2011" in www.iea.org/weo/docs/weo2011/homepage/WEO2011_Press_Launch_London.pdf, accessed on 6 May 2012.

[7] BP Energy Outlook 2030, 2011. BP Statistical Review of World Energy, London, United Kingdom.

[8]International Energy Agency, "World Energy Outlook 2009" in http://www.iea.org/textbase/npsum/weo2009sum.pdf, accessed on 6 May 2012.

[9] International Energy Agency, "World Energy Outlook 2011 Factsheet, "How will global energy markets evolve to 2035?" in www.iea.org/weo/docs/weo2011/factsheets.pdf, accessed on 6 May 2012.

[10] DIRECTIVE 2009/28/EC of the European Parliament and of the Council, Official Journal of the European Union, L 140/16.

[11] Balat, M.,Balat, H., and Öz, C., 2008. Progress in Bioethanol Processing Progress in Energy and Combustion Science, 34, 551–573.

[12] Ohgren, K, Bura, R., Saddler J., Zacchi, G., 2007. Effect of Hemicellulose and Lignin Removal on Enzymatic Hydrolysis of Steam Pretreated Corn Stover, Bioresource Technology, 98, 2503–2510.

[13] Palmarola-Adrados, B., Choteborsk´a, P., Galbe, M., Zacchi, G., 2005. Ethanol Production from Non-Starch Carbohydrates of Wheat Bran. Bioresource Technology, 96, 843–850.

[14] Renewable Fuels Association (RFA). World Bioethanol Production, in http://ethanolrfa.org/pages/World-Fuel-Ethanol-Production, accessed on 6 May 2012.

[15] Hoyo, M. T., and Pinto, G.,2008. Using the Relationship Between Vehicle Fuel Consumption and CO_2 Emissions to Illustrate Chemical Principles, Journal of Chemical Education, 2008, 85 (2), 218-220.

[16] Demirbas, M., F., Balat, M.,and Balat, H., 2009. Potential Contribution of Biomass to the Sustainable Energy Development, Energy Conversion and Management 50 (2009) 1746–1760.

[17] Clean Cities, U.S Department of Energy, in http://www1.eere.energy.gov/cleancities/, accessed on 6 May 2012.

[18] European Renewable Energy Council (EREC), 2010. RE-thinking 2050, A 100% Renewable Energy Vision for the European Union.

[19] LIFE Programme, 2005. Exploitation of Agricultural Residues in Turkey, Ankara, Turkey, Funded by the European Commission, EC Contract Number LIFE03 TCY/TR/000061.

[20]NREL, 2009. Theoretical Ethanol Yield Calculator, in http://www1.eere.energy.gov/biomass/ethanol_yield_calculator.html accessed on 6 May 2012.

[21] The Turkish Ministry of a Energy and Natural Sources, 2010, The Installed Bioethanol Capacity in Turkey, in http://www.enerji.gov.tr/BysWEB/DownloadBelgeServlet;jsessionid=ac100a1530d8436f60a6539d4e518a6180fd3c638609.e3mPbheTb3j0bxiTaO0?read=db&fileId=41998 accessed on 6 May 2012.

[22] Wyman, C., 1996. Handbook on Bioethanol: Production and Utilization, Copyright by Taylor & Francis.

[23] World Energy Council Turkish National Committee Energy Report 2010, in http://www.dektmk.org.tr/upresimler/Enerji_Raporu_20106.pdf, accessed on 6 May 2012.

[24] The Turkish Private Consumption Tax Bulletin, 2005.