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Current and future aspects of bioethanol production and utilization in Turkey

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ABSTRACT

This study aims to present a comprehensive review on the production of bioethanol, both the first and second generation in Turkey and future aspects regarding R & D studies, standards, and statutory regulations. Due to the primary energy demand in Turkey, petroleum becomes prominent, which is almost wholly exported and causes the emissions of greenhouse gases such as CO_2, CO, CH_4 and NO_X. As an alternative fuel, and to match the convenient features of petroleum, bioethanol has been considered, and has become a large research area in order to improve production from plant residues known as second generation bioethanol (SGB). Instead of first generation bioethanol, producing and using SGB is highly recommended according to sustainability, development, and the domestic economy. Alternative fuels became more prominent in Turkey after Turkey signed the protocol to the United Nations Framework Convention on Climate Change (UNFCCC). Also, according to Turkey's Intended Nationally Determined Contributions (INDCs) report Turkey will carry on studies to increase the usage of wastes to produce alternative fuel at the appropriate sectors, promote alternative fuels and clean vehicles, and reduce fossil fuel consumption. When Turkey's biomass potential and dependence on foreign energy sources are taken into account, bioethanol production and utilization become prominent. Although, Turkey still produces bioethanol form corn, sugar beet, and barley, it falls short of total gasoline consumption. Lignocellulosic materials should be thought as alternative to first generation, and R & D studies should improve how to optimize second generation bioethanol production in the name of decreasing the total process cost.

1. Introduction

Petroleum and natural gas are the most important and primary energy sources for Turkey like rest of the world. Transportation and industry are mostly based on these fossil energy sources. However, as is well-known, the emissions from petroleum cause greenhouse gases and implications in regard to climate change. While it is known that energy is a critically important component in industry, and contributes to long-term economic growth, fossil energy sources emissions are also a threat for sustainability. For these reasons, most countries decided to reduce greenhouse gas emissions. On 11 December 1997, The Kyoto Protocol was adopted in Kyoto, Japan, and entered into force on 16 February 2005 by the Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). Including Turkey, 192 countries signed (191 states and 1 regional economic integration organization) this protocol, and began to reduce greenhouse gases emissions based on the premise that global warming exists and man-made CO_2 emissions have caused it [1]. However, Turkey, which is listed in Annex I to the UNFCCC, has been recognized as having exceptional circumstances, and was, placed in a different situation than the other parties included in Annex I. As Turkey was not a party to the UNFCCC at the time the Protocol was adopted, it was not included in the Annex B of the Protocol which defined quantified emissions limitation or reduction commitments for Annex I parties. Therefore, Turkey does not have a quantified emissions limitation or reduction commitment in the first commitment period between the years 2008–2012 under the Protocol [2]. In December 2015, UNFCCC organized a meeting and invited all countries that had signed the UNFCCC to the "2015 United Nations Climate Change Conference", which was held in Paris, France as a term "Intended Nationally Determined Contributions (INDCs)". In this event, Turkey also submitted their own INDCs just as the other 132 countries had done. The main topic of the meeting was preventing the increasing average global temperature to more than 2 °C, and to reap the many benefits that arise from a necessary global transformation for clean and sustainable development [3]. According to Turkey's INDCs, total greenhouse gas emissions will be reduced up to 21% by 2030. Turkey will implement or contribute to this effort between 2021 and 2030. It covers energy, industrial processes and

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products use, agriculture, land use land-use change and forestry, and the waste sectors. According to Turkey's plan, reported in the “Republic of Turkey, Intended Nationally Determined Contribution, related to bioethanol, Turkey will carry out studies to increase use of waste as an alternative fuel in the appropriate sectors, promote alternative fuels and clean vehicles, and reduce fuel consumption and emissions of road transport with the National Intelligent Transport Systems Strategy Document (2014–2023) and its Action Plan (2014–2016), reuse, recycle, and use of other processes to recover secondary raw materials in order to utilize them as an energy source, or to remove wastes, to recover energy from waste by using processes such as material recycling, bio-drying, bio-methanization, composting, advanced thermal processes or incineration, the utilization of industrial wastes as an alternative raw material, or alternative fuel in other industrial sectors through industrial symbiosis approach. Turkey announced a reduction in greenhouse gas emissions from 1175 to 929 million ton CO_2 equal in 2030 [4]. These obligations bring strict responsibilities in order to start new research and to improve the current methods to produce renewable and domestic energy. When Kyoto Protocol, Turkey's INDC report and the primary energy demand in Turkey are taken into account, utilization of renewable energy resources instead of fossil energy sources became prominent. Bioethanol is distinguished depending on its similar properties to gasoline. Also, the reasons for the increased interest in biofuels and bioethanol can be grouped as follows;

1.1. Increase in technological developments such as product cultivation and transformation methods

The raw material to be used in the production of biofuels can be supplied at a cheaper price and can be converted into higher yields. In other words, in the production of cheap and highly efficient bioenergies, the total cost can come to a position where it can compete with the fossil energies commonly used today. In addition, with the development of technology, it will be possible to obtain more than one product instead of a single product in the process.

1.2. Development of the agricultural sector

National regulations are being made for raw materials to be used for the production of biofuels, production costs and producers. Livestock farming, agricultural activities and forestry products differ according to the climate and geographical conditions of the countries. However, it is expected that employment and production in the agriculture sector will increase and the local economy will improve as well, in case the ideal raw material cultivation for each region is promoted and product procurement is applied.

1.3. Global climate change

Greenhouse gases arising from the use of fossil fuels are increasingly released into the atmosphere every day. Countries have established obligations and sanctions in the light of their work and foresight on sustainability. It is known that the use of biofuels can reduce carbon dioxide (CO_2), which has a large share, especially in greenhouse gases. In particular, the resulting CO_2 from the plants is treated as atmospheric CO_2 in the photosynthetic cycle of the plant. In this case, it is stated that plants will be able to photosynthesize using this CO_2, the amount of CO_2 in the atmosphere will remain constant and there will be no increase in the amount [5].

This study investigates the Turkey's bioethanol production and utilization situation, and future prospects about improving the current status of bioethanol.

2. Bioethanol properties and historical development

Bioethanol can be used in gasoline vehicles, as the pharmaceutical sector is also preferred in cosmetic and industrial processes, and that's why there is an increase in the amount of production every year on a global scale [6]. The reason for the bioethanol to come to the fore is not that it is just an alternative to the gasoline. Global consciousness initiated against fossil fuels surrounding the environment and attempting to reduce greenhouse gas emissions to the lowest are also criteria that increase the importance of bioethanol [7].

When bioethanol compared with gasoline; it is seen that bioethanol has higher octane number, higher burning limit and speed, higher evaporation temperature. Because of these properties, bioethanol can be used as a fuel in engines, resulting in a higher compression ratio and the least damage to the motorcycle can be reduced. However, because of its bioethanol structure, it also has a lower energy density than gasoline. The energy density of bioethanol is 33% lower than that of gasoline. Furthermore, the high probability of corrosion, low combustion luminescence and high tendency to easily form an azeotropic mixture with water are among the disadvantages of bioethanol [8].

Bioethanol provides more efficient combustion in the vehicle engine with approximately 35% oxygen content. As a result of this more efficient combustion, NO_x, hydrocarbons and particle emission values are observed to decrease. The resulting combustion CO_2 is not an extra released gas to the environment, as the bioethanol is produced from biomass sources. Emission CO_2 is captured by plants and used in photosynthesis reactions. Thus, there is no increase in the amount of net CO_2 in the atmosphere [9].

In addition to the use of bioethanol as an alternative fuel to petrol, studies are also being made on the use of diesel-biodiesel-bioethanol mixtures in diesel engines. With this mixture called e-diesel, the effects of adding ethanol on the diesel fuel cetane and octane number are investigated and applied on oxygen combustion efficiency and performance values [10–13].

The term of bioethanol means, unlike synthetic production methods, ethanol is obtained by biomass by biological methods. The widespread use of bioethanol as a fuel has increased in the 20th century. But the first use of ethanol in engines was in 1826 and 1876 by Nicolaus Otto, the inventor of the modern four-cylinder internal combustion engine. In addition, the popularity of ethanol used in lamps for lighting purposes in the 1850s was reduced due to the high usage tax at the time of civil war. In 1908, just after the tax cuts, ethanol was used as fuel in the model named "T" manufactured by Henry Ford. In the 1920s and 1930s, it began to be used as an octane enhancer in gasoline and to be used on vehicles in certain proportions. Especially during the Second World War, its importance and use increased due to the necessity that is near [14].

During World War II, the Japanese used a mixture of bioethanol and gasoline on their warplanes in order to meet their fuel needs. Between 1937 and 1944, the amount of bioethanol production is reported to be about 170 million liters per year. At that time, the use of ethanol as a fuel has become so widespread that the share of bioethanol production in liquid fuels has increased to 26.7%. However, the decline in oil prices following World War II has limited to the production of bioethanol [15].

Due to the serious oil crisis between 1973 and 1979 and therefore the increase in the unit price of gasoline, the use of bioethanol as fuel has been on the agenda again. Today, Brazil and America, which are still pioneers, have gone to serial ethanol production in 1975 and 1978, respectively, by developing the ethanol production industry with the program named "Proalcool" [16]. Despite the intensive effort and production of America and Brazil, the failure of other countries to come to alternative biofuels, especially bioethanol, has led to the inability of bioethanol to develop sufficiently on a global scale. Along with the increase in agricultural product quality and prices in the 1980s, falling oil prices constituted a major obstacle to ethanol production [17].

Today's ethanol industry has emerged in the 1990s, when oil prices began to rise and gasoline and other gasoline-type harms to the environment. Corn has become a basic raw material for an ethanol

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