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Significance and Potential of Bio-Renewable Liquid Fuels in the Energy Sector

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Abstract-With the onset of the Industrial Revolution, innovations in production led to the establishment of factories, resulting in a growing demand for energy across various sectors. Initially, energy was predominantly sourced from fossil fuels; however, due to their finite nature and the environmental damage they cause, there has been a quest for alternative energy sources. Additionally, the increasingly discussed topic of climate change has prompted researchers worldwide to explore new avenues.
The significance of alternative energy sources is underscored, alongside an overview of the current status of energy sources in Turkey and globally. Recent studies indicate that fossil fuels still dominate as an energy source. However, considering the environmental emissions and costs associated with their usage, there has been a shift towards renewable energy sources.
Recent developments in the energy sector, particularly the Russia-Ukraine conflict, have had significant ramifications across Europe and notably in Turkey. Given Turkey's status as an agricultural country, there has been an acceleration in research on biofuel-based energy, a renewable energy source.
Keyword- Bio-Renewable Liquid Fuels, Energy Sector, Biofuel Production, Sustainable Energy Sources.

I. INTRODUCTION

The increasing population and industrialization have led to a rise in energy demand, consequently exacerbating dependency on fossil fuels. However, the intensive use of fossil fuels has resulted in the emission of greenhouse gases into the atmosphere, contributing to various environmental issues such as climate change, acid rain, air, and water pollution. These issues pose significant threats not only to specific regions or countries but to the entire world [1].

In response to these global challenges, governments have begun to prioritize research on environmental sustainability and alternative energy sources. Sustainable energy sources, including bioenergy, are at the forefront of these efforts [1].

In conclusion, the measures and policies taken by governments to address global environmental issues can have significant implications not only within national boundaries but also on an international scale. In this context, renewable and eco-friendly energy sources are receiving considerable attention. According to a study by the International Energy Agency, it is projected that between 2000 and 2030, fossil energy sources will account for approximately 85% of total energy consumption, with oil and natural gas comprising around 60%. In contrast, renewable energy sources are expected to constitute around 15% of the total energy mix. This projection emphasizes the need for further efforts and investments in the energy sector towards sustainable and environmentally friendly solutions [2].

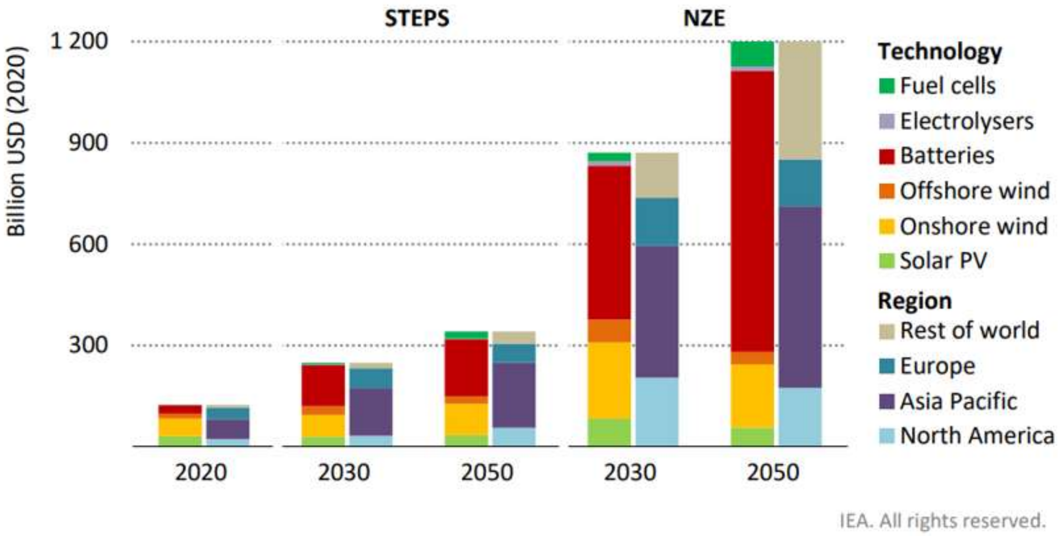

Figure 1. Energy Outlook and Future Approaches in Turkey and Worldwide [2].

1.1. Types of Biofuels

Biofuels are solid, gas, and liquid fuels obtained through various transformation stages of agricultural and forest products along with household waste. These energy sources can be derived from biomass and can be used either independently or in combination with fossil fuels. The combustion of biofuels contributes to an increase in carbon dioxide in the Earth's atmosphere. Studies conducted by De Santi in 2008 revealed that biofuels obtained from crops grown in unsuitable areas for food production contribute to a reduction in greenhouse gas emissions by 18% to 50% [2].

The most well-known liquid biofuels are bioethanol and biodiesel. As depicted in Figure 2, various types of biofuels are produced from biomass, including fertilizers, hydrogen, methane, and wood briquettes [3].

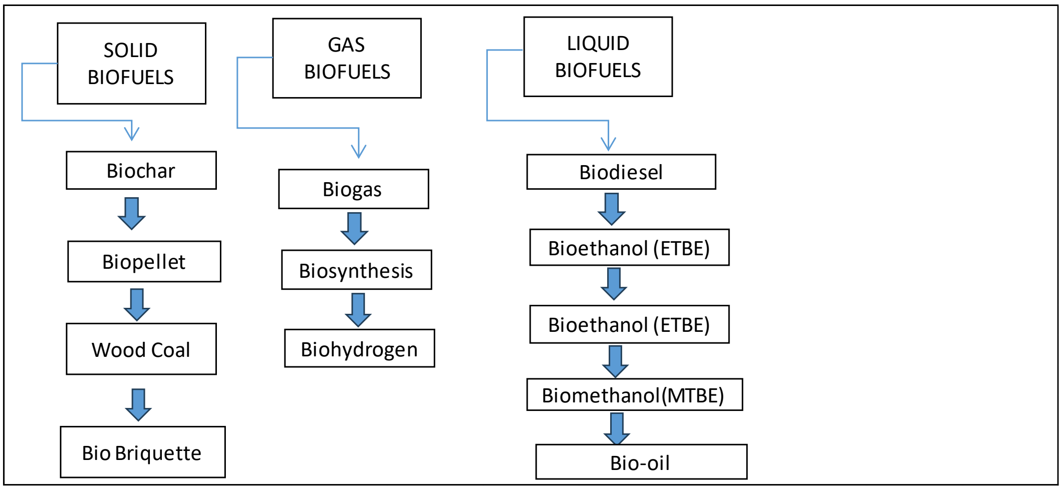

Figure 2. Types of Biofuels [3].

Biofuels derived from biomass include:

- Solid products such as sweet sorghum, oilseed, rapeseed, mustard, grass, and animal waste.
- Liquid products (biologically derived vegetable oils).
- Gas products.

In generally, it is known that ethanol or biodiesel is derived from plant species, certain crops, and animal waste biomass.

1.2 Production Types And Feedstock Selection

Biofuels are categorized into three main generations based on production type and feedstock selection [4].

1st generation biofuels primarily consist of food products, with cereal crops being the most common sources. However, the use of these biofuels sourced mainly from food crops creates competition between the fuel and food sectors. Therefore, balancing this competition and transitioning towards more sustainable sources are crucial for the future sustainability of biofuels [4].

2nd generation biofuels represent advanced biofuel types that can be produced from a wide range of biomass sources. This category typically includes lignocellulosic materials and agricultural residues, which are often challenging to obtain in demand [4].

3rd generation biofuels refer to biofuels that do not compete with food items. Examples in this category often include algae-based biofuels [4].

Biofuel types can also be classified in their mixtures with traditional fuels [5]. This classification emphasizes the compatibility of biofuels with traditional energy sources. Some biofuel types can be used as alternatives to diesel fuels, thereby increasing energy sector diversification and reducing environmental impacts. On the other hand, bioethanol can be blended with gasoline, promoting the use of bioenergy in gasoline consumption. The compatibility of biofuels with traditional fuels is a significant step in supporting sustainability in the energy sector [5]. In this context, the importance of biodiesel production is increasingly growing worldwide. Biodiesel, typically produced from oilseed plants such as sunflower, is a fuel product obtained by reacting oil-bearing seeds with a catalyst. The processing of this biomass yields biodiesel. Various vegetable oils such as castor oil, jojoba, rapeseed, mustard, and peanut oil can be used in biodiesel production. The majority of biodiesel produced worldwide, approximately 86%, is derived from rapeseed [6].

Rapeseed is preferred due to its high oil content (38% to 45% in its seeds), versatility in being used as solid, liquid, and raw oil, containing moderate to high levels of oleic acid, and containing low levels of saturated fatty acids. Additionally, its high boiling point makes it suitable for use as frying oil, while its enrichment with vitamin E is advantageous [7]. FAME stands for "Fatty Acid Methyl Ester," and its production is based on the transesterification reaction. Essentially, this process involves converting oils obtained from biomass sources into methyl esters. Major crops highlighted in FAME production include rapeseed, sunflower, palm oil, and soybeans [6]. Since these vegetable oils are also commonly used in food production, the sourcing of biomass used in biofuel production is a significant global issue [7].

Different oil varieties are converted into a product called HVO (Hydrotreated Vegetable Oil) using the hydrogenation method. In this process, the separation of triglycerides' oxygen in the oil results in the formation of LPG (Liquefied Petroleum Gas) as a byproduct. The obtained LPG can be used in heating and other energy needs. Due to its chemical composition, HVO is highly suitable, especially as a substitute for diesel [8].

In comparison to FAME, HVO has lower fuel quality. Despite the low fuel quality of HVO, its potential as a significant alternative in the biofuel sector lies in its substitutability for diesel and the utilization of various raw materials [8].

BTL (Biomass to Liquids) stands out as one of the biodiesel types. In this type of biofuel, biomass is converted into synthesis gas by Fischer-Tropsch synthesis, then converted into a hydrocarbon liquid through a catalyst [8]. The resulting hydrocarbon liquid typically exhibits compatibility with traditional fuels and can be used in various industrial applications.

1.3 Methods And Stages Of Biofuel Production

The following methods are used in biodiesel formation [9]:

- Blending
- Microemulsion formation
- Pyrolysis
- Transesterification

Currently, biodiesel production is commonly achieved through the transesterification (alcoholysis) method. This process begins with the use of vegetable oils obtained from oilseed-bearing plants. The reaction results in the main products of biodiesel and glycerin [10].

The stages of biodiesel formation are presented in Figure 3 [10].

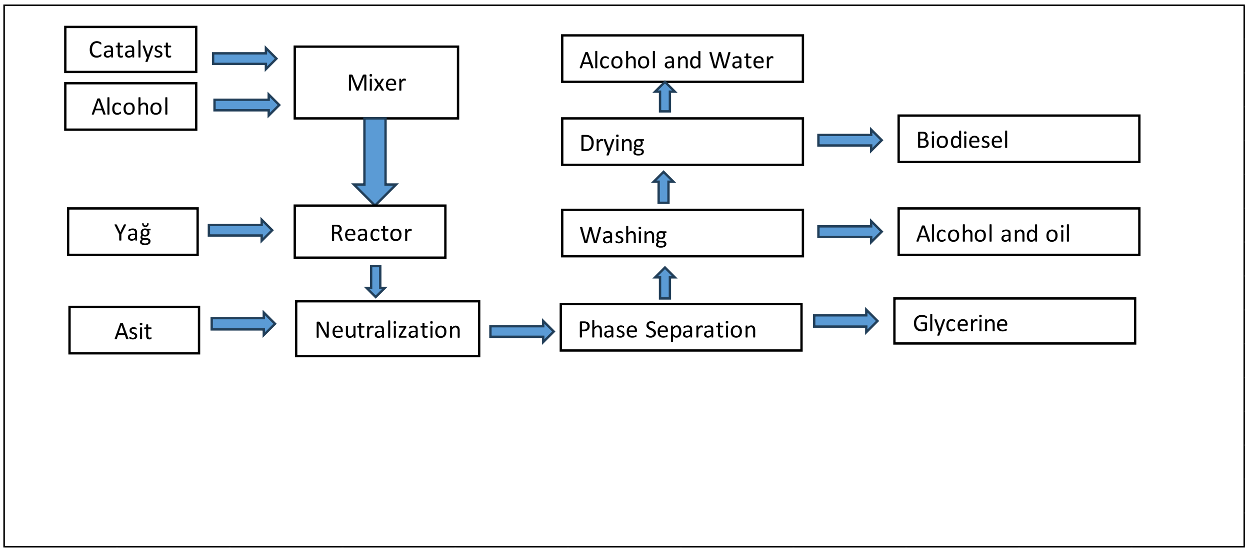

Figure 3. Production of Biodiesel [10].

1.4 The Advantages of Biofuel Production

When examining the fuel properties of biodiesel, it is observed that its flash point is higher compared to diesel fuel, indicating that the use, transport, and storage of biodiesel can be considered a highly reassuring alternative [11].

When considering the positive aspects of biodiesel, the following important factors emerge [12]:

Biodiesel, an alternative to fossil fuels derived from biological sources, stands out as a renewable biofuel. This renewable energy source attracts attention due to its various positive effects.

- Environmentally Friendly: Since biodiesel is produced from biological sources, its carbon footprint is generally lower. Biodiesel feedstocks such as vegetable oils or animal wastes contribute to reducing the amount of carbon released into the atmosphere. This aids in reducing greenhouse gas emissions and combating climate change [12].

- Renewable Resources: Biodiesel can be obtained from various plant sources such as vegetable oils, soybeans, canola, corn oil, or animal wastes [12].

- Low Sulfur Content: Compared to fossil diesel, biodiesel has a lower sulfur content. This characteristic can help improve air quality by reducing air pollution. The low sulfur content particularly has a positive impact on the exhaust emissions of diesel-powered vehicles [12].

- Contribution to Engine Performance: Biodiesel can be used in a compatible manner with traditional diesel fuels and generally has a positive effect on engine performance. Biodiesel can produce cleaner energy during combustion processes, which can contribute to longer lifespans for engines and exhaust systems [12].

- Contribution to Agricultural Economy: The plant sources used for biodiesel production can increase agricultural product diversity and provide additional income for farmers [12].

In conclusion, biodiesel emerges as an important alternative in the energy sector to increase sustainability due to its environmentally friendly characteristics, renewable sourcing, and positive impact on engine performance. These attributes can be evaluated as part of global efforts to reduce the adverse effects of fossil fuels [13].

These positive effects indicate that biodiesel use offers a more environmentally sustainable and less harmful energy alternative to human health. These characteristics contribute to the promotion of biodiesel usage in various sectors and its significance as an alternative replacing fossil fuels [14].

1.5 Challenges Encountered in Biodiesel Utilization

Challenges encountered in biodiesel use include:

- Performance issues such as viscosity increase and fluidity decrease in biodiesel at low temperatures.
- Lack of oxidation stability can lead to sedimentation and formation during storage.
- Since biodiesel has hygroscopic properties, it can lead to microbial growth during storage and difficulty in coping with the corrosive effects of water.
- High concentrations can have a damaging effect on seals in the fuel system.
- Biodiesel can cause blockages by dissolving deposits in fuel tanks due to its solvent effect.
- Gasoline + ethanol blends can be corrosive to copper alloys, zinc, cast iron, and manganese.
- The tendency to evaporate may require special precautions in biodiesel storage [15].

1.6 Bioethanol as an Alternative Fuel

Bioethanol is a biofuel produced through the fermentation of sugar and starch crops into ethanol [16]. Ethanol production occurs through the fermentation of substances containing ethyl alcohol, such as sugar, cellulose, or starch.

In the European Union (EU), wheat and sugar beet, in the United States (US), corn, and in regions where the bioethanol market is advanced such as Brazil, sugarcane are the most commonly used raw materials for bioethanol production. After wheat and corn are processed for ethanol production, the remaining fibers, proteins, and oils are used to produce high-nutrient feed materials. Bioethanol is a clean, non-toxic liquid that does not have any color but has a lower calorific value compared to gasoline [17].

The conversion stages of different biomass into ethanol are illustrated in Figure 4 [18].

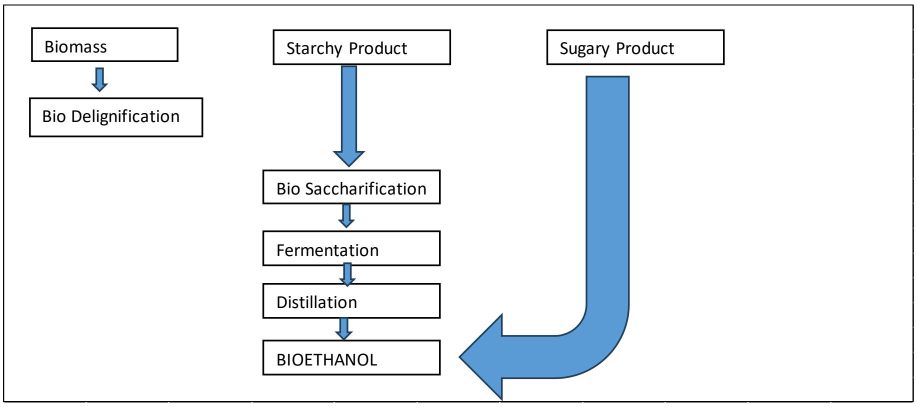

Figure 4. Stages of Bioethanol Production [18].

The main components of biogas are CH_4 and CO_2; additionally, it may contain small amounts of H, SO_3, N, O_2, and CO [18].

1.7 General Evaluation of Biofuels

The benefits of using biofuels include:

- Reduction of Fossil Fuel Dependency: The use of biofuels reduces dependency on finite fossil energy sources, thereby enhancing energy security.
- Reuse of Agricultural Lands: Cultivating crops for biofuel production can create new areas in the agricultural sector and increase economic diversity.
- Balancing Excessive Agricultural Production: Crops used in biofuel production can help balance excessive agricultural production, contributing to food security and promoting diversity in agricultural practices.
- Utilization of Waste Products: Recycling waste products and organic waste in the biofuel production process contributes to waste management, creating a positive impact on waste management practices.
- Reduction of Exhaust Emissions: The use of biofuels leads to lower exhaust emissions compared to fossil fuels, improving air quality and reducing environmental impacts.
- Mitigation of Climate Change Threats: The use of biofuels helps reduce carbon emissions, thereby minimizing the threat of climate change.
- Correction of CO_2 Balance: Plants used in biofuel production absorb CO_2 from the atmosphere through photosynthesis, helping to balance atmospheric CO_2 levels.

These positive effects of biofuels are evaluated in conjunction with increasing interest in sustainable energy sources and environmental responsibility [18].

The negative effects of biofuels can be evaluated from various perspectives:

- Dependence on Agricultural Production: Biofuels relying heavily on agricultural production can lead to various issues with increased demand. Using new agricultural lands for biofuel production may hinder their use for food production purposes. The use of tropical forest areas in the southern hemisphere for bioenergy production can harm natural ecosystems. The expansion of agricultural lands may result in a reduction in land available for food production and lead to increased food prices. Large-scale bioenergy production areas may have adverse effects on the expansion of small farm operations.

- Changes in Forests and Meadows: Creating agricultural lands for biofuels may lead to changes in forests and meadows, resulting in additional and continuous CO_2 loss [18].

II. RESULT

Plants and plant residues used in biofuel production have been identified as alternative and environmentally friendly renewable energy sources that can be used without harming human nutrition or adversely affecting environmental health. In this context, plant-based fuels are generally classified as bioethanol, biodiesel, biogas, biomethanol, biodimethyl ether, and bio-oil.

These renewable energy sources have significant potential for sustainable energy production and use. Bioethanol is an alcohol-based biofuel derived from plant sources. Biodiesel is another type of biofuel produced from oilseed plants or animal fats. Biogas is a gas mixture obtained through the anaerobic digestion process of organic materials. Biomethanol is a biofuel obtained through the methanolization of bioethanol. Biodimethyl ether is another biofuel produced by the reaction of methanol and dimethyl ether. Bio-oil, on the other hand, is a biofuel form that can directly utilize vegetable oils or animal fats. Except for biodiesel, biofuels have limited competitiveness with fossil fuels. Apart from this situation, given the current conditions, the sector's competition with petroleum-based products without tax exemptions is not even considered.

Biofuels find their place in the carbohydrate economy and biolife as biorefinery products. The Ninth Development Plan includes the goal of maximizing the share of domestic and renewable energy sources within the production system. There is a need for the employment opportunities that biofuels will create for this goal. In Turkey's energy production-consumption balance, biofuels should increasingly find a place in a suitable range. Turkey holds a significant position in the biofuel sector considering energy crops and waste quantities. These environmentally friendly and sustainable energy sources represent an important step towards reducing dependence on fossil fuels and minimizing environmental impacts. Encouraging the production and use of these alternative energy sources in our country will support environmental sustainability by increasing diversity in the energy sector.

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