POLİTEKNİK DERGİSİ

JOURNAL of POLYTECHNIC

ISSN: 1302-0900 (PRINT), ISSN: 2147-9429 (ONLINE)

URL: http://dergipark.org.tr/politeknik

Promoting utilization of biofuels in the transportation sector to reduce CO_2 emissions: A comparative analysis

CO_2 emisyonlarını azaltmak için ulaşım sektöründe biyoyakıt kullanımının teşvik edilmesi: Karşılaştırmalı bir analiz

***Author(s) (Yazar(lar))** : Utku BOZBAY[1], Mine GÜNGÖRMÜŞLER[2]*

ORCID[1]: 0000-0003-0458-5790

ORCID[2]: 0000-0002-0207-405X

To cite to this article (Bu makaleye şu şekilde atıfta bulunabilirsiniz): Bozbay U., and Güngörmüşler M, "Promoting utilization of biofuels in the transportation sector to reduce CO_2 emissions: A comparative analysis", ***Journal of Polytechnic***, 25(4): 1741-1751, (2022).

Erişim linki (To link to this article): http://dergipark.org.tr/politeknik/archive

DOI: 10.2339/politeknik.1066167

Promoting Utilization Of Biofuels In The Transportation Sector To Reduce CO_2 Emissions: A Comparative Analysis

CO_2 Emisyonlarını Azaltmak Için Ulaşım Sektöründe Biyoyakıt Kullanımının Teşvik Edilmesi: Karşılaştırmalı Bir Analiz

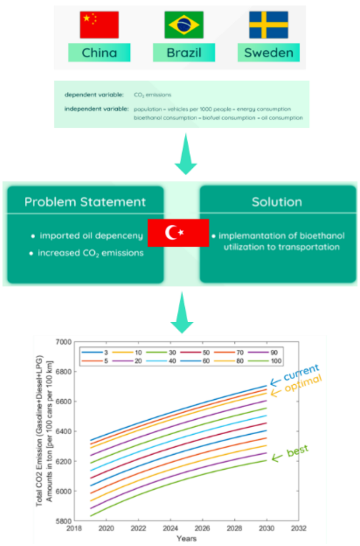
Highlights / Önemli noktalar

- *Economics and sustainability of bioethanol utilization were assessed./Biyoetanol kullanımının ekonomisi ve sürdürülebilirliği değerlendirildi.*
- *Significant reduction in CO_2 emissions by replacing oil with biofuels was reported./ Petrolü biyoyakıtlarla değiştirerek CO_2 emisyonlarında önemli azalma raporlandı.*
- *Comparison of four countries in regards to their energy policies./ Enerji politikaları açısından dört ülke karşılaştırıldı.*
- *Sustainable utilization of renewable sources for the Turkish transportation sector was evaluated./ Türkiye ulaştırma sektörü için yenilenebilir kaynakların sürdürülebilir kullanımı değerlendirildi.*
- *A 10 year forecast analysis demonstrated the effectiveness of bioethanol use./ 10 yıllık tahmin analizi ile biyoetanol kullanımının etkinliği gösterildi.*

Graphical Abstract

The paper reports the outcomes of the comparative study by the selected countries under the scope of the concept of energy security./ Makale, enerji güvenliği kavramı kapsamında seçilmiş ülkeler tarafından yapılan karşılaştırmalı çalışmanın sonuçlarını rapor etmektedir.

Figure. Graphical abstract



Aim

This study aims to assess cases from various perspectives, to discuss and to compare the outcomes with Turkey's policies. / Bu çalışma, vakaları çeşitli açılardan değerlendirmeyi, tartışmayı ve sonuçlarını Türkiye'nin politikalarıyla karşılaştırmayı amaçlamıştır.

Design & Methodology

The parameters of total energy consumption, biofuels consumption, CO_2 emissions, population, and vehicle numbers were used for the statistical and forecasting analysis. / İstatistik ve tahmin analizi için toplam enerji tüketimi, biyoyakıt tüketimi, CO_2 emisyonları, nüfus ve araç sayıları parametreleri kullanılmıştır.

Originality

This is the first report in the literature handling the comparative evaluation of the utilization of bioethanol in the transportation sector with a focus on Turkey, China, Sweden, and Brazil./ Bu, Türkiye, Çin, İsveç ve Brezilya'ya odaklanarak ulaşım sektöründe biyoetanol kullanımının karşılaştırmalı değerlendirmesini ele alan literatürdeki ilk rapordur.

Findings

The results of the study reported the necessity of the use of bioethanol to increase the overall utilization rate of biofuels. / Çalışmanın sonuçları, biyoyakıtların genel kullanım oranını artırmak için biyoetanol kullanımının gerekliliğini bildirmiştir.

Conclusion

The results of the statistical analysis of the study lead to a projection of several nation-wide policies. At the outset, setting governmental milestones to utilize bioethanol in the transportation sector is of great importance. / Çalışmanın istatistiksel analizinin sonuçları, ülke çapında çeşitli politika projeksiyonlarını ortaya çıkarmıştır. Ulaşım sektöründe biyoetanolün kullanılması için hükümet kilometre taşlarının belirlenmesi büyük önem taşımaktadır.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Promoting Utilization of Biofuels in The Transportation Sector to Reduce CO_2 Emissions: Comparative Analysis

Araştırma Makalesi / Research Article

Utku BOZBAY[1], Mine GÜNGÖRMÜŞLER[2]

[1]Division of Sustainable Energy, Graduate School, Izmir University of Economics, Sakarya Caddesi No: 156 35330 Balçova – Izmir, TURKEY

[2]Division of Bioengineering, Graduate School, Izmir University of Economics, Sakarya Caddesi No: 156 35330 Balçova – Izmir, TURKEY

(Geliş/Received : 01.02.2022 ; Kabul/Accepted : 08.06.2022 ; Erken Görünüm/Early View : 24.08.2022)

ABSTRACT

In this study, due to the high contribution of the transportation sector to generate CO2 emissions, an evaluation for the best scenario of the replacement of petroleum derived fuels by renewable and sustainable alternatives was assessed with a multi collative approach suggesting the second-generation bioethanol as the most promising one. In this context, this paper focused on the practices over the past 23 years in the following four countries; Turkey, China, Sweden, and Brazil, with a comparative regression analysis between the CO_2 emissions generated from the consumptions of total energy and biofuels. Accordingly, a curve-fitting and an estimation on the formation of CO_2 emissions with the incrementing blends of gasoline by 3 to 100% of bioethanol was forecasted for 2020 to 2030. The outcomes of the comprehensive research indicated the international and national benefits of biofuel use, thus, promoting the potential integration of bioethanol in the Turkish transportation sector.

Keywords: Greenhouse Gas emissions, bioethanol, energy policies, transportation sector, mitigation of CO_2 emissions.

CO_2 Emisyonlarını Azaltmak Için Ulaşım Sektöründe Biyoyakıt Kullanımının Teşvik Edilmesi: Karşılaştırmalı Bir Analiz

ÖZ

Bu çalışmada, ulaşım sektörünün CO2 emisyonu oluşumuna yüksek katkısı nedeniyle, petrol türevi yakıtların yenilenebilir ve sürdürülebilir alternatiflerle ikame edilmesinin en iyi senaryosuna yönelik bir değerlendirme, ikinci nesil biyoetanolün kullanımının önerildiği çoklu bir yaklaşımla değerlendirilmiştir. Bu bağlamda, bu makale, belirtilen dört ülkede son 23 yıldaki uygulamalara odaklanmıştır; Türkiye, Çin, İsveç ve Brezilya. Toplam enerji ve biyoyakıt tüketiminden kaynaklanan CO2 emisyonları arasında karşılaştırmalı bir regresyon analizi ile İlgili ülkeler incelenmiştir. Buna göre, 2020 ila 2030 yılları için biyoetanolün %3 ila %100 oranında artan benzin karışımlarıyla CO2 emisyonlarının oluşumuna ilişkin bir eğri uydurma ve bir tahmin öngörülmüştür. Kapsamlı araştırmanın sonuçları biyoyakıt kullanımının uluslararası ve ulusal faydaları gösterilmiştir, böylece biyoetanolün Türk ulaşım sektörüne potansiyel entegrasyonunun teşvik edilmesi önerilmiştir.enerjili hava kollektörleri (GEHK) genellikle mahal ısıtma ve tarımsal ürünlerin kurutulmasında kullanılmaktadır. GEHK'nde yutucu plaka ve akışkan arasındaki ısı transferinin düşük olmasından dolayı ısıl verimleri düşüktür. Bu çalışmada ısıl verimin yükseltilmesine yönelik olarak yeni bir yutucu plaka geometrisi tasarlanmış ve imal edilmiştir. Konik yayların çapraz sıralı olarak monte edildiği yutucu plakalı ve karşılaştırma amaçlı düz yutucu plakalı kolektörlerden ibaret test düzeneği kurulmuştur.

Anahtar Kelimeler: Sera Gazı emisyonları, biyoetanol, enerji politikaları, ulaşım sektörü, CO2 emisyonlarının azaltılması

1. INTRODUCTION (GİRİŞ)

The excessive use of fossil fuels in almost every area of daily life including the productions of fuels and plastics inevitably resulted in their depletion together with the formation of incrementing amounts of greenhouse gas (GHG) emissions. Specifically, dating back to the first gasoline-powered vehicle being patented to Carl Benz in 1886, the consumption rates of petroleum have increased exponentially [1]. Accordingly, the resulting climate change motivated the use of alternative and renewable energy resources and the research for innovations in this discipline [2], [3]. As expected, this emerging issue is recognized more in the transportation sector where the global current share of fossil fuels is 98% [4], thus, the oil reserves are expected to be exhausted in the following 50 years. According to the International Energy Agency [5], total consumption of oil products reached 4 billion tons of oil equivalent compared to 2.6 billion tons of oil equivalent in the transport sector as of 2018. Due to the sector needing urgent energy-efficient replacements, four generations of biofuels, which are is still under investigation for their environmental impact, have been

** Corresponding Author (Sorumlu Yazar)*
e-mail : mine.gungormusler@ieu.edu.tr

introduced [6]. The different generations are classified regarding their requirement of varying feedstocks and technologies together with their sustainability levels [7]; first-generation (1G), second-generation (2G), third-generation (3G), and fourth-generation (4G) biofuels are derived from food carbohydrates, vegetable oils, and animal fats; agricultural wastes aka lignocellulosic resources; macro and micro algae; and genetically modified algae, respectively. Although 1G and 2G are the major contributors to the sector, 2G is the most abundant one considering their lack of competition with cultivable lands [8]. On the other hand, 3G and 4G biofuels result in the lowest carbon footprints while the requirement of high energy-demanding production processes makes them unavailable for industrial-scale applications [9]. Despite 1G productions accounting for 96% of global bioethanol production, the present study focused on the use of a more sustainable alternative in the transportation sector as 2G bioethanol. It is well known fact that the economic feasibility of the biotechnoligical production is also as significant as the positive environmental impacts. Thus, lignocellulose driven manufacturing of 2G bioethanol meets the criteria by having a raw material that is relatively cheap, readily available, renewable and a safe source of carbon which exists in many plants [10]. The substrate can be converted into bioethanol by two routes; biochemical and/or thermochemical. Considering the molecular nature of the lignocellulosic materials, high temperature (60 to 800°C, respectively) is needed to either apply pretreatment or to gasify the substrate. Following this process, the utilization of microbial fermentation leads to the biochemical pathway [2]. On the other hand, the thermochemical pathway requires the formation of syngas coupled with Fischer-Tropsch (FT) conversion immediately after the gasification step [11]. A combination of these two routes by the fermentation of syngas, which mainly consists of C1 gases such as CO, CO_2, and CH_4, to ethanol is another clean alternative recently introduced to the field [12].

The uncertain future of fossil fuels, as a result of climate change and globalization, has accelerated a shift in energy security studies from a classical approach to an interdisciplinary field. Thus, it became interconnected with the concept of energy security with environmental, social, political, and cultural issues [13]. Considering the six pillars of the energy security concept [14], this paper reveals the importance of security of supply, security of demand, reliability of supply, and security of critical infrastructures for the production of renewable energy sources, nationally, and internationally. In parallel to our statements, it was also historically reported that energy security perspectives have moved from a single-dimensional view of security of supply to a more multi-dimensional context that includes cultural, environmental as well as security and policy dimensions [15]. The drastic increase in the number of vehicles using gasoline in the transportation sector contributes to the instability in energy security. The high demand has not only led to a threat to energy security regarding dependency but also created serious environmental concerns such as a rise in CO_2 emissions. An important step to decrease the toxic emissions was taken by several countries by blending the gasoline with ethanol in varying proportions (5 to 85%) [9]. Bioethanol is commonly considered as a strong alternative to gasoline, specifically for transportation, due to owning the appropriate characteristics such as the high heat of vaporization, having high caloric volumetric values amongst liquid fuels (similar to petroleum as 35.7 MJ/L for petroleum and 23.4 MJ/L for ethanol), being less toxic to the environment thus contributing to the reduction in GHG emissions [9], [16]. In the ethanol market, the second-largest share belongs to Brazil by 30%, which is followed by the European Union and China by 5 and 3%, respectively [17].

The importance of the use of renewable resources became even more visible following the COVID-19 pandemic [18]. Due to the need for isolated spaces during transportation, public transportation is currently being replaced with private cars. A survey that was completed in May 2020 depicted that this trend will continue even after the end of the outbreak [19], [20]. These reports clearly depict that there is an urgent need to find alternative solutions for the use of petroleum considering a rise in their consumption is expected. Recently, the use of renewable energy sources is suggested as one of the main solutions [21]. Accordingly, due to Turkey reliying heavily on imported fossil fuels to meet a significant portion of the energy demand [22], in this study, the role of biofuels has been investigated to determine their contribution to reducing CO_2 emissions released by the transportation sector with a comparative evaluation of Turkey and three other countries that have high contributions to the renewable energy market together with their energy perspectives and recent practices. The selected countries Brazil, China, and Sweden were assessed by statistical analysis with a focus on biofuel policies. The significant outcomes of the study reflect the correlations between the parameters of overall energy consumption, type of fuels used, biofuel consumption, and generated CO_2 emissions. Furthermore, an estimation for CO_2 emissions with the replacement of gasoline by 3 to 100% of ethanol was made for the period between 2020 and 2030. Accordingly, the extent of oil dependency and the impacts of CO_2 emissions on Turkey's energy security was discussed. As a result, as far as our concern, this is the first research article to address the environmental concerns by the promotion of biofuel use in the Turkish transportation sector together with short and long-term policy recommendations.

2. MATERIAL and METHOD (MATERYAL VE METOD)

2.1. Data collection

In this study, the parameters of total energy consumption, biofuels consumption, CO_2 emissions, population, and vehicle numbers were used for the statistical and forecasting analysis. The dataset corresponding to these parameters was obtained from open access web pages such as iea.org, worldometer.info, countryeconomy.com, and knoema.com, respectively. The dataset with respect to each country between 1997 and 2017 was extracted separately. Due to the variation in the range of parameters for each country, the dataset used was normalized by per million population regarding the population of the corresponding year and the country.

2.2. Computational analysis

The methodology of the paper follows a multi comparative approach as shown in Fig. 1. The study examines Turkey's dependency on imported foreign oil and the issue of the release of high amount of CO_2 emissions along with the solutions for the transport sector. Under the scope of this framework, the positive impacts of the utilization of an alternative energy source in the transport sector were investigated. Three countries; one being a developed one and two being developing ones, with a total share of %35 in the biofuel market, have been chosen to compare recent practices since 1997. Accordingly, amongst the selected countries; Sweden was chosen because of its applications promoting biofuel use; Brazil was chosen due to being the second-largest bioethanol producer in the world and China was chosen due to the country taking place through the end of the best bioethanol utilizing countries list after the US, Brazil, and the European Union in 2019 [23]. This study aims to assess cases from various perspectives, to discuss and to compare the outcomes with Turkey's policies.

As also mapped in Figure 1, the first part of the research includes the comparison of the key parameters between the countries. Change over a specified period of time and cross-correlation analysis considering total energy consumption, biofuels consumption, and CO_2 emissions were evaluated. Regression analysis by calculating the corresponding Pearson coefficient were used to discover the correlation between the CO_2 emissions-total energy and CO_2 emissions-biofuel consumption for each country. Following, in the second part of the research, the mitigation strategies to reduce CO_2 emissions in the nation-wide transportation sector was investigated. The curve-fitting analysis was performed to the data of the total number of vehicles between 2004 and 2019 including the different types of fuels; gasoline, diesel, and LPG. These forecasted vehicle numbers for the following 10 years (2020 to 2030) were used to estimate the expected CO_2 emissions for the next decade. The analysis and the visualizations were conducted by MATLAB version R2019a [24].

The transportation sector, especially land transport, is the fastest growing source of all GHG including CO_2 emissions thus being considered as the primary contributing sector [25]. For this reason, the investigation on the number of cars has been focused on the amount of CO_2 emissions generated from transportation sector, specifically gasoline cars, therefore the calculations were based on number of gasoline cars in the transportion sector.

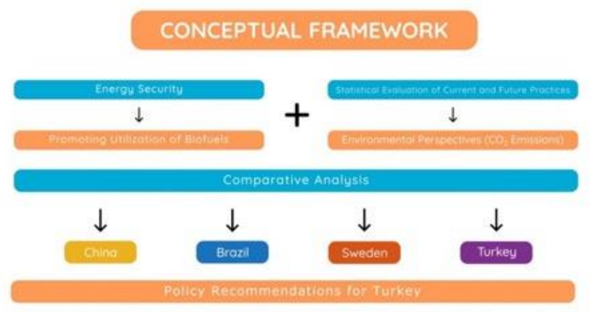


Figure 1. Conceptual framework of the study represented by the key variables of the research.

3. RESULTS (BULGULAR)

3.1. Comparison of energy sources used in the transportation sectors of selected countries

The correlation between energy security concepts in terms of security of supply and reliable supply, as well as the dependence on foreign sources and CO_2 emissions in the transport sector, were examined among the selected countries. Accordingly, as illustrated in Figure 2, a linear trend was observed in the parameters between 1997 and 2017 for all countries except for Sweden. In 2070, which is one of Sweden's major goals, it triggered a serious transition in the transportation sector in an effort to become a net zero country together with the utilization of biofuels. Although there was not a sharp increase in 2009-2010, it is depicted that Sweden has been successful in the related target when the CO_2 emissions of relevant dates is examined. The results of the regression analysis also supported this phenomena by reporting a strong relationship between the total energy consumption and CO_2 emissions by R^2=0.9997, 0.9997, and 0.9999 in Brazil, China, and Turkey, respectively, and by R^2=0.19 for Sweden. In accordance, a statistically significant relationship was obtained between CO_2 emissions and biofuel consumption for Brazil (R^2=0.6626) and China (R^2=0.9674) indicating the ineffectiveness of their policies to mitigate GHG emissions while Sweden depicted statistically insignificant results (R^2=0.0536).

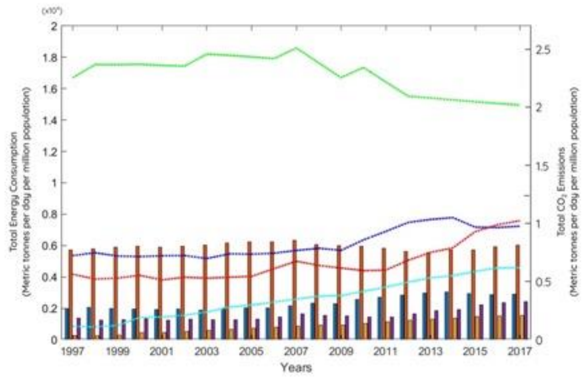


Figure 2. Total energy consumption (1000 barrels per day per million population) in Brazil (blue bar), Sweden (orange bar), China (yellow bar), and Turkey (purple bar) in comparison to released CO2 emissions (metric tons per day per million population) in Brazil (blue line), Sweden (green line), China (turquoise line), and Turkey (red line) between 1997-2017 [5].

China

Countries around the world has their own goals to reduce GHG emissions and they have been submitting their pledges to the UN, aka, "intended nationally determined contributions", or INDCs, by the Paris Agreement [26]. China is one of the countries that commited to source 20% of its energy from low-carbon sources by 2030 and to cut emissions per unit of GDP by 60-65% of 2005 levels. The country has been the world's biggest energy importer since 2009. It is also the second-largest oil consumer since 2018 by 618 million tons.[27] Similar to other countries mentioned in this study, the largest share of the consumption has occurred in the transportation sector in parallel with the increased number of vehicles [28]. Thus, from 1997 to 2017, CO_2 emissions increased from 94 million tons to 881 million tons (Figure 2). Such a rapid increase threatened the national energy security and became one of the main motivations of bioethanol manufacturing in China to lessen dependency and improve air quality [29]. Starting from the 2000s, China began to make arrangements for production and in 2019, it became the world's fourth-largest bioethanol producer with 3 400 million liters after the US, Brazil, and the EU [30]. Although China wanted to achieve a national E10 blending rate for bioethanol by 2020 [31], in 2018 almost all manufacturing relied on 1G bioethanol where 87% was corn-based, with only 2% derived from cellulose feedstocks, thus, the country failed to reach its bioethanol goals due to the issues of food security [32].

Brazil

Brazil, as the largest country in South America and the leading energy consumer, has been confronted with the economic and environmental security aspects of energy. Providing safe, affordable, and clean energy has become the main concern for energy security [33]. The country was severely affected by the oil crisis of the 1970s, when net imported oil accounted for about 70% of the gross domestic supply. Besides, a rapid increase in CO_2 emissions was reported by 200 million tons in 2015 from 137 million tons in 2005, in the transportation sector [5]. Accordingly, aggressive policies have been adopted to minimize Brazil's dependence on imported oil and the country moved to first place amongst crude oil exporters since 2006 (except for 2007), thus, became self-sufficient in the quantity of crude oil [34]. While Brazil has become to exporter from importer over time through strict law oil regulatory, the laws put in place have increased the consumption of bioethanol (1G) in the country [35]. The use of bioethanol-powered vehicles in the transport sector was encouraged by the government [36]. The country generated nearly 35 billion liters of ethanol in 2019 [23], and became the world's second-biggest ethanol producer and the biggest exporter. The developments in the automotive industry have to lead the invention of flexible-fuel-vehicles (FFV). FFVs are capable of running on ethanol or gasoline, thus, they offer unique independence from a single source of energy. According to the annual sales report on different types of fuels by ANFAVEA, sales of FFVs increased by 12.5% y/y to 2 million units in 2018 with a market share of 87.6% [37], making the country the largest biofuel transport program in the world. Brazil's resolution in 2015 called for a 27% blend of ethanol in gasoline. Today, this blended rate requirement is still in process [38]. From the perspective of the car owner, flex-fuel technology also serves the advantage of having the option to choose the cheapest fuel each time.

Sweden

States of the European Union (EU) have agreed on focusing on sustainable energy effectiveness to act on climate change [39]. Accordingly, Sweden aimed to become a net-zero carbon economy by 2045. The total energy consumption in Sweden was reported to be 33 million tons in 2017 with oil products taking second place. Their objective is to reduce transport emissions by 70% from 2010 to 2030 [5]. As also investigated in the present paper, the transportation sector is responsible for a large proportion of oil consumption. In 2017, 65.9% (6 million tons) of the total consumption belonged to the transportation sector [5]. A peak was observed in 2007 with 23 million tons of CO_2 release while it decreased to 20 million tons after that year despite the increase in energy consumption due to the shift to biofuels (Figure 2). Sweden has one of the highest biofuel consumption rates in Europe, 32%, mainly due to the widespread commitment to E85 [40]. In this context, ethanol-powered ED95 (a mix of 95% ethanol) busses and other FFVs were on a trial basis starting from 1986.

Turkey

An increased energy use was reported for Turkey from 2010 by 107 million tons of oil equivalent increased to 153.5 million tons in 2018 [27]. Moreover, oil consumption in the transport sector was approximately 10 million tons in 1997 while it reached 30 million tons in 2017 [5]. Considering the limited fossil resources of the country, a significant amount of oil is currently being imported. It is considered a major threat to national energy security [41]. According to the Turkish Statistical Institute [42], as of the mid of November 2020, 12 million vehicles are registered in traffic where 38% is diesel-powered, 37.4% is LPG powered, 24.2% is gasoline-powered, and 0.1% is electric-powered or hybrid [43]. According to the Sector Report of PETDER [44], the total sales in fuel oil increased by an average of 7% annually in the last five years and reached 35 million tons. It can be suggested that such growth may have an influence on the transportation sector as well generating negative impacts on the mitigation of CO_2 emissions. As also depicted in Figure 3, the inevitable outcomes of the incrementing number of vehicles since 2004 resulted in increased emissions of Turkey to 84 million tons in 2017 from 34 million tons in 2007 [5].

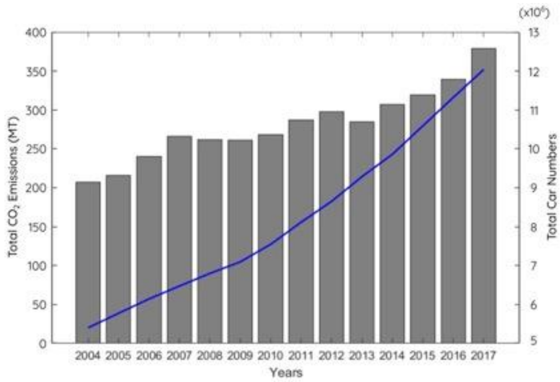


Figure 3. The amount of CO_2 released (in bars) compared to the total number of cars (in solid line) in Turkey between 2004 and 2017.

Table 1. The model coefficients (a, b and c) defined in Equation 1 for each type of vehicle

Fuel Type	a	b	c
Gasoline	1.012E+04	-4.080E+07	4.111E+10
Diesel	1.151E+04	-4.598E+07	4.592E+10
LPG	-1.123E+04	4.545E+07	-4.598E+10
Total	1.252E+04	-4.986E+07	4.964E+10

In accordance with the Paris Agreement, the EU has pledged at least a 40% domestic reduction in GHG by 2030 compared to 1990 levels. Turkey has pledged a 21% reduction in emissions by 2030, compared to a business-as-usual scenario. Moreover, for instance, India promised a 33-35% reduction in emissions compared to 2005 levels, Russia promised a 25-30% domestic reduction compared to 1990 levels, Canada promised a 30% reduction compared to in 2005 levels, Japan promised a 26% reduction in emissions at 2013 levels, Korea planned to reduce its GHG emissions by 37% by 2030 across all economic sectors [45]. Accordingly, a path of action towards sustainability has taken by the Republic of Turkey Energy Market Regulatory Authority (EPDK) on using agricultural wastes as raw material for local biofuel manufacturing. Beginning from 1st of January 2013, the nearby fuel content was 2% while as of 1st of January, 2014, the local gas content rate was anticipated to be at least 3% [46]. As of 2016, bioethanol consumption was reported as approximately 0.79 thousand barrels per day in 2016 (Figure 2), suggesting the requirement of significant improvements in utilization of biofuels and their policies of the country.

3.2. Evaluation of transportation-related CO_2 emissions in Turkey

Transportation-related CO_2 emissions for Turkey was evaluated as a dependent variable towards the total number of vehicles. A projection on the total number of vehicles together with the estimated CO_2 emissions was carried out with the utilization of Equations 1 and 2. Accordingly, the impact of varying amounts of bioethanol blend with gasoline on total CO_2 emissions was evaluated. The transport sector, which constitutes an important part of the total energy need, was discussed to reduce Turkey's CO_2 emissions in line with the Paris Agreement. In this context, the number of vehicles in the Turkish transport sector and the type of fuels (gasoline, diesel, LPG) between 2004 and 2019 were used (Figure 3). A second-order polynomial fit was applied in accordance with the least amount of error for the projection of the total number of vehicles between 2020 and 2030 as defined in Equation 1 by,

$$y=at^2+bt+c \quad (1)$$

where y represents the total number of vehicles, t represents the time and a, b, and c represent the model coefficients. Matlab [24] curve fitting toolbox was used with the following parameters; the total number of vehicles, gasoline, diesel, and LPG powered vehicles (subclass) using the available data between 2004 and 2019. The estimated coefficients are provided in Table 1.

Using the coefficients provided in Table 1, the vehicle numbers with respect to each subclass were forecasted for 2020 and 2030 (Table 2). As depicted in Table 2, the number of vehicles is expected to increase in the next decade with a decrease in the number of LPG type vehicles.

Turkey's current bioethanol rate in transportation is %3. In order to predict the implementation of higher amounts of bioethanol, the impacts on the emissions were evaluated with the incrementing ratio of bioethanol to gasoline as depicted in Figure 4. The data in Table 2 and Table 3 were further used to calculate [24] the potential release of CO_2 emissions in the following 10 years with incrementing bioethanol blends (3-100 %) to gasoline using Equation 2. For each blend, the CO_2 emission rate was estimated with the utilization of Equation 2. Accordingly, the average CO_2 emission reduction rate was determined as 35% taking into account the one over one ratio of fuel and bioethanol as defined in the Bioethanol for Suitable Transport Report supported by the European Commission [47].

$$CO_2=Percent(FuelType) * Emission\ Amount\ (Fuel\ Type) \quad (2)$$

Bioethanol is an alcohol-based fuel often combined with gasoline and diesel in motor vehicles. Up to 80% relative reduction to petroleum use in CO2 emissions was reported with the biofuel encouraging a safer climate for the future (Lashinsky and Schwartz, 2006). Figure 4 represents the gradual reduction in CO2 emissions in parallel with the increasing bioethanol mixing rate. To ensure Turkey's energy security and to reduce CO_2 emission rates, it is clearly shown that effective bioethanol use in fuels is the key factor. Figure 4 indicates that increasing the amounts of the alternative energy source in the fuel mixture will have a significant effect on the reduction of the total CO_2 emissions.

Table 3. The forecasted numbers and amounts acquired by regression analysis for vehicles

	Fuel Consumption (lt/100 km)	CO_2 Emissions (tons)
Gasoline	7.5	60 664
Diesel	7.5	79 86
LPG	7.5	48 803
	Fuel Consumption (lt/100 km)	**CO_2 Emissions (tons)**

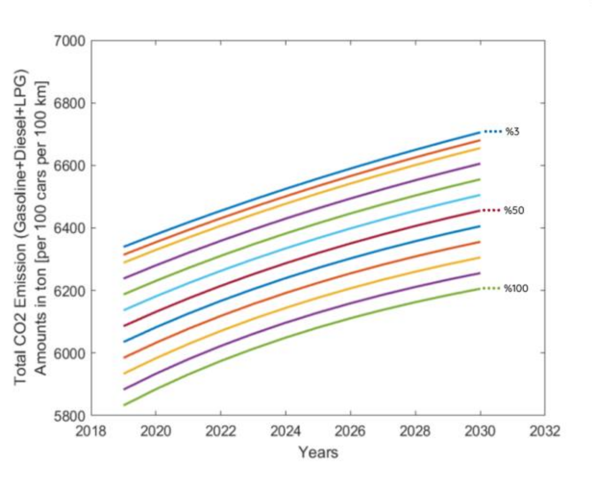


Figure 4. The projection of CO_2 emissions as a result of the incrementing bioethanol blends (3 to 100%) for the total amount for 100 vehicles and per 100 km between 2020 and 2030.

Table 2. The forecasted numbers and amounts acquired by regression analysis for vehicles powered by gasoline, diesel, and LPG, and CO2 emissions (MT; million tons) between the years 2020 and 2030

	Total	Gasoline	Diesel	LPG	Forecasted CO_2 (MT)
20 20	13 727 262,8	3 199 256,0	5 539 458,8	4 902414,8	6 399
2021	14 463 281,2	3 311 128,2	6 068 844,1	4 973 207,6	6 448
2022	15 224 339,4	3 443 247,7	6 621 247,7	5 021 542,2	6 497
2023	16 010 437,4	3 595 614,6	7 196 669,7	5 047 418,6	6 547
2024	16 821 575,2	3 768 228,8	7 795 110,1	5 050 836,8	6 597
2025	17 657 752,8	3 961 090,4	8 416 568,8	5 031 796,7	6 648
2026	18 518 970,2	4 174 199,3	9 061 045,8	4 990 298,4	6 698
2027	19 405 227,4	4 407 555,6	9 728 541,2	4 926 341,9	6 749
2028	20 316 524,4	4 661 159,1	10 419 054,9	4 839 927,2	6 801
2029	21 252 861,1	4 935 010,1	11 132 587,0	4 731 054,3	6 852
2030	22 214 237,7	5 229 108,3	11 869 137,4	4 599 723,1	6 904

The present study clearly depicted that various parameters such as population, number of vehicles, and economical activities are directly affected by the outcomes of practices of each country including energy policies and bioethanol utilization. Total energy and consumption of oil products showed an increasing trend especially in the last ten years for Brazil and China, resulting in a 300% rise in total CO_2 emissions. On the other hand, even though Sweden increased its total energy consumption in recent years, specifically, in the last 5 years, the consumption of oil products has decreased significantly due to the enhanced utilization of biofuels. Therefore, when compared, Sweden represents a very good example of how countries can benefit from the use of biofuels by lowering their toxic emissions. On the other hand, the overview of the total energy consumption per capita resulted in the lowest in China whereas nation-wide consumption and associated CO_2 emissions were considerably high. Although the use of biofuels and bioethanol increases annually, it remains relatively low compared to the overall energy consumption (Figure 2). Similar to China, Brazil has the largest share of energy consumption in oil and petroleum-based products. However, the rate of use of biofuels and bioethanol is almost higher than that of Sweden due to the country having an active program for over 30 years, and is the world leader both in terms of technology and ethanol use. The pushing of the industry by the government led directly to the technical innovation of FFVs that eventually made the market viable in the long run [49].

4. DISCUSSION (TARTIŞMA)

Turkey's emissions in the BAU scenario is expected to triple in the coming years, forecasting a difference 246 million tons of higher CO2.[50] Urgent actions need to be taken to handle the gap in emissions. Due to the current situation, the present study suggested scenarios including the utilization of bioethanol in Turkey. The choice of this cleaner and sustainable fuel source over its conventional counterpart in the transportation sector may provide a lessened overdependence on fossil fuels [51].

Amongst all 4 generations of biofuels, 1G is the oldest and the cheapest technique, however, many conflicts have arisen due to the use of food croplands for energy production [52]. Between 2005 and 2015, in addition to conflicts with food and feed production, concerns about sustainability for both the environment and biodiversity were also raised because of the requirement of large amounts of soil, water, and chemical fertilizers during the biotechnological production. Thus, the nutrient shortage following the destruction of agricultural lands and the generation of toxic emissions has revealed the necessity of new technologies. Thus, 1G biofuel production is becoming less popular every other day and the research shifted to alternative solutions [6]. The most preferred and more efficient alternative source is the lignocellulosic based 2G biofuels. Further research to improve the yields resulted in 3G biofuels that use micro and macro algae [7]. Since they do not compete with food croplands, they stand in a very advantageous position [53]. Even though 3G bioethanol seems like the best option in terms of carbon footprint, the installation costs are very high so that large scale productions are not as preferable [54]. Lastly, a modification of 3G bioethanol with the use of the genetically modified algae is defined as 4G biofuels which is still under development [55], [56]. Overall, it is depicted that the price of bioethanol is highly affected by the cost of the raw material, thus, the use of food wastes as feedstock would inevitably result in sustainable fuels at lower prices [57]. Production of biofuels, specifically bioethanol, does not only come with advantages but also disadvantages. Its biggest advantage is undoubtedly reducing GHG emissions [58], although at the same time releasing CO2 emissions as a result of several processing steps especially in the 1G production. Due to the valorization of waste raw materials by the 2G and 3G bioethanol production processes, they are considered more environmentally friendly. However, the biggest disadvantage at this point is the high cost of the installation of new production facilities, together with the possibility that they may not be a priority in the current agenda of developing countries. Within this context, keeping in mind the economical state of each country, the valorization of waste materials into value-added clean biofuels and the use of these fuels in the transportation sector will help reduce CO2 emissions. Accordingly, it is wise to state that countries should immediately focus on reducing unnecessary transport and developing more energy-efficient systems while the market share of alternative fuels is increasing. The world recently witnessed a relevant example as a result of the COVID-19 pandemic. The significant decrease in demand for fossil fuels has caused the biggest drop in energy demand in the last 70 years together with increasing the share of renewable energy sources [59]. This serious reduction in CO2 emissions proves the efficiency of simultaneous worldwide actions towards sustainability.

In the present study, the recommendations were made based on the evidence acquired from the practices of Sweden and Brazil to replace fossil fuels with biofuels and specifically bioethanol, to mitigate GHG emissions. Accordingly, a higher ethanol ratio in the mixture should be promoted for a more effective reduction in CO2 emissions keeping in mind the requirement of new technologies for vehicle engines if more than 10% of ethanol will be used. A gradual increase and incentives towards technological developments in the field are planned to be applied in the long run to make a significant contribution to Turkey's energy security according to the 11th National Development Plan [60]. In this context, the current 3% blend of bioethanol may be increased to 5% in the mediocre and 10% mediocre and long term. It may also have a positive contribution to lessen the energy imports, which is forecasted at 94%. Thus, all the links in the bioethanol chain should be managed simaltenously focusing on the fact that all parameters within the chain such as uncooked materials, manufacturing, tools, distribution, public awareness taxes and regulations, market development, vehicles, and end-users ought to be taken into consideration when the fuel is introduced locally and nationally.

Globally, the implementation of new technologies for the effective use of biofuels has attracted attention for the last 20 years. Sweden is one of the main contributors to the vehicle market by its FFVs that the engine structures are allowed to mix more than 10% bioethanol. In contrast, although China's 10% bioethanol target may seem reasonable, the country could not achieve the desired objectives due to the production of 1G bioethanol. As expected, bioethanol production has been suspended in a country where food safety is a threat to the country. Brazil has a better improvement than China. The country has become an oil exporter as a result of the legal reforms it implemented from its importer position, the laws put in place have increased the consumption of bioethanol (1G) in the country [61]. The country reached 30.5 million of FFVs, about 60% of the total car fleet [37]. Gasoline in Brazil is blended by 25% ethanol as determined by the government. This ratio and a lower price (30-40% cheaper than petroleum) guarantees and protects the ethanol sector in a sense to attract consumers. As a result, the ethanol industry in Brazil is implementing state planning and support in such a way that the manufacturer chooses the advantages of ethanol while the consumer prefers these tools because they provide flexibility. In South Korea, mandatory ethanol mixing from 2G bioethanol with 10% gasoline was scheduled to start in 2020 [62]. Prior to consumption the advantages and disadvantages of bioethanol were assessed through public surveys. The results depicted the benefits of lignocellulose-based ethanol as giving better environmental sustainability, positive impact on food prices, and supply security in terms of price. In addition, consumer acceptance also was reported as an important parameter in the case of mandatory fuel mixing policies (E5 or E10) or the introduction of E85 to the market. The Swedish Government initially created public awareness for the issue followed by a gradual reduction in oil consumption in the transport sector such as emphasizing the use of public FFVs, or personal FFVs under the name of the green future and a decline by almost 30% of vehicles was reported. In recent years, Swedish policymakers have used tax incentives to encourage higher sales of vehicles that can use alternative fuels. Under the pump act, the sale of biofuels with the installation of alternative fuel pumps at each station has become mandatory [63]. Accordingly, the use of biofuels for the final consumer has become economically convenient, as well as a good balance of supply and demand. The increase in the number of busses working with bioethanol also contributed significantly to the reduction of CO2 emissions [64]. As also depicted in the regression analysis (Table 2), while CO2 emissions have decreased, energy consumption has increased in the transport sector. Although other contributors may be present for this decline, the most important factor was suggested as the increased use of biofuels. For instance, a recent study on the alteration in the standard of living after COVID-19 showed that the most important changes in business life turned out to be working from home, as a result, air pollution was significantly reduced [65]. Currently, Turkey uses a 3% blend of bioethanol to gasoline [66]. According to a recent study on the effects of transportation on GHG emissions in Istanbul, Turkey 3 forecasted scenarios for mitigation including electric rail transportation, electric, and hybrid were reported for reduced CO2 emissions. The results of the study depicted that with the recommended strategies GHG reduction can be realized by 1.1%, 1.11%, and 39% by 2050, respectively [67]. Many governments support biofuels and renewable energy in general for a variety of perceived benefits, including increased domestic energy security, reduced GHG emissions, local environmental and health benefits, and economic growth and job creation. According to a report on developing countries in Asia, bioenergy has a greater positive effect on rural job growth than other energy sources. Furhermore, the biofuel industries hire nearly 100 times more employees per unit of energy generated than fossil fuel industries [68].

Another important issue is the adjustment of bioethanol prices to petroleum. The price of bioethanol versus gasoline is 1.32$/L-1.59$/L, 0.51$/L-0.65$/L, 0.57$/L-0.81L, and 0.81$/L-1.57$/L in Sweden, the US, Brazil, and France, respectively [69]. In this context, incentives should be linked to the development of the market at a particular location such as selecting some regions as pilot areas for bioethanol applications in Turkey as a first step. Incentives for vehicle supply and fuel delivery ought to be promoted for the duration of the pre-marketing section in addition to the removal of legal obstacles and tax deterrents [70]. According to the results of a research conducted in Sweden, the most essential incentive was to ensure that the rate of bioethanol is equal to or lower than that of fuel at the degree of marketplace development together with forcing fuel stations to introduce special fuels [71]. Similar to Sweden, governments can specify the presentation of clean vehicles to alter environmental activity designs and receive models for clean vehicle methodologies. It is also important for countries to discourage the utilization of petroleum derivatives together with enhancing the advancement of energy proficient vehicles utilizing arbitrary power sources. A framework for the recognition of feasible biofuels should be actualized. To sum up, the authors suggest that the use of 2G bioethanol in Turkey may assist with lessening the discharges by 21% offered under the Paris Agreement.

5. CONCLUSIONS AND FUTURE PROSPECTS (SONUÇ ve ÖNERİLER)

The present study reported the necessity of the use of bioethanol to increase the overall utilization rate of biofuels. On that note, energy security policies were also suggested to be supported by the use of renewable energy sources. In this regard, the use of 2G biofuels from waste or cheaper raw materials including lignocellulosic biomass or waste gas streams such as syngas, will make an effective contribution to the field. The use of syngas as a substrate may also help to reduce the emissions of harmful gasses released into the air from several industries. Such an approach will provide a bilateral advantage. Due to syngas mainly being generated as a waste from steel industries, certain pilot regions in Turkey such as Zonguldak, Karabük, Hatay, Bursa, Kocaeli, and Izmir where steel production plants are present, can be selected for the integrated production of 2G bioethanol from syngas.

According to the evaluation of the results of the statistical analysis of the present study, several nation-wide policies are projected. At the outset, setting governmental milestones to utilize bioethanol in the transportation sector is of great importance. This can be followed by urging the use of bioethanol blended fuels essential for public use vehicles with a green future approach. The Turkish Government may first make the public awareness towards this issue and then reduce oil consumption gradually in the transport sector. Another perspective would be promoting incentives and tax reductions for companies and/or individuals that manufacture and sell bioethanol blended fuels. This situation also should be supported by investing in start-ups to develop technologies (engine, pump, etc.) that support the use of bioethanol. In addition to the above mentioned short and medium-term objectives, long-term consideration should be taken into account to open up large scale bioethanol production facilities. Such initiatives can also be encouraged by grants or discounts at very low-interest rates.

As indicated previously, to meet the significant portion of its domestic energy demand, Turkey relies heavily on imported fossil fuels and the country has been importing much more oil due to the continuous increase in energy consumption. However, dependence on imports, from Russia, Iran, or any other country, has created a major threat to energy security and it is emerging as a key factor contributing to the increase in the foreign trade deficit. Moreover, such energy use also resulted in a rapid increase in CO_2 emissions over the past decade while causing added problems regarding energy security since the number of vehicles and oil use in the transportation sector increased drastically. This is particularly important considering the current price instability caused by the global crisis of fossil fuels and derivatives between Russia and Ukraine. This may trigger the orientation to different energy sources in many countries, e.g. bioethanol potentially creating the possibility of a faster decrease in CO_2 emissions.

DECLARATION OF ETHICAL STANDARDS (ETİK STANDARTLARIN BEYANI)

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission./Bu makalenin yazar(lar)ı çalışmalarında kullandıkları materyal ve yöntemlerin etik kurul izni ve/veya yasal-özel bir izin gerektirmediğini beyan ederler.

AUTHORS' CONTRIBUTIONS (YAZARLARIN KATKILARI)

Utku BOZBAY: Investigation, Methodology, Software, Writing-Original draft preparation/İnceleme, Metodoloji, Yazılım, Yazma-Orijinal taslak hazırlama.

Mine GÜNGÖRMÜŞLER: Writing- Reviewing and Editing, Conceptualization, Supervision./Yazma-İnceleme ve Düzenleme, Kavramsallaştırma, Denetim.

CONFLICT OF INTEREST (ÇIKAR ÇATIŞMASI)

There is no conflict of interest in this study./Bu çalışmada herhangi bir çıkar çatışması yoktur.

REFERENCES (KAYNAKLAR)

[1] Dietsche K. and Kuhlgatz, D. "Fundamentals of Automotive and Engine Technology," in ***Fundamentals of Automotive and Engine Technology***, (2014), pp. 1–7.

[2] Miranda J. C. de C., Ponce G. H. S. F., Arellano-Garcia H., Maciel Filho R., and Wolf Maciel M. R., "Process design and evaluation of syngas-to-ethanol conversion plants," ***Journal of Cleaner Production***, vol. 269, p. 122078, (2020).

[3] T. Nasterlack, H. von Blottnitz, and R. Wynberg, "Are biofuel concerns globally relevant? Prospects for a proposed pioneer bioethanol project in South Africa," ***Energy for Sustainable Development***, vol. 23, no. 1, pp. 1–14, (2014).

[4] Liew W. H., Hassim M. H., and Ng D. K. S., "Review of evolution, technology and sustainability assessments of biofuel production," ***Journal of Cleaner Production***, vol. 71, pp. 11–29, (2014).

[5] ***https://www.iea.org/countries/*** IEA, "Countries and Regions," (2020).

[6] Darda S., Papalas T., and Zabaniotou A., "Biofuels journey in Europe: Currently the way to low carbon economy sustainability is still a challenge," ***Journal of Cleaner Production***, vol. 208, pp. 575–588, (2019).

[7] Alaswad A., Dassisti M., Prescott T., and Olabi A. G., "Technologies and developments of third generation biofuel production," ***Renewable and Sustainable Energy Reviews***, vol. 51, pp. 1446–1460, (2015).

[8] Yildirim O., Songür R., Bayraktar E., Demir A., and Ozkaya B., "Recent advances in the pretreatment of lignocellulosic biomass for enhanced biofuel production," ***International Journal of Global Warming***, vol. 22, no. 3, pp. 342–374, (2020).

[9] Sharma B., Larroche C., and Dussap C. G., "Comprehensive assessment of 2G bioethanol production," ***Bioresource Technology***, vol. 313, no. January, p. 123630, (2020).

[10] Tsita K. G., Kiartzis S. J., Ntavos N. K., and Pilavachi P. A., "Next generation biofuels derived from thermal and chemical conversion of the Greek transport sector," ***Thermal Science and Engineering Progress***, vol. 17, no. May 2019, p. 100387, (2020).

[11] Zhao J., Xu Y., Wang W., Griffin J., and Wang D., "Conversion of liquid hot water, acid and alkali pretreated industrial hemp biomasses to bioethanol," ***Bioresource Technology,*** vol. 309, no. March, p. 123383, (2020).

[12] Reyes Valle C., Villanueva Perales A. L., Vidal-Barrero F., and Ollero P., "Integrated economic and life cycle assessment of thermochemical production of bioethanol to reduce production cost by exploiting excess of greenhouse gas savings," ***Applied Energy***, vol. 148, pp. 466–475, (2015).

[13] Jakstas T., "What does energy security mean?," in ***Energy Transformation Towards Sustainability***, (2019).

[14] Biresselioğlu M. E., *Enerji Güvenliği Perspektifinden Türkiye'ye Bakış*. (2015).

[15] ***http://www.cap.lmu.de/download/2008/CAP-Policy-Analysis-2008-01.pdf,*** Baumann F., "Energy Security as multidimensional concept," (2018).

[16] Nigam P. S. and Singh A., "Production of liquid biofuels from renewable resources," ***Progress in Energy and Combustion Science***, vol. 37, no. 1, pp. 52–68, 2011, doi: 10.1016/j.pecs.2010.01.003.

[17] ***https://ethanolrfa.org/ statistics/annual-ethanol-production*** RenewableFuelsAssociation, "Annual Ethanol Production," (2019).

[18] Gray R. S., "Agriculture, transportation, and the COVID-19 crisis," ***Canadian Journal of Agricultural Economics,*** vol. 68, no. 2, pp. 239–243, (2020).

[19] ***https://www.energysufficiency.org/news/news/pandemic-makes-private-cars-more-popular-public-transport-loses-out-survey*** CleanEnergyWire, "Pandemic makes private cars more popular, public transport loses out – survey.," (2020).

[20] ***https://www.cleanenergywire.org/news/public-transport-loses-ground-private-cars-pandemic-survey*** CleanEnergyWire, "Public transport loses ground to private cars in pandemic – survey," (2020).

[21] Tian X. *et al.*, "A bibliometric analysis on trends and characters of carbon emissions from transport sector," ***Transportation Research Part D: Transport and Environment***, vol. 59, no. December 2017, pp. 1–10, (2018).

[22] Özgül S., Koçar G., and Eryaşar A., "The progress, challenges, and opportunities of renewable energy cooperatives in Turkey," ***Energy for Sustainable Development***, vol. 59, pp. 107–119, (2020).

[23] ***https://www.statista.com/statistics/981955/brazil-ethanol-fuel-production*** Statista, "Ethanol fuel production in Brazil from 2009 to 2019," (2020).

[24] ***https://www.mathworks.com/products/matlab.html*** MATLAB, "Mathworks," (2020).

[25] Kawamoto R. *et al.*, "Estimation of CO_2 Emissions of internal combustion engine vehicle and battery electric vehicle using LCA," ***Sustainability (Switzerland)***, vol. 11, no. 9, (2019).

[26] Savaresi A., "The Paris agreement: A new beginning?,**"** ***Journal of Energy and Natural Resources Law***, (2016).

[27] ***https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf*** BP, "BP Statistical Review of World Energy 2019 68th Edition," (2019).

[28] ***http://autonews.gasgoo.com/china_news/70016117.html*** Monika, "China's automobile population totals 250 million units by June 2019," (2019).

[29] Zha J., Tan T., Fan R., Xu H., and Ma S., "How to reduce energy intensity to achieve sustainable development of China's transport sector? A cross-regional comparison analysis," ***Socio-Economic Planning Sciences***, (2020).

[30] ***https://www.statista.com/statistics/281606/ethanol-production-in-selected-countries/*** Statista, "Fuel ethanol production worldwide in 2019, by country," (2020).

[31] Kim G., "Biofuels Annual, China Will Miss E10 by 2020 Goal by Wide Margin," (2019).

[32] ***https://www.fuelsandlubes.com/fli-article/china-pulls-plug-ambitious-fuel-ethanol-target/*** Fuels&Lubes, "China pulls the plug on ambitious fuel ethanol target," (2020).

[33] ***https://wwfeu.awsassets.panda.org/downloads/wwf_powerswitch__scenario_brazil.pdf*** WWF, "Brazil's Sustainable Power Sector Vision 2020," *World Wide Fund for Nature*, (2020).

[34] Luciana, "Oil in Brazil: Evolution of Exploration and Production," (2018).

[35] Susmozas A. *et al.*, "Process strategies for the transition of 1G to advanced bioethanol production," ***Processes***, vol. 8, no. 10, pp. 1–45, (2020).

[36] Corrêa Da Silva R., De Marchi Neto I., and Silva Seifert S., "Electricity supply security and the future role of renewable energy sources in Brazil," ***Renewable and Sustainable Energy Reviews***. (2016).

[37] ***http://www.anfavea.com.br/*** ANFAVEA, "Sao Paulo and Brasilia Brazil: Brazilian Automotive Industry Association," (2020).

[38] ***https://www.transportpolicy.net/standard/brazil-fuels-biofuels/#:~:text=Bio-ethanol&text=E25*** TransportPolicy, "Transport Policy Brazil: Fuels: Biofuels.," (2020). was reinstated in June,produced from domestically-grown sugarcane

[39] Strambo C., Nilsson M., and Månsson A., "Coherent or inconsistent? Assessing energy security and climate policy interaction within the European Union," ***Energy Research and Social Science,*** (2015).

[40] ***https://theicct.org/publications/advanced-biofuel-policies-select-eu-member-states-2018-update*** ICCT, "Advanced Biofuel Policies in Select Eu Member States: 2018 Update," *The International Council on Clean Transportation*, (2018).

[41] TSKB, "Sector Overview. Energy.," (2019).

[42] ***http://www.xn--tik-hoa03x.gov.tr/UstMenu.do?metod=temelist*** TÜİK, "Motorlu Kara Taşıt Sayısı," (2020).

[43] ***http://www.xn--tik-hoa03x.gov.tr/UstMenu.do?metod=temelist*** TÜİK, "Trafiğe Kayıtlı Otomobillerin Yakıt Cinsine Göre Dağılımı," (2020).

[44] PETDER, "2017 Sector Report," (2017).

[45] ***https://www.carbonbrief.org/paris-2015-tracking-country-climate-pledges*** Carbonbrief, "Paris 2015: Tracking country climate pledges," (2015).

[46] ***https://www.epdk.gov.tr/Detay/Icerik/3-3098/benzin-turlerine-etanol-harmanlanmasi-hakkinda-teblig*** EPDK, "Tebliğler," (2014).

[47] ***https://www.sekab.com/app/uploads/2019/01/best-bioethanol-for-sustainable-transport.pdf*** SEKAB, "BioEthanol for Sustainable Transport: Results and recommendations from the European BEST project," (2020).

[48] ***https://money.cnn.com/magazines/fortune/fortune_archive/2006/02/06/8367959/index.htm*** Lashinsky N., Schwartz A,, "How to Beat the High Cost of Gasoline. Forever!," (2006).

[49] Hira A. and de Oliveira L. G., "No substitute for oil? How Brazil developed its ethanol industry," ***Energy Policy***, (2009).

[50] ***https://www.carbonbrief.org/carbon-brief-profile-turkey*** T. Jocelyn, "The Carbon Brief Profile: Turkey," (2018).

[51] Lozano F. J. and Lozano R., "Assessing the potential sustainability benefits of agricultural residues: Biomass conversion to syngas for energy generation or to chemicals production," ***Journal of Cleaner Production***, (2018).

[52] Damay J., Boboescu I. Z., Duret X., Lalonde O., and Lavoie J. M., "A novel hybrid first and second generation hemicellulosic bioethanol production process through steam treatment of dried sorghum biomass," ***Bioresource Technology***, (2018).

[53] Gaurav N., Sivasankari S., Kiran G. S., Ninawe A., and Selvin J., "Utilization of bioresources for sustainable biofuels: A Review," ***Renewable and Sustainable Energy Reviews***. (2017).

[54] Alam F., Mobin S., and Chowdhury H., "Third generation biofuel from Algae," (2015).

[55] Stephen J. L. and Periyasamy B., "Innovative developments in biofuels production from organic waste materials: A review," ***Fuel***. (2018).

[56] Adeniyi O. M., Azimov U., and Burluka A., "Algae biofuel: Current status and future applications," ***Renewable and Sustainable Energy Reviews***. (2018).

[57] Karmee S. K., "Liquid biofuels from food waste: Current trends, prospect and limitation," ***Renewable and Sustainable Energy Reviews***. (2016).

[58] M. Mirzajanzadeh *et al.*, "A novel soluble nano-catalysts in diesel-biodiesel fuel blends to improve diesel engines performance and reduce exhaust emissions," ***Fuel***, (2015).

[59] ***https://www.weforum.org/agenda/2020/05/covid19-energy-use-drop-crisis/*** D. Broom, "5 things to know about how coronavirus has hit global energy," (2020).

[60] SBB, "Eleventh Development Plan," (2019).

[61] Cortez L. A. B. and Baldassin R., "Policies Towards Bioethanol and Their Implications: Case Brazil," in ***Global Bioethanol: Evolution, Risks, and Uncertainties***, (2016).

[62] Mamadzhanov A., McCluskey J. J., and Li T., "Willingness to pay for a second-generation bioethanol: A case study of Korea," ***Energy Policy***, (2019).

[63] Månsson A., "Energy security in a decarbonised transport sector: A scenario based analysis of Sweden's transport strategies," ***Energy Strategy Reviews***, (2016).

[64] Lindfeldt E. G., Saxe M., Magnusson M., and Mohseni F., "Strategies for a road transport system based on renewable resources - The case of an import-independent Sweden in 2025," ***Applied Energy***, (2010).

[65] ***https://tr.euronews.com/2020/04/22/dunya-covid-19-onlemleri-sayesinde-kendini-temizliyor-arast-rma*** Aktan S., "Dünya Covid-19 önlemleri sayesinde kendini temizliyor," (2020).

[66] ***https://www.resmigazete.gov.tr/eskiler/2017/06/20170616-7.htm*** ResmiGazete, "Benzin türlerine etanol harmanlanmasi hakkinda tebliğde değişiklik yapilmasina ilişkin tebliğ," *Resmi Gazete (2017:30098),* (2017).

[67] Güzel T. D. and Alp K., "Modeling of greenhouse gas emissions from the transportation sector in Istanbul by 2050," *Atmospheric Pollution Research*, no. August, pp. 0–1, (2020).

[68] Gheewala S. H., Damen B., and Shi X., "Biofuels: Economic, environmental and social benefits and costs for developing countries in Asia," ***Wiley Interdisciplinary Reviews: Climate Change***, vol. 4, no. 6, pp. 497–511, (2013).

[69] ***https://www.globalpetrolprices.com/*** GPP, "Retail energy price data," *Global Petrol Prices*, (2020).

[70] Sprei F. and Wickelgren M., "Requirements for change in new car buying practices-observations from Sweden," ***Energy Efficiency***, (2011).

[71] TheSwedishParliament, "The Act on the Obligation to Supply Renewable Fuels – A follow-up report," (2009)