**Düzce University**
**Journal of Science & Technology**

*Research Article*

# The Investigation on Economic and Ecological Impacts of Tendency to Electric Vehicles Instead of Internal Combustion Engines

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## ABSTRACT

Transportation is nearly entirely (<99.9) powered by internal combustion engines (ICEs) burning the fossil fuels like oil and liquefied petroleum gas. However, the world fossil fuels' reserves are finite, and it is foreseen it will run out nearly 50 years for oil, 60 years for natural gas, and 80 years for coal. Thus, humankind has rapidly started to seek new, renewable and clean energy sources for particularly powering the vehicles. In this scope, the biggest alternative to classic internal combustion engines is undoubtedly electric vehicles (EVs) like in the past. In recent years, there has been an increasing interest in electric vehicles, and over the past decade, there has been a dramatic increase in EVs production of 1500%. On the other hand, Turkey has failed to keep pace with this increase, and seen 475 EVs by end of 2017. It is thought Turkish dependence on fossil fuels, and more greenhouse gas emissions than its undertaken in the Kyoto protocol as a country of signed Kyoto protocol, Turkey should rapidly turn its route to the electric vehicles to reduce fossil fuel consumption and greenhouse gas emissions. Additionally, as together with a tendency to electric vehicles, it will be useful tending to renewable and alternative energy sources for contributing to the countries' economies depending on decreasing on fossil-based fuels. For this scope, this paper aims not only to compare the electric vehicles and internal combustion engines but also to give information about the influence over the ecological balance of the world, arising from these powering methods. Finally, the nuclear energy policy of Turkey was also evaluated as an alternative to the rapidly increasing electricity consumption of the country in this paper.

***Keywords:*** *Electric vehicles, Fossil fuels, Greenhouse gas emission, Internal combustion engines.*

# İçten Yanmalı Motorlar Yerine Elektrikli Araçlara Yönelmenin Ekonomik ve Ekolojik Etkilerinin Araştırılması

## ÖZET

Ulaşım neredeyse tamamen (<99.9) petrol ve sıvılaştırılmış petrol gazı (LPG) gibi fosil yakıtları kullanan içten yanmalı motorlar (IYM) tarafından sağlanmaktadır. Ancak, dünya fosil yakıtlarının rezervleri sınırlıdır, petrol

Received: 06/09/2018, Revised: 05/10/2018, Accepted: 10/10/2018

için yaklaşık 50, doğalgaz için 60 ve kömür için 80 yıllık bir ömür öngörülmektedir. Bu yüzden insanoğlu, özellikle araçların tahrik edilebilmesi için yeni, yenilenebilir ve temiz enerji kaynakları arayışına başlamıştır. Bu kapsamda, klasik içten yanmalı motorlara en büyük alternatif, geçmişte de olduğu gibi şüphesiz elektrikli araçlardır (EA). Son yıllarda elektrikli araçlara olan ilgi giderek yükselmiş ve geçtiğimiz on yılda elektrikli araç üretiminde % 1500'lük çarpıcı bir artış gerçekleşmiştir. Öte yandan, Türkiye bu artışa ayak uyduramamış ve 2017 yılı sonuna kadar ülkede yalnızca 475 elektrikli araca rastlanmıştır. Türkiye'nin fosil kökenli yakıtlara olan bağımlılığı ve Kyoto protokolüne imza atmış bir ülke olarak bu protokolde taahhüt ettiğinden daha çok sera gazı emisyonuna sebep olduğu düşünüldüğünde, fosil yakıt tüketimini ve sera gazı emisyonunu azaltmak için rotasını hızlıca elektrikli araçlara çevirmesi uygun olacaktır. Ayrıca, elektrikli araçlara yönelmeyle birlikte fosil yakıt tüketimindeki azalmayı destekleyici olarak yenilenebilir ve alternatif enerji kaynaklarına özellikle de nükleer enerjiye yönelmenin ülke ekonomisine de katkıda bulunacağı düşünülmektedir. Bu kapsamda, bu çalışma sadece elektrikli araçları ve içten yanmalı motorları karşılaştırmakla kalmamış, aynı zamanda araçların tahrik yöntemlerinden kaynaklanan, dünyanın ekolojik dengesi üzerindeki etkiler hakkında da bilgi vermeyi amaçlamıştır. Son olarak, çalışmada; hızla artış gösteren elektrik enerjisi tüketimine karşı bir alternatif olarak ülkenin nükleer enerji politikasına da değinilmiştir.

***Anahtar Kelimeler:*** *Elektrikli araçlar, Fosil yakıtlar, İçten yanmalı motorlar, Sera gazı emisyonları.*

# I. INTRODUCTION

The globalizing world, rapidly developing technology and growing population has also led to the rapid depletion of high-energy and non-renewable energy sources, particularly petroleum products. The global primary energy consumption growth averaged 2.2% in 2017, and this growth average was 1.7% per year in the last 10 years term [1], and the vehicles have the big sharing on energy consumption. As is well-known, the vehicles need a powering system to generate motion, and this motion is generally provided by two methods. The first and foremost is by an internal combustion engine and the second is by an electric motor. In-vehicle technology, despite the fact that it is initially thought that vehicles could be powered by electric motors, the route was completely turned to internal combustion engines in next times. Also, there are some big reasons to turn route such as; basically low-battery capacity and non-existing charging-stations in that time; however, the internal combustion engines require the more complex systems for the vehicles. In addition, the use of internal combustion engines has led to more problems for all humanity and the ecological balance of the world on a long-term scale. Thus, this paper aims not only to compare the electric vehicles and internal combustion engines but also to give information about the influence of the ecological balance of the world, arising from these powering methods.

Of many energy sources, fossil fuels are currently the most frequently used as a primary energy source (nearly 85%), particularly in production, heating, transportation and many other activities. Transportation of the goods and people accounts for nearly 20% of the total global primary energy consumed, around 23% of $CO_2$ emissions and around 14% of the total global greenhouse gas emissions [1,2]. The world global primary energy consumption sharings by sources are shown in Fig. 1. However, fossil fuels continued to maintain the basic and dominant share of all consumption in 2016. Oil made up the one-third of all global energy consumption [3] and fossil-fuels also make up 85% of all energy consumption by sector in 2017.

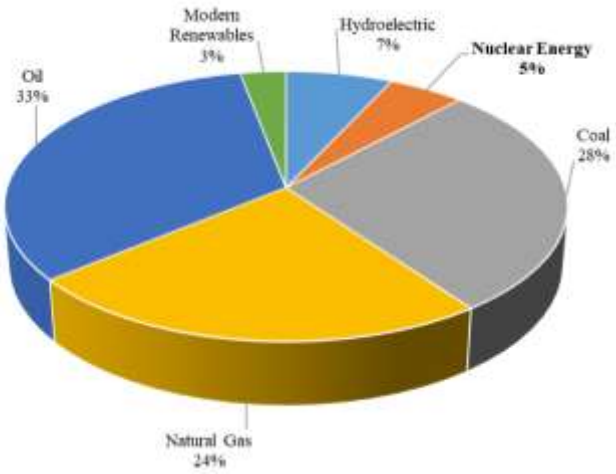


***Figure 1.*** *Global primary energy consumption by source in 2017 [3]*

According to the international projections, it is foreseen that the lifespan of the oil reserves in the world together with the known reserves are approximately 50 years. Although the last 50 years term has been introduced in petroleum use, the yield of gasoline vehicles varies between around 25-28% and the yield of diesel vehicles varies between around 34-38% [4]. Many studies have been made in the literature to improve the efficiency of internal combustion engines, and unfortunately, the efficiency has not reached even 40% level, although it is still a hot topic of many studies by scientists. Even though efficiency cannot be significantly increased for engines, approximately 62% of used oil worldwide is consumed in vehicles for transportation. It is also predicted that the oil price could reach 200 $ [5] in the next 20 years by estimating petroleum at the end of 2015 as 1.7 trillion barrels depending on decreasing reserves and increasing demand. Because there are about 1.2 billion passenger cars and 380 million commercial vehicles all around the world [6], and also there is a big tendency to produce electric vehicles and in 2016, over 750 thousand sales worldwide. This is a new sales-record for electric vehicles. The history of transition to electric road transport technologies which is only a decade ago but it is gaining a big momentum, and promising for the future of low harmful gas emissions. Table 1 shows the electric car stock (BEV: Battery electric car and PHEV: Plug-in hybrid electric vehicles) by country from 2005 to 2016 [7].

***Table 1.*** *Electric car stock (BEV and PHEV) by country, 2005-16 (thousands).*

| **Country** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Canada | - | - | - | - | - | - | 0.52 | 2.54 | 5.66 | 10.73 | 17.69 | 29.27 |
| China | - | - | - | - | 0.48 | 1.91 | 6.98 | 16.88 | 32.22 | 105.39 | 312.77 | 648.77 |
| France | 0.01 | 0.01 | 0.01 | 0.01 | 0.12 | 0.30 | 3.03 | 9.29 | 18.91 | 31.54 | 54.49 | 84.00 |
| Germany | 0.02 | 0.02 | 0.02 | 0.09 | 0.10 | 0.25 | 1.89 | 5.26 | 12.19 | 24.93 | 48.12 | 72.73 |
| India | - | - | - | 0.37 | 0.53 | 0.88 | 1.33 | 2.76 | 2.95 | 3.35 | 4.35 | 4.80 |
| Japan | - | - | - | - | 1.08 | 3.52 | 16.14 | 40.58 | 69.46 | 101.74 | 126.40 | 151.25 |
| Korea | - | - | - | - | - | 0.06 | 0.34 | 0.85 | 1.45 | 2.76 | 5.95 | 11.21 |
| Netherlands | - | - |  | 0.01 | 0.15 | 0.27 | 1.14 | 6.26 | 28.67 | 43.76 | 87.53 | 112.01 |
| Norway | - | - | 0.01 | 0.26 | 0.40 | 3.35 | 5.38 | 9.89 | 20.37 | 44.21 | 84.18 | 133.26 |

***Table 1. (continue).*** *Electric car stock (BEV and PHEV) by country, 2005-16 (thousands).*

| Country | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sweden | - | - | - | - | - | - | 0.18 | 1.11 | 2.66 | 7.32 | 15.91 | 29.33 |
| United Kingdom | 0.22 | 0.55 | 1.00 | 1.22 | 1.40 | 1.68 | 2.89 | 5.59 | 9.34 | 24.08 | 48.51 | 86.42 |
| United States | 1.12 | 1.12 | 1.12 | 2.58 | 2.58 | 3.77 | 21.50 | 74.74 | 171.44 | 290.22 | 404.09 | 563.71 |
| Others | - | - | - | - | 0.64 | 0.83 | 3.25 | 6.90 | 12.76 | 25.35 | 52.63 | 87.48 |
| **Total** | **1.37** | **1.69** | **2.15** | **4.54** | **7.47** | **16.81** | **64.58** | **182.64** | **388.07** | **715.39** | **1262.61** | **2014.22** |

As seen in Table 1, electric car stocks showed an increase of nearly 1500% in a decade. Despite the new sales record in electric cars, the powering of vehicles in the traffic is almost entirely achieved by means of internal combustion engines (>99%).

To sum up, the efficiencies of internal combustion engines are pretty low, and it causes the harmful gas emissions (particularly greenhouse gas emissions) for human health and the environment as well [8] because 2.9 kilograms of greenhouse gas emissions can be emitted to the atmosphere by burning only 1 liter diesel fuel, and this amount is equal to the emitted 2.7 kilograms of greenhouse gas emission to the atmosphere by burning only 1 liter diesel fuel.

Additionally, ICEs have operated in high-vibration, and they are actually high noise sources. Also, it has the constantly decreasing and limited reserves, and price increases due to particularly the transportation of fossil fuels and depending on the dollar exchange rate, especially for the countries like Turkey. Owing to these reasons, almost all automobile industry has turned again its route to electric and hybrid vehicles [9]. In parallel with this, the biggest step to take is undoubtedly possible by a new and renewable energy source that can replace internal combustion engines in order to reduce dependence on fossil fuels. This is because the energy required to power the currently existing vehicles is derived from fuels derived from petroleum at approximately 95% [1,2]. In line with this, many studies have been carried out to improve fuel consumption, vibrations, noise and harmful gas emissions of existing internal combustion engines with some practical applications [10-16]. In addition, the searches for alternative fuels to petroleum-based fuels continued, but good results were not obtained. At present, the main alternatives to petroleum-based fuels are biofuels, compressed natural gas (CNG) and liquefied petroleum gas (LPG), which make up about 5% of total global transportation energy. Among these alternatives, the rate of electricity is very small and hydrogen or synthetic fuels have negligible proportions.

## II. A View To Electric Vehicles In Turkey

The number of electric cars in Turkey has reached 475 by the end of 2017. This amount was 184 by 2013, 215 in 2013, 262 in 2016, 385 in 2015 and 426 in 2016 as shown in Table 2 [17]. This total amount is much less than many countries globally. While the electric cars in traffic are only 475 in Turkey, nearly 2 million electric cars were sold across the world in the year 2016. Also, 4.661 million

registered-electric cars were sold all over the world from 2005 to 2016. This means that the world has aimed to decrease the harmful gas level despite a rapidly increasing population.

***Table 2.*** *Sale amount in an electric car by September 2017 in Turkey.*

| Year | Selling Amount | Cumulative Sales |
|---|---|---|
| by 2013 | 184 | 184 |
| 2013 | 31 | 215 |
| 2014 | 47 | 262 |
| 2015 | 120 | 382 |
| 2016 | 44 | 426 |
| by September 2017 | 49 | 475 |

Turkey has imported nearly all of its fuel needs and despite this, an electric car using is still much less in Turkey. The biggest reasons for less using on electric cars are that there is a big difference between a dollar and Turkish lira rate and much less existing charging-stations across Turkey. Also, Turkey's consumption like many other countries on petroleum and other liquids has continuously increased depending on the growth-population rate. Owing to Turkey's own limited domestic reserves, Turkey imports nearly all its oil supplies. In Fig. 2, it is shown Turkey's net imports, consumption and production on petroleum and other liquids in 2014. Fig. 3 shows the countries where Turkey supply crude oil [18].

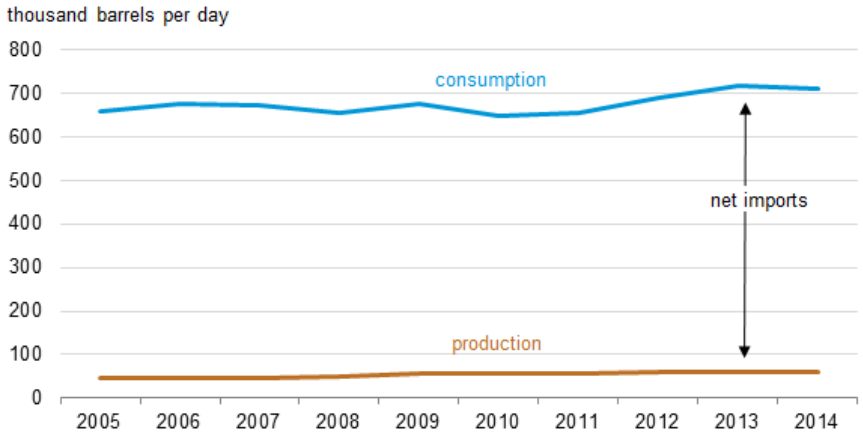


***Figure 2.*** *Turkey petroleum and other liquids consumption and production [18].*

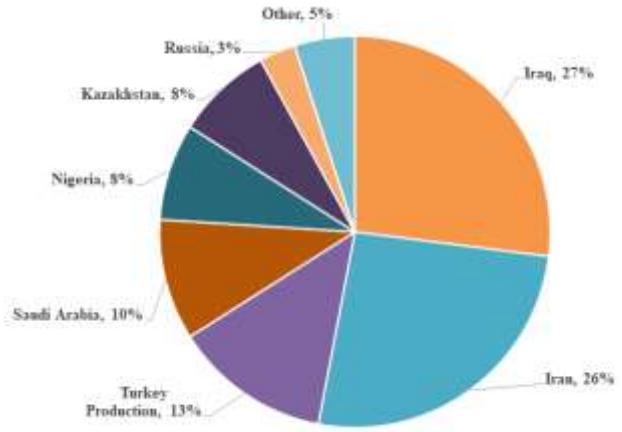


***Figure 3.*** *Turkey crude oil supply mix, 2014 [18].*

As seen in Fig. 2 and 3, Turkey has imported a large amount of petroleum and other liquids demands. Also, Fig. 2 and 3 clearly presented the dependence of Turkey on energy sources. That is why Turkey can reduce the usage of fossil-based fuels' sources while transiting to electric cars. Reducing fossil-based fuel dependency will increase electricity usage in Turkey. At this point, it will be useful to share Turkish electricity generation percentage by sources. Fig. 4 shows Turkey's electricity generation by sources in 2017 [19].

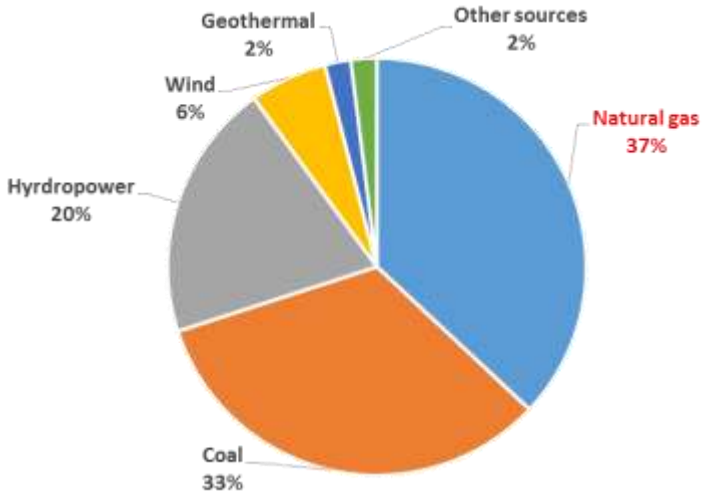


***Figure 4.*** *Turkey's electricity generation in 2017 [19].*

Turkey is able to meet 45-55 per cent of its electricity generation by domestic sources according to Republic of Turkey Ministry of Energy and Natural Resources (RTMENR). Turkey needs to increase its domestic electricity generation percentage especially for positively contribute to the economy and greenhouse gas emissions while reducing its dependence on fossil fuels. Turkey uses the natural gas to generate electricity in the first order, and a large number of natural gases are imported from Iran and Russian in Turkey. In line with this, Turkey needs to increase the electricity generation capacity for contributing to its economy as well as reducing the petroleum dependency. RTMENR has launched the "National Energy and Mines Policy" in the scope of nuclear energy, and 3 separate nuclear power plant projects are being carried out in this scope, and their locations on Turkish map are shown in Fig. 5 [20].

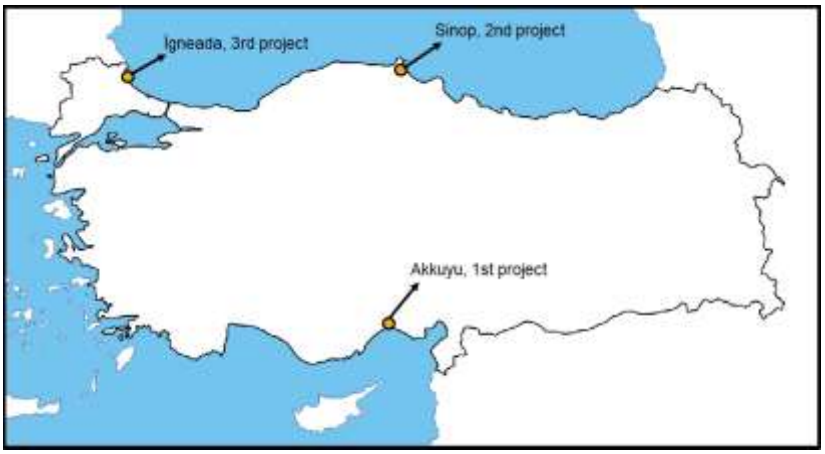


***Figure 5.*** *Turkish nuclear power projects locations.*

As shown in Fig. 6, nuclear energy provides 10.6% of the whole world's electricity production [21], and Turkey has no nuclear power stations till now. The first concrete step to increase the electricity generation capacity from Turkey is to tend to nuclear. It is important that other steps include the new and renewable energy sources such as; solar, wind etc.

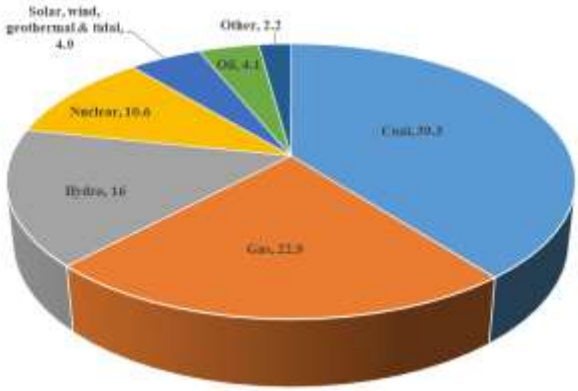


***Figure 6.*** *World electricity production by source 2015 [21].*

## III. The Effect Of Transition To Electric Cars On Carbon Emissions

Transition to electric cars provides many profits globally for countries and the world. Also, one of the profits is to reduce directly $CO_2$ emissions arising from transportation because carbon dioxide emissions have increased day by day across the world, and carbon dioxide emissions make up globally 65% of the greenhouse as shown in Fig. 7 [22].

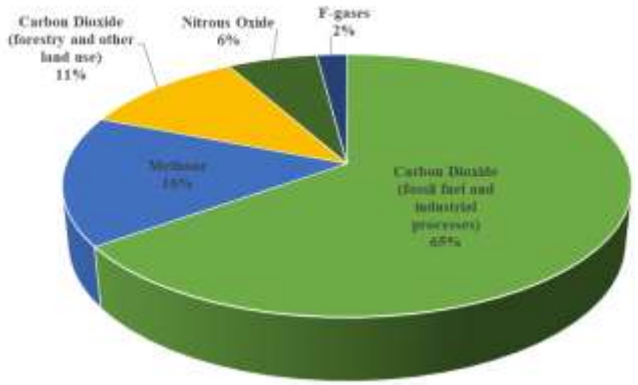


***Figure 7.*** *Global greenhouse gas emissions by gas, 2014 [22].*

Figure 7 clearly explains the sharing of 65% carbon dioxide. As seen in fig. 8, the transportation is responsible for 14% totally greenhouse gas emission globally, and the big pie slice belongs to electricity and heat production by 25% and agricultural, forestry and other land use by 24% respectively [22].

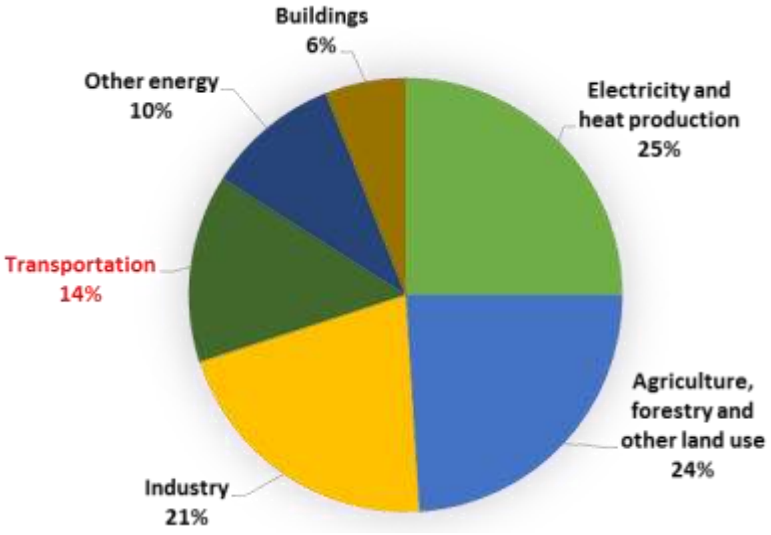


***Figure 8.*** *Greenhouse gas emissions by economic sectors, 2014 [22].*

Fig. 9 shows the changes in global carbon emission arising directly from fossil fuels between the years 1900 to 2014. Depending on the increasing the amount of fossil-fueled cars, especially after the beginning of the 1950s, carbon emissions sharply increased.

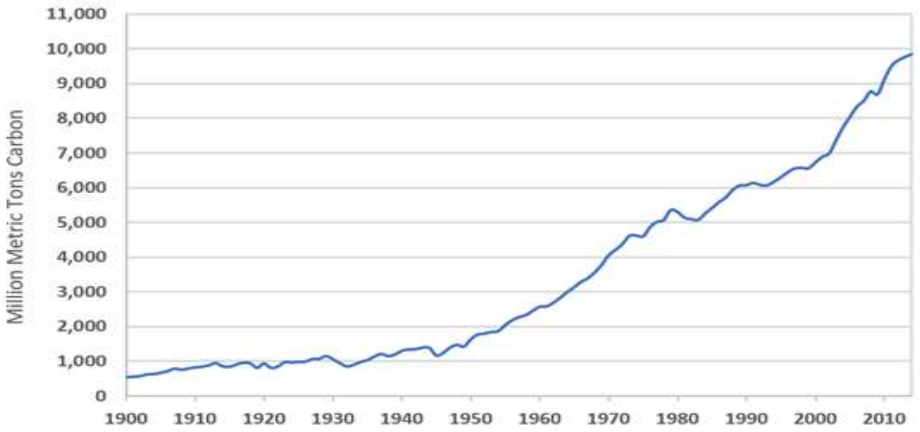


***Figure 9.*** *Global carbon emissions from fossil fuels, 1900-2014 [22].*

While $CO_2$ equivalent emissions per capita in 1990 was calculated as 3.8 tons of carbon dioxide emissions per capita, this value was changed as 6.3 tons of carbon dioxide emissions per capita in 2016. Carbon dioxide emissions per capita for Turkey was 4.63 metric tons in 2016. Turkey has a fluctuated tending of carbon dioxide per capita but especially past years it tended to increase direction in carbon dioxide emission per capita. Turkey – $CO_2$ emission values per capita from 2005 to 2016 are shown in Table 3 [22].

***Table 3.*** *Turkey – $CO_2$ emissions per capita.*

| Date | Value (metric tons) | Change, % |
|---|---|---|
| 2016 | 4.63 | 3.66 % |
| 2015 | 4.47 | -0.35 % |
| 2014 | 4.48 | 5.03 % |
| 2013 | 4.27 | -5.69 % |
| 2012 | 4.53 | 1.82 % |
| 2011 | 4.44 | 4.34 % |
| 2010 | 4.26 | 2.79 % |
| 2009 | 4.14 | -2.88 % |
| 2008 | 4.27 | -0.46 % |
| 2007 | 4.29 | 8.45 % |
| 2006 | 3.95 | 9.07 % |
| 2016 | 4.63 | 3.66 % |
| 2005 | 3.62 | - |

# IV. Results And Discussion

This study mainly aims to evaluate the future of electric cars in the world and particularly Turkey. In line with this, some graphs, table-data, pie-charts and views are presented in this study, and the following conclusions are drawn based on the given outputs in the study;

- It is one of the most important controversial issues of nowadays to supply particularly the new and renewable energy resources instead of the limited and harmful resources such as petroleum and natural gas that feed the nearly all production and consumption process. Hence,

there is a need for a source that is more stable as an energy, has a less negative impact on the climate, and is more environmentally friendly.

- The purchase cost of electric vehicles is very high compared to the classic internal combustion engine' vehicles. However, some countries are encouraging people to buy electric cars. For example, as compared to internal combustion engine' cars, Turkey takes much less Special Consumption Tax (SCT) for hybrid and electric cars.

- As compared to classic internal combustion engines, electric vehicles are more effective on fuel consumption and friendly environment.

- Many countries like Turkey don't have their own petroleum reserves. Therefore, electric vehicles will reduce petroleum consumption for these countries, and will positively affect their economies. However, reducing on the petroleum consumption will cause increasing the electricity consumption across the world. As an example, Turkey meets nearly 50% of its electrical energy source demand from domestic reserves and the rest meets from other sources such as especially natural gas, and even if reducing on petroleum, it will face the more natural gas imported in order to generate electricity. That is why these countries should find new and renewable energy generation methods such as; nuclear, wind and solar etc.

- Many countries like Turkey suffer from an insufficient amount of charging stations. This is also a big problem to directly transmit to electric vehicles worldwide.
- Transiting to electric vehicles is promising to reduce carbon emissions for the countries signed the Kyoto protocol.

- Electric vehicles have more safety and simpler structure, but not the long-distance way. Also, their battery fully charges in a long time. In this scope, there are a necessity more studies focusing on shorting this time.

- Existing electric vehicles in the markets have the big battery size and high battery mass. Hence, it should be studied on the optimization of the electric vehicles such as; mass reduction and getting smaller of battery size.

- As compared to classic internal combustion engines, the electric vehicles are equipped with totally different drive systems, for which the energy consumption and greenhouse gas emissions associated with vehicle production could radically change.

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