Environmental Research and Technology
https://ert.yildiz.edu.tr - https://dergipark.org.tr/tr/pub/ert
DOI: https://doi.org/10.35208/ert.1113781

Research Article

Global commercial aviation policies in the context of the climate crisis and an analysis of these approaches from the perspective of Türkiye

Selçuk GÜRÇAM*

Independent Researcher, Iğdır, Türkiye

ARTICLE INFO

Article history
Received: 08 May 2022
Revised: 12 June 2022
Accepted: 26 June 2022

Key words:
Climate crisis; Commercial aviation sector; Turkish aviation sector; United Nations; Paris Agreement

ABSTRACT

The climate crisis is becoming more visible day by day and is affecting the ecological system more and more. However, despite such a visible threat and its severe effects, efforts at the national and international levels are far from tackling the climate crisis. Especially with its rapid growth and ever-increasing emission rates, the commercial aviation sector remains inadequate in combating the climate crisis. This study discusses the global and Turkish commercial aviation sectors' struggles with the climate crisis. As a result, both international and domestic commercial aviation sectors follow an unrealistic attitude in the fight against the climate crisis, and there is still a long way to go.

Cite this article as: Gürçam S. Global commercial aviation policies in the context of the climate crisis and an analysis of these approaches from the perspective of Türkiye. Environ Res Tec 2022;5:3:227–240.

INTRODUCTION

Commercial airlines carrying billions of passengers employ millions of people and contribute to the world economy with their tourism and trade connections. It also contributes large sums to the global gross domestic product [1]. However, the commercial aviation sector negatively affects the environment. In terms of the climate crisis, the share of emissions of the commercial aviation sector is increasing day by day with its rapid growth potential compared to other transportation sectors. These emissions from airplanes are especially greenhouse gases such as carbon dioxide (CO_2), nitrogen oxide (NOx), and water vapor (H_2O) [2]. While the average impact rate of the aviation industry in the climate crisis is 3.5% today, this impact is expected to increase rapidly in the coming years [3].

Towards the end of the 20th century, the global climate crisis displaying environmental symptoms turned into an international security problem that requires international consensus and a joint struggle. The United Nations Framework Convention on Climate Change (UNFCCC, 1992) has drawn a comprehensive roadmap that allows global combat against climate change. However, this convention did not force the parties to reduce emissions, which is the major problem in the climate crisis. Later, the Kyoto Protocol was signed in 1997 and came into effect hardly in 2005 after the necessary conditions were met. However, just like the convention, the protocol also did not contain any enforcement for aviation emissions. Likewise, no explicit reference was made to aviation in the Paris Agreement signed in 2015 [4].

***Corresponding author.**
*E-mail address: selcukgrcm@gmail.com

European Union Emissions Trading System (EU ETS), the Carbon Offset and Reduction Scheme for International Aviation (CORSIA), and local Carbon/fuel tax restrictions are market-based chief practices to reduce aviation emissions against climate change. European Union implemented the ETS, the world's first emissions trading system [5], in 2005 to reduce aviation emissions in Europe. The second practice -Carbon Offset and Reduction Scheme for International Aviation- was launched by the International Civil Aviation Organization (ICAO) to combat aviation emissions globally [6, 7]. In addition, various countries locally enforce carbon/fuel tax to reduce emissions from aviation. When first established, the EU ETS structure did not include aviation emissions. However, because of the rapid increase in aviation emissions, the EU has published the 2008/101/EC Directive for this system to cover commercial aviation activities from 2012. At the outset, the EU ETS system covered all flights to and from the European Economic Area (EEA). But later, airlines operating outside the EEA were excluded from the scope of the EU ETS because of the global political backlash and concerns about complying with global practices to be carried out by ICAO [7].

Although the contribution of the commercial aviation sector to the global economy and ease of human life is quite remarkable, its negative effects on the climate crisis cannot be denied. In order to reduce these adverse effects, various improvements in aircraft efficiency have been made as well as market-based applications. Some operational applications such as efficient airplane routes or fuel-efficiency applications such as biological or hydrogen fuels are (or will be) in progress. However, the recovery rate is slower than the market demand, and plan end dates are later than the critical deadlines predicted for the climate disasters (Airbus stated that they would launch their first hydrogen-powered zero-emission commercial aircraft in 2035) [8]. Therefore, greenhouse gas emissions in the commercial aviation sector are growing and will continue to increase if no action is taken. In Türkiye, both the sectoral investments and the country's geographical location contributed to the development of the commercial aviation sector. While there were 162 active aircraft in 2003, the number amounted to 558 in 2021 in the Turkish airline sector. While the number of flights was 529,205 in 2003, it reached 1,461,577 in 2021. While 34,443,000 passengers were transported in 2003, Turkish aviation companies carried 128,565,706 passengers in 2021. In parallel with global commercial aviation, the rapidly growing Turkish commercial aviation sector also bears certain responsibilities for the climate crisis [9].

In today's world, as in the past, environmental problems are under the shadow of economic development. The main reason for the outbreak of the climate crisis is the greed for continuous growth and production. This strategy of the neoliberal system is particularly influential in the field of aviation. New aircraft models and technologies, the constant expansion of the commercial aviation sector, and intense intercontinental travels are the factors that support the uninterrupted growth of the sector. For this reason, although there are global initiatives against the climate crisis, the main reason underlying the climate change crisis is the ambition for more growth. Considering the nearly 30 years of efforts to combat the climate crisis, there has been no real success; greenhouse gas emissions and global temperatures have increased exponentially during this time. All policies that facilitate the operation of the system established by neoliberalism prevent the combat against the climate crisis [10, 11].

Within this theoretical framework, the current study discusses the fight against commercial aviation emissions, which will pose a significant problem in the future with its rapid growth -although it has a small proportion of global emissions today- and examines environmental practices from the perspective of global, regional, and Türkiye-based studies. This study aims to reveal whether the carbon footprints left behind by the commercial aviation industry, which provides fast, reliable, and comfortable transportation services, pose an exponentially increasing risk in terms of the climate crisis, whether the technology and efficiency improvements applied to the aircraft provide an overall success, whether the result of global and regional carbon reduction initiatives is rational, and whether these initiatives are efficient at the desired level. In addition, this study determines whether the environmental investments made in the rapidly growing Turkish commercial aviation sector comply with the international practices and whether any other different applications exist. The current study dealing with the climate crisis issue and global and Turkish commercial aviation together is unique. Especially in this period, when environmental concerns increase, examining a sector that overlooks these problems will guide future studies.

MATERIALS AND METHODS

The current study, using online databases, benefited from previous literature studies dealing with the world and Türkiye and thoroughly examined the practices against the climate crisis in the commercial aviation sector, and developed a classification covering market-based policies, efficiency and fuel policies, and Turkish commercial aviation's situation and practices. The study divided Market-based strategies into three -regional, global and national- and discussed EU ETS (regional), CORSIA (global), and jet fuel tax application in Japan (national). While the study evaluated efficiency applications and fuel policies in terms of technological improvements and biofuel, hydrogen, and electric aircraft initiatives, it collected the original data on the Turkish aviation sector from The General Directorate of Civil Aviation, Turkish Airlines, and Pegasus Airlines activity reports. The study handled all these data separately in the discussion section and evaluated the results and progressive projections from the climate crisis perspective.

RESULTS

Market-Based Policies

European Union Emissions Trading System

The UN set a negotiation environment considering the global concern about the climate crisis in 1992. In these negotiations, parties agreed on the UN Framework Convention on Climate Change. However, the paucity of this convention to eliminate the concerns about the climate change crisis paved the path to the adoption of the 1997 Kyoto Protocol bringing contracting countries the emission reduction-related obligations [12]. In this regard, the European Greenhouse Gas Emissions Trading Plan, initiated by the EU in 2005 [13, 14] to realize the 8% CO_2 reduction commitment in the Kyoto Protocol [15, 16], is the world's largest market-based and first multi-country trading scheme on greenhouse gas emissions [15, 17, 18]. The system applies to EU member states' large and fixed emitters of greenhouse gases in the energy and industrial sectors [18]. The first ETS phase (pilot phase) started in 2005 and ended in 2007. The second phase began in 2008, which coincided with the Kyoto Protocol, and ended in 2012. The third phase started in 2013 and ended in 2020 [13, 15, 18, 19]. As a cap-and-trade scheme, the EU ETS sets a peak emission amount and distributes allowances. Companies that do not declare the right amount of emissions face severe sanctions [13, 18]. The primary purpose of the EU ETS is to create an environment in which prices increase while allowances decrease [15].

The launch of the EU ETS in 2005 as a product of the flexible mechanisms of the Kyoto Protocol is considered a turning point in this field [12]. In the first stage in 2005, a significant carbon price formation (a price close to zero) could not be achieved. However, this period can be considered a learning or preparation phase for the EU ETS. Initially, the EU ETS included all CO_2 emissions but the commercial aviation sector [20]. During this period, the facilities in the EU ETS system were allowed to release 2.1 billion tons of CO_2 emissions per year. Companies included in the EU ETS system with emission permits have been trading emissions between each other since 2005. At the outset, the allowance price was around €8 but increased to €30 per tonne in June 2005. The prices, which fell to roughly €20 until the end of the year, decreased to €0 towards the end of 2007. In the second period covering 2008–2012, allowances were traded at €20 per ton [12, 19]. Unlike other periods, the third period of the EU ETS also included CO_2 emissions from the commercial aviation sector. The integration of the commercial aviation sector into the EU ETS has been evaluated as a significant step in reducing aviation-related emissions considering climate change. The EU ETS inclusion cost for the aviation companies varies according to airline companies' fuel consumption per flight, operational and efficiency practices, the number of passengers, and the amount of cargo. In other words, more efficient airlines will face lower costs than less efficient airlines. On 9 July 2008, the European Parliament released Directive 2008/101/EC on the integration of aviation into the EU ETS. According to this directive: a) As of 1 January 2012, all commercial airlines operating within the EU will join the EU ETS. In other words, third-country commercial airlines that land and depart from airports within the EU are also in this scope [13, 20, 21]. b) The EU ETS will be implemented within the borders of the EU, considering past CO_2 emissions of companies. In 2012, airline operators will receive a quota of 97% of their average greenhouse gas emissions between 2004 and 2006. This cap will be reduced to 95% annually from 2013 to 2020. c) The allowances will be distributed to the airline companies based on the ton-kilometers performed on the flights in the relevant year. d) The distribution of allowances will be non-discriminatory and applied to all member states. Of the allocations determined, 85% in 2012 and 82% between 2013 to 2020 will be free of charge, and the remaining part will be traded by auction. e) A special reserve of 3% will be allocated for airlines newly included in the EU ETS [13, 20–23].

ICAO and the International Air Transport Association (IATA) reacted strongly against the EU, which supports market-based emission reduction programs and seeks to cover all commercial aviation CO_2 emissions of all countries into the EU ETS system. Furthermore, many developed countries and airline companies, especially the United States (USA), objected to the EU ETS, claiming it was both an unfair practice and contrary to the Chicago Convention. At the same time, several airline companies, such as US-based aviation company Airlines for America, filed a lawsuit against the European Court of Justice for the EU ETS. Some countries, such as China, requested exemptions from the EU ETS [13]. However, the EU, which enacted the ETS, defended itself, claiming that the system neither violates the Chicago Convention nor requires permission to implement the application [24]. After this defense, the Airlines for America opened a case to the European Union Court of Justice for the cancellation of the civil aviation application of ETS. However, the decision rendered by the court did not satisfy the objecting party because the court ruled out that the EU ETS did not violate the sovereignty rights of states, the Chicago Convention, the Kyoto Protocol, and the US-EU Open Skies Agreement [25]. Then, some severe objections arose from the international community to the court decision. Reconsidering the situation, the European Commission issued a stay of execution (Stop-the-Clock), with the decision numbered 377/2013/EU [26], by approving the implementation of the ETS only for civil flights within EU and EEA member countries [27].

To Miyoshi [15], EU ETS has assessed a price for the CO_2 emissions of aviation. The estimated cost of emissions from aviation was around 20 billion Euros in 2020. This source provides large amounts of economic activity to the commercial aviation sector. However, the EU ETS poses an enormous challenge for airlines. For this reason, airline companies need to economically internalize aviation-related CO_2 costs. Airline companies included in the EU ETS receive allowances in proportion to CO_2 they emit. This allowance is a kind of working license for airline companies, and each company has its own specific amount of allocation. Each year in March, all aviation companies must accurately turn in their verified CO_2 emissions to the authorities from which they receive allotments. Companies can trade allowances between each other throughout the year [19].

Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

Although there was no specific statement regarding the control of the commercial aviation sector emissions in the Kyoto Protocol on the climate crisis (1997), the duty and responsibility of aviation emissions have been given to ICAO. ICAO is a United Nations specialized agency on international air navigation techniques and the planning and development of international air navigation. The Kyoto Protocol is an agreement that aims to combat global greenhouse gas emissions by imposing binding obligations on the party countries in the fight against the climate crisis since the UNFCCC has no sufficient regulations to combat the climate crisis. However, the protocol did not include the commercial aviation sector, which emits many emissions and requires precautions [4, 28]. As in the Kyoto Protocol, the Paris Agreement, which is active in the fight against the current climate crisis, does not explicitly include emissions from the commercial aviation sector [4].

Since then, ICAO has been working on policies to reduce global aviation emissions within the framework of its responsibility under the Kyoto Protocol (1997). However, as with other UN agencies, the efforts of ICAO have been hampered by the slow progress of negotiations. The parliamentary decisions signed by ICAO in 2010 (A37–19), 2013 (A38–18), and 2016 (A39–3) are significant steps that have been agreed upon. According to the ICAO A37–19 parliamentary decision taken in 2010, the 2020 Carbon Neutral Growth Target (CNG) was agreed upon and aimed to reduce the carbon footprint of global aviation [28]. Regarding this target, which was also agreed upon at the 38th Assembly meeting, ICAO decided to take a market-based measure to reduce global aviation emissions at the 39th Assembly meeting. The reason ICAO has turned to a market-based mitigation policy is that biofuel-like alternative fuels to current jet fuels do not seem to meet future carbon-neutral targets [4, 29].

At the 39th Assembly meeting of ICAO in 2016, the offset program called "Carbon Offsetting and Reduction Scheme for International Aviation" which is a market-based action was accepted and became official [29, 30]. The working principle of the carbon offset program is as follows: In CO_2 offset programs, the emitter party uses carbon credits for compliance. While these credits represent the right to emit tonnes of CO_2 equivalent (or CO_2e), they are also tradable certificates or emission permits. Adopted in the ICAO assembly, CORSIA has targeted to support carbon-neutral targets from 2020 [4]. According to Resolution A39–3 of the ICAO assembly, CORSIA functions as follows [29]:

a) First of all, CORSIA is a carbon offset program. Parties offset emissions by investing in carbon credits or CO_2 reduction projects in other countries [4, 28].

b) Airline companies can also meet the carbon offset requirement by using sustainable alternative fuels [29].

c) The CORSIA program basically covers international flights between participating states. Therefore, flights between non-participating states or between a state party and a non-party state are exempt from CORSIA [4, 29].

d) CORSIA consists of three phases: The pilot phase covering 2021 to 2023, Phase-1 covering 2024 to 2026, and Phase-2 covering 2027 and 2035 [4, 29–31].

e) Participation in the pilot phase and phase-1 of CORSIA is voluntary. As of 6 July 2021, the number of countries included in the voluntary CORSIA program is 104 [32].

f) In the second phase, which will begin in 2027 and continue until the end of 2035, CORSIA will be mandatory for all ICAO members except (1) Small emitters (airlines with less than 10,000 tons of CO_2 share), (2) Flights with aircraft with a Maximum Takeoff Mass (MTOM) of less than 5.7 tons, (3) Humanitarian/medical and firefighting operations, etc. [4, 30, 33].

Taxes on Jet Fuel

Emissions from the commercial aviation sector are increasing rapidly within the general transport sector. For this reason, it is essential to reduce aviation emissions. Many carbon pricing initiatives are carried out to save fuel used for aircraft jet engines and improve emissions. The tax on jet fuel is one such initiative. The tax on jet fuel is an effective practice to reduce the fossil fuels used by airline transportation and emissions. Implementing a tax on jet fuel may pass on savings in fossil fuel usage, and tax revenues can contribute to technological improvements to reduce carbon emissions [34]. More precisely, a fuel-based tax method effectively reduces emissions, as it burdens more costs to airline companies and more ticket fees to passengers [35]. Taxation on aviation is more applied to domestic flights because the Chicago Convention and ICAO do not support it in international flights [36]. In this context, charging a carbon tax on jet fuel to reduce emissions yielded impressive results in Japan. Therefore, the jet fuel tax applied on domestic routes in Japan to diminish civil aviation emissions covered all air transport vehicles, including helicopters [37]. In this application, fuel taxpayers are required to submit a declaration and also pay monthly taxes for the fuel purchased. The aviation fuel tax applied in Japan is an application that exempts international flights as per the Chicago Convention. The Japanese government transfers 1/13 of the revenue from the aviation fuel tax from the state treasury to the Airport Construction and Improvement Account through Social Infrastructure Improvement Special Accounts. The remaining 12/13 of the tax revenue is transferred to local governments to meet the needs of airports. The aviation fuel tax in Japan has been levied to improve aviation and airports rather than the environment. The aviation fuel tax imposed by Japan in the 1970s and 1980s proved to be a significant step forward. The tax collection has provided substantial developments in infrastructure and self-sufficiency in the Japanese aviation network. In other words, with this system, the aviation network can respond to its own needs autonomously [38]. Studies show that the aviation fuel tax applied in Japan has reduced CO_2 emissions [39]. On the other hand, after the tax cut between 2004 and 2013, fuel consumption increased by 246 million gallons in Japan, which caused 2.4 million metric tons of CO_2 emissions. For this reason, more countries adopting the fuel tax system implemented by Japan will yield more effective results [40]. Japan, which stands out with its environmental studies and efforts to reduce greenhouse gas emissions, is a significant role model for the countries offering cheap flights in its region [38].

EFFICIENCY AND FUEL POLICIES

As environmental demands increase, "Greenwashing" efforts in the commercial aviation industry are also doubling. This situation raises unrealistic technological change proposals for "greener" flights. This part of the study covers improvement efforts for civil aviation emissions. There are various initiatives of aircraft manufacturers and airline companies to reduce emissions in civil aviation. The current study discusses efficiency improvements, electric flights, hydrogen-powered flights, and biofuels among these initiatives [41–45].

Productivity Improvements

Aircraft efficiency refers to an aircraft's burnt fuel amount (and released emissions) to carry its payload (passenger or cargo) to a certain distance (for example, one kilometer). Efficiency improvements—i.e., reductions in fuel consumption rate—are achieved by making the aircraft design, engines and airline operations such as flight routes- more efficient and by increasing the number of passengers/cargos carried onboard [44, 46]. A common misconception about the commercial aviation industry is that airplanes are getting more efficient, and emission rates are falling with each passing year. There are even misleading statements announcing an 80% reduction in aviation emissions since the beginning of jet technology. Efficiency improvements reduce per capita emissions for each flight, but tax breaks, subsidies, and rising purchasing power double air traffic and CO_2 emissions every 15 years, far beyond the efficiency-related savings [41, 44, 47].

Electric Flights

Electric aircraft propulsion systems (propeller or fan blades) are driven by electric motors. In all-electric airplanes, these engines are powered by electrical energy supplied directly from batteries or hydrogen fuel cells. In hybrid-electric aircraft, these electric motors run in series or parallel with jet fuel combustion engines [44, 48, 49]. All-electric airplanes run on batteries. If these batteries are rechargeable with renewable power, then the operation of the aircraft can be called "zero emissions" [44, 48, 50, 51]. However, it has not yet become possible to decarbonize electricity production. In addition, batteries have significant social and environmental impacts because essential materials such as lithium and cobalt are extracted from the earth by mining, and other components are manufactured in factories. Therefore, even all-electric aircraft are not yet considered zero emissions. In addition, it is foreseen that this type of aircraft will not become electrified in the short or even medium-term, but only miniature and short-range aircraft may become electrified in the future. Besides, unlike an airplane fuel tank, where its poundage decreases during flight, the battery keeps its weight during the journey. These issues further affect the payload and range capability of the aircraft [44, 52].

Hydrogen-Powered Planes

There are plans and studies to use hydrogen instead of jet fuel as a power source for aircraft. Hydrogen can be burned in a jet engine or utilized for powering a fuel cell to generate electrical energy to turn a propeller [53]. While producing hydrogen from other energy sources, a significant amount of energy gets lost. The produced hydrogen is usually stored in liquid form at -253°C. Airbus worked on hydrogen planes in the 2000s, but they shelved the project in 2010 because they could not overcome some technical problems. In 2020, the company announced its plan to develop a new hydrogen-powered aircraft that could be operational by 2035. This plan includes four concept aircraft, of which the company will select one by 2025 [54].

The hydrogen plane does not meet the climate and environment targets set under the Paris Agreement in terms of time and quantity. Even if the program targets announced by Airbus in 2020 are achieved, it will be too late to meet the actual climate targets [44]. According to the United Nations Environment Program (UNEP), worldwide greenhouse gas emissions must be reduced by 55% by 2030 so that the global warming limit will not exceed 1.5°C as agreed in the Paris Agreement. When the design of the entire aircraft and the conversion of the fleet to hydrogen begins late, these targets will take too long to achieve [55].

Biofuels

Alternative jet fuels or Sustainable Aviation Fuels (SAF) are liquid hydrocarbon fuels used in existing aircraft instead of kerosene, produced from fossil fuels [42]. The leading motive of the SAF investments in the commercial aviation industry is the expectation that biofuels will reduce aviation emissions by substituting or being blended with conventional fossil fuels [56, 57]. Biofuel production uses various sources of biomass (renewable organic material from plants and animals) as inputs [58]. While first-generation biofuels use agricultural products, second-generation biofuels use industrial, agricultural, or domestic wastes such as waste cooking oil, shortening, corn husks, forest resources, or food waste [59, 60]. The sustainability and availability of biomass severely constrain biofuel use [61].

It is often claimed that aviation will only use second-generation biofuels obtained from "waste" sources, thus avoiding direct or indirect impact on sustainability [62]. However, no one can ignore the industry using first-generation biofuels from crops or even whole trees. There are plans for a massive SAF refinery in Paraguay to process soybeans as a feedstock [44] under the permission of CORSIA, the only internationally accepted aviation policy valid until 2035 [63]. The strong political emphasis particularly placed on the presumed benefits of SAF causes increased soy or palm oil usage in fuel production, posing a risk of deforestation [44].

Seber et al. [64] argued that biofuels would reduce aviation emissions in comparison with fossil fuels, while Ganguly et al. [65] claimed that SAF could reduce aviation-related emissions only by up to 78% during its entire life cycle. Even if the SAFs usages are widespread, aviation biofuels will still cost much more than kerosene [44]. Biofuel from waste oil is the most cost-competitive but still doubles the cost [66]. These rising costs will undermine the industry expansion plans [67]. The only way the aviation industry can continue to grow using larger quantities of alternative fuels is to provide alternative fuel producers (such as biofuel makers) with massive government subsidies [44]. The 2016 report by ICAO has documented that it is necessary to build 328 new large bio-refineries each year by 2035 with an average annual cost of $29 billion to $115 billion to produce enough biofuels for international use [68]. This situation suggests that aviation biofuels can not be sustainable, and future investments will be severely risky for public finances [44].

TURKISH COMMERCIAL AVIATION AND INITIATIVES FOR EMISSION REDUCTION

Air transportation, which stands out among other modes of transportation because of its speed, reliability, and comfort, is rapidly increasing its share in the sector. Transportation is the action of transporting someone or something from one point to another. Airline transportation is significant for a country's economy and people's welfare. The statistical studies conducted on the transportation sector show that aviation contributes to preparing the infrastructure of globalization in cultural, economic, and political activities. Civil air transportation which is fast, comfortable, and safe, has been the highest growing transportation type in the 20th century [69].

The commercial aviation industry has entered a rapid growth process with technological developments since the beginning of the 20th century. Especially in the 1970s, the liberalization movements in the commercial aviation sector of the USA went beyond this country's borders and affected many countries. With the global hegemony of neoliberalism, the beginning of a new era in the commercial aviation sector has also influenced the domestic market of Türkiye. The 1983 Turkish Civil Aviation Law No. 2920 has allowed private airline companies to engage in civil aviation activities. This period was marked by the liberalization policy aimed at reducing the role of the state in the markets. While tourism has come to the fore in the liberalization movement, the most critical role in the efforts to revive tourism has fallen to the aviation sector. Meanwhile, the civil aviation sector has gained a broader movement opportunity with liberalization. The Turkish Civil Aviation Law No. 2920 was a significant step in this direction, and it paved the way for the sector on domestic and international routes [70].

The Turkish commercial aviation sector has increased more than the international growth rates. The rapid development, especially over the last 17 years, has made regional and global contributions to the aviation sector in Türkiye. Various reports have supported that the growth in Türkiye's commercial aviation sector will steadily continue [71–73].

According to the General Directorate of Civil Aviation [69], special attention has been paid to the development of civil aviation within the global integration framework for Türkiye's economic and social development. Furthermore, the diversity stemming from Türkiye's geographical location has contributed to developing the commercial aviation industry and becoming one of the fastest-growing countries. The rapidly growing Turkish civil aviation has established a flight network connected to almost any point worldwide. According to the Airports Council International (ACI) 2019 Airport Connectivity Report, Türkiye ranked 5th among European countries with the indirect, direct, airport, and central connection numbers in 2019 by increasing its direct connections by 2.5%, indirect connections by 13.7%, airport connections by 8.1%, and central connections by 18.1%. In the period between 2009 to 2019, it has become the most developing country with its direct and indirect civil aviation connections in "new flight lines" and "new flight destinations." According to the data of the last ten years, it has increased its direct connections by 159.9%, indirect connections by 144.5%, airport connections by 151.5%, and central connections by 386% [74].

The Turkish commercial aviation sector is rapidly growing in Europe and the world, and thus its climate-change-related activities are of significance. The General Directorate of Civil Aviation 2012–2021 annual reports show that operational practices aimed at improving efficiency, in general, come to the fore rather than market-oriented approaches. For example, the Green Airport Project implemented in the 2013 Annual Report of the General Directorate of Civil Aviation awards airports the title of Green Airport and particular discounts on some fees when they meet the necessary conditions. This practice would significantly contribute to disseminating environmentally friendly practices in the sector [75]. Another example was the Flexible Use of Airspace Project, which was deliberated in the 2016 Activity Report of the General Directorate of Civil Aviation. This project aimed to shorten flight paths, instantly establish additional flight paths, save fuel and time, reduce maintenance costs, reduce the impact of global warming and environmental pollution and increase efficiency in the commercial aviation sector [76].

In its 2020 Corporate Sustainability Report, Pegasus Airlines, a private Turkish commercial aviation company, has announced that its operations are within the market-based CORSIA and EU ETS framework. In this context, while they record and report emissions as a requirement of being included in the CORSIA, they fulfill the obligations of the EU ETS for the few flights performed within the EU Economic Area. In addition, they carry out operational activities that increase efficiency and reduce fuel and emissions [77].

Turkish Airlines, the locomotive of the Turkish commercial aviation industry with its largest flight network and fleet, positively increased its efficiency (fuel-saving, operational activities, etc.) initiatives to combat the climate crisis and environmental sensitivities compared to ten years ago. Turkish Airlines works in close cooperation with navigation service providers, especially on domestic and international flights, to improve air traffic management for efficiency [78]. Like Pegasus Airlines, Turkish Airlines is a member of CORSIA and is subject to EU ETS for flights within the European Economic Area [79]. As reported in Turkish Airlines 2018 Sustainability Report, Turkish Airlines carries out an efficiency project to produce bio-fuel (Micro-Jet) from micro-algae in cooperation with Boğaziçi University [80]. In addition, the use of sustainable aviation fuel in the flight Istanbul (IST) - Paris (CDG) on 02 February 2022 is an exceptional practice. Turkish Airlines also stated that sustainable aviation fuel usage would be a regular-weekly practice. The Turkish Airlines flight with sustainable aviation fuel between Istanbul Airport to Paris Charles de Gaulle Airport was also featured on TRT News, Milliyet News, and Turkish Airlines Blog webpages [81–83].

DISCUSSION

Although the initiatives in aviation from the past to the present were individually productive, they were not efficient collectively. Because while making a single aircraft or fleet efficient contributes to fuel savings and natural emission reduction, an increasing number of passengers, flight points, cargo, and aircraft wipes out all efficiency improvements. Because the growth of the commercial aviation industry is demand-driven, reducing the volume of travel today is the most effective way to limit the impact of industry on the climate. For this reason, it would be more reasonable to evaluate environmental sensitivities by looking at aviation practices from a broad framework and building the future rather than saving the day. Therefore, the current study discusses whether the initiatives from past to present regarding the improvement and market-based developments in the commercial aviation sector have positively developed global and domestic aviation in terms of climate change. So, the discussion part is discussed under three headings for better understanding.

Market-Based Applications

First, EU ETS covers CO_2 emissions from flights within the EEA, while CORSIA covers international flights. The EU ETS, which has been in force for nearly 17 years, has considerably decarbonized various sectors of the European Union. It has accelerated the transition from coal to natural gas and renewable energy sources in the energy industry. However, the EU ETS could not achieve the same success in carbon emissions in other sectors other than energy. In particular, the fact that it only includes flights within the EEA shows that it deals with the tip of the iceberg only. Besides, granting too many free allowances has led to more supply, thus distracting the EU ETS from its climate crisis objectives [84]. Anger & Köhler [85] has stated that the EU ETS should reduce aviation carbon emissions and encourage new technologies for the future because aviation emissions have covered a small share of the EU ETS, and the EU ETS determined carbon pricing lower than expectations after 2012.

As for CORSIA, which is more important in terms of international aviation, Atmosfair [86] states that even the name of CORSIA is misleading. Although the letter R in the name denotes the word reduction, the program did not set any emission reduction targets about emissions reduction. Mandatory measures to reduce emissions are insufficient, especially for airlines. Besides, if ICAO honestly tried to reduce aviation emissions, it wouldn't have bothered with a makeover like declaring CORSIA, 19 years after the Kyoto Protocol. Another criticism is toward the requirement that airlines balance their emissions within the framework of carbon-neutral targets starting from 2020. However, avoiding the impact of carbon dioxide formation alone will not make the commercial aviation industry carbon neutral. This is because the contrails and the gases that cause ozone formation released into the atmosphere by the aircraft also harm global warming. Therefore, this structure is not expected to take an effective measure in the fight against the climate crisis [86]. Magdalena Heuwieser, the cofounder of the Stay Grounded activist group, states that CORSIA is irreparably-damaged wreckage because it diverts resources and the policy-making trajectory away from real solutions to climate change; and its existence is worse than doing nothing [87]. Waiting whether CORSIA will be fruitful will result in "too little, too late" in tackling the climate crisis. After 2020, the commercial aviation sector cannot reduce global aviation emissions and achieve “carbon neutral” targets even with the comprehensive implementation of CORSIA and initiatives such as sustainable aviation fuels [6]. The fact that 1% of the world population who use the airlines harm climate than other people of 99% who never use airlines reflects a large inequality among people. Because this 1% of the world population is the least affected, despite their severe influence on climate change. The following question occurs for CORSIA when considering all these criticisms: If flying conditions are not proper environmentally yet, why do more and more people continue to board the planes? [87].

Another topic discussed to reduce aviation emissions is the taxation system. This application is a matter to which the Chicago Convention and ICAO show massive opposition. Therefore, while international flights remain tax-free, local taxation on aviation emissions applies in some countries that take the climate crisis seriously and have strong willpower to make an effort. Governments need to stop subsidizing airline practices, especially given the rapid increase in emissions from the commercial aviation sector. For this purpose, it will be more effective for governments to reflect the cost of all environmental effects arising from aviation to airlines and introduce quotas to reduce fuel use gradually. The fuel tax implemented by Japan has been a significant step in reducing the commercial aviation sector emissions. If a fuel/carbon tax application is implemented globally, it will yield more effective results than other market-based applications. Because the primary objective in the commercial aviation sector, as in other sectors, is profit. Therefore, the emission tax imposed on the commercial aviation sector will naturally drop the profits, slow the growth, and thus decrease emissions. Besides, it would be beneficial, especially in terms of the individual carbon footprints, to impose additional taxes on passengers who use airlines frequently [87].

Efficiency and Fuel Policies

Improvements to efficiency in the commercial aviation sector are largely pseudo efforts to gloss over and ignore reality. When we look at all "so-called" improvements made from past to present, it is clear that they did not affect the total emission rate in the commercial aviation sector, and the emissions steadily increased. On the other hand, depending on increasing aircraft efficiency, some airlines cause a decreasing efficiency per seat by simultaneously increasing the number of business seats or first-class seats, which are more profitable. Furthermore, using private and business jets is also advancing worldwide. These jets are 5 to 14 times more pollutants than commercial aircraft because of their lower number of passengers and higher flight speeds. Despite the decline in air traffic due to COVID-19, the industry is still expected to grow at around 4% annually from 2024 to 2038. For this reason, despite the lowering aviation emissions per capita, the total emission rate is increasing rapidly, negatively affecting the climate system. Therefore, efficiency gains alone are not enough to decarbonize the industry; air traffic should be limited by regulations [44].

Large electric aircraft will not operate in the commercial aviation sector soon because the weight of the batteries still poses an obstacle and disadvantage [57]. Unless a radical and yet uninvented paradigm shift emerges in energy storage today, hydrocarbon fuels will continue to be used in the future [44]. The Net Zero by 2050 report, published by the International Energy Agency (IEA) in 2021, has predicted that commercial battery-powered electric and hydrogen aircraft will be adopted from 2035 but that these aircraft will account for just less than 2% of the global aviation energy consumption in 2050 [88].

Along with many technically incomprehensible aspects, hydrogen flight also has security problems [89]. Accordingly, Airbus stated that hydrogen flight could not be widespread before 2050, and airplanes with only 50 to 100 seats might fly in the 2030s [90]. Eventually, since these aircraft will hold a minor market share, this situation will not reduce global emissions. Furthermore, getting these hydrogen aircraft operational will cause a need for rebuilding many infrastructure elements, such as fuel supply and airport infrastructure design [91]. Hence, the future prevalence and efficiency of hydrogen flight are still uncertain [44].

Innovative technologies are offering alternatives to fossil-based jet fuels, but each option faces challenges, such as cost, investment, market formation, political support, and consumer acceptance. Although forestry residues are the potential raw material for SAF production, high costs, lack of production facilities, limited government subsidies, concerns about the sustainability and competitiveness of raw materials, and customer willingness to pay less are decisive factors for their usage [92]. The aerospace industry has promised a scale-up of biofuel use for more than a decade, but this promise is still unfulfilled. For example, in total fuel consumption, the biofuel aim of IATA in its 2015 report was 10% by 2020 [93], and the Air Transport Action Group (ATAG) aimed at 6% by 2020 [94]. However, at the end of the day, biological fuel uses by 2021 were at a negligible level (less than 1%) compared to the rate of jet fuels [67].

Turkish Commercial Aviation

At present, the Turkish commercial aviation sector does not integrate with the EU ETS, one of the market-based applications, but pays their fixed fees when performing flights within the EEA. However, the sector has participated in the CORSIA system, which is more comprehensive, and agreed to fulfill its obligations regarding future applications. As seen in the activity reports of the General Directorate of Civil Aviation, Turkish Airlines, and Pegasus Airlines, the sector institutions carry out more efficiency-oriented studies to combat the climate change factors. For example, Turkish Airlines has started experiments on biofuels in cooperation with Boğaziçi University, and it performed the first biofuel flight from Istanbul to Paris in February 2022, also as stated in TRT News, Milliyet News ve Turkish Airlines Blogs. The Turkish commercial aviation sector aims to prevent the aviation-related climate crisis, but the measures are far from the existing reality. There is no market-based carbon/fuel tax application in Türkiye. It is anticipated that the Turkish aviation industry will continue to grow under global CORSIA measures, which are far from solving high emission releases in the commercial aviation industry. As for the fuel studies, despite the Turkish Airlines reports declaring ongoing Biofuel studies, it is almost impossible to carry out a cost-effective agricultural production for biofuel use in Türkiye while the system has not proven itself on a global scale.

Turkish Airlines has stated sustainable aviation fuel usage in flights, but it has not specified the most vital information, namely, the amount of sustainable fuel planned. For this reason, it should be well understood that announcing sustainable aviation fuel uses in flights does not mean that we have effectively eliminated environmental impacts. Considering the increasing applications of "Greenwashing" [43], especially in the commercial aviation sector, it is significant to know how much biofuel was used in the Turkish Airlines flight or how much of it was blended with the existing jet fuel, and this information was not available on news sites (TRT News, Milliyet News, and Turkish Airlines Blog). Using biofuel during just one flight does not mean becoming successful in the struggle against the climate crisis, as many global airlines already operate flights through a blend of biofuel and jet fuel. However, at this point, it has not been possible to free the commercial aviation industry from fossil fuels.

As a result, the measures in the commercial aviation sector, whose impact on the climate crisis is increasing rapidly, are implicit methods of continuing to grow rather than combating this crisis. For this reason, a sector that does not give up on growth will not care about environmental concerns, and the findings indicate this. The ever-increasing fleets, passenger numbers, fuel consumption, and emissions are profound indicators of this.

CONCLUSION

As the first Emissions Trading System, EU ETS has been operating since 2005. It has covered the aviation sector since 2012, but it has a narrow scope. Over these years, the EU ETS has reached no significant success in reducing emissions stimulating climate change. The existing emissions have not decreased in these years; on the contrary, they have increased. CORSIA, on the other hand, is far from reducing aviation emissions, although it has, with great hope and a big advertisement, claimed that it would neutralize aviation emissions. In terms of aviation, carbon/fuel tax offers a more effective solution than other applications. Of course, considering that the best aviation is the one generating no emissions, even if this solution is insufficient, it is the one that will contribute to solutions more than other applications. For this reason, local carbon/fuel tax practices should be allowed to spread globally as soon as possible.

It should be recalled that the emissions of each extra flight will erase all gains of the efficient activities like flying over the shortest possible route, flying at the most efficient altitude, maximizing the airplane's load factor, using minimal fuel enough to complete the flight safely, minimizing non-profitable flights, and keeping the hull and engine clean. As everybody knows, as long as there is no extraordinary situation in the commercial aviation sector, the demand will continue to increase.

As the world population increases, the use of natural resources will synchronously increase at the same rate, even many times more compared to the past. Hence, considering the global danger of insufficient agriculture and starvation, using agricultural products as aircraft biofuel seems to be an unlikely solution. For this reason, the commercial aviation sector approaches, which are practically based on dreams and greenwashing, should review its practices on the climate crisis and be more effective and solution-oriented. The most alternative solution for the commercial aviation industry is to cancel short-haul flights immediately and adopt rail systems supported by renewable energy sources. Thus, a more effective step will be taken for the future of the world and humanity.

The Turkish commercial aviation industry has undergone a rapid growth process since the 2000s. New international and domestic routes and flight destinations have been the booster of this growth. The sector has topped in air transportation regionally and globally, using modern airway technologies and fleets. The growth trend in the Turkish commercial aviation sector has coincided with a period when people worldwide have started to voice environmental problems more. The Turkish aviation sector, integrated into the global aviation system, has also taken precautions against the environmental sensitivity within the available possibilities. However, its continuous growth and domestic expansion targets require the Turkish commercial aviation sector to take urgent action against the climate crisis. But, it is unrealistic to expect some positive outcomes for local purposes by following the same already-tried global practices, introducing no additional innovation, and appearing environmentally sensitive.

In conclusion, people either will make this world livable for today and the next generations or cause it to become more unlivable for their extreme pleasure and needs. This election will determine the course of aviation emissions and even the fight against the global climate crisis. Because, as stated in the Climate Change 2022: Climate Change Mitigation Report by Intergovernmental Panel on Climate Change [95], global warming will continue towards the end of the century unless solution-oriented political steps are taken and Existing Nationally Determined Contributions (NDCs) are updated. In this case, global warming will go up towards 2.1–3.4°C, exceeding the 1.5°C-threshold. The commercial aviation industry has the most destructive role in the world climate crisis. Instead of supporting huge polluters such as airlines and airports, spending the public's taxes on more climate-friendly and efficient alternatives, such as rail systems in Türkiye and worldwide, will be a more sustainable approach.

DATA AVAILABILITY STATEMENT

The author confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1] European Commission. (2022a). "Aviation and the EU ETS," https://ec.europa.eu/clima/eu-action/european-green-deal/delivering-european-green-deal/aviation-and-eu-ets_en Accessed on August 08, 2022.

[2] S. Berger, A. Kilchenmann, O. Lenz, and F. Schlöder, Willingness-to-pay for carbon dioxide offsets: Field evidence on revealed preferences in the aviation industry. Global Environmental Change, Vol. 73, Article 102470, 2022. [CrossRef]

[3] S. Becken, B. Stantic, J. Chen, and R. M. Connolly, "Twitter conversations reveal issue salience of aviation in the broader context of climate change," Journal of Air Transport Management, Vol. 98, Article 102157, 2022. [CrossRef]

[4] J. Scheelhaase, S. Maertens, W. Grimme, and M. Jung, "EU ETS versus CORSIA – A critical assessment of two approaches to limit air transport's CO 2 emissions by market-based measures," Journal of Air Transport Management, Vol. 67, pp. 55–62, 2018. [CrossRef]

[5] European Commission. (2022b). "EU Emissions Trading System (EU ETS)," https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets_en Accessed on July 28, 2022.

[6] C. Lyle, "Beyond the icao's corsia: Towards a more climatically effective strategy for mitigation of civil-aviation emissions," Climate Law, Vol. 8(1–2), pp. 104–127, 2018. [CrossRef]

[7] D. T. T. Mai, "Revising the EU ETS and CORSIA in times of the COVID-19 pandemic: challenges for reducing global aviation emissions," Climate Policy, Vol. 21(10), pp. 1357–1367, 2021. [CrossRef]

[8] Y. M. Ching, (2021). "My say: Getting the aviation industry to act on climate change," https://www.theedgemarkets.com/article/my-say-getting-aviation-industry-act-climate-change Accessed on July 28, 2022.

[9] General Directorate of Civil Aviation. (2022). "2021 annual report," https://web.shgm.gov.tr/documents/sivilhavacilik/files/kurumsal/faaliyet/2021.pdf Accessed on July 28, 2022.

[10] S. Gürçam, (2021). İklim Değişikliğiyle Mücadelenin Önündeki Barikat: Neoliberalizm. In H. S. Eti (Ed.), Ekonomi, Yönetim ve Pazarlama Alanında Akademik Araştırmalar (pp. 109–126). Karadeniz Kitap. [Turkish]

[11] E. Konuralp, "Between neoliberal appetence and environmentalist reservations: the political economy of sustainable aviation," International Journal of Sustainable Aviation, Vol. 6(2), pp. 134–147, 2020. [CrossRef]

[12] Hoffmann, V. H., Trautmann, T., & Schneider, M. "A taxonomy for regulatory uncertainty—application to the European Emission Trading Scheme," Environmental Science & Policy, Vol. 11(8), pp. 712–722, 2008. [CrossRef]

[13] R. Malina, D. McConnachie, N. Winchester, C. Wollersheim, S. Paltsev, and I. A. Waitz, "The impact of the European Union Emissions Trading Scheme on US aviation," Journal of Air Transport Management, Vol. 19, pp. 36–41, 2012. [CrossRef]

[14] L. Meleo, On the determinants of industrial competitiveness: The European Union emission trading scheme and the Italian paper industry. Energy Policy, Vol. 74, pp. 535–546, 2014. [CrossRef]

[15] C. Miyoshi, "Assessing the equity impact of the European Union Emission Trading Scheme on an African airline," Transport Policy, Vol. 33, pp. 56–64, 2014.
[16] J. Wang, F. Gu, Y. Liu, Y. Fan, and J. Guo, "Bidirectional interactions between trading behaviors and carbon prices in European Union emission trading scheme," Journal of Cleaner Production, Vol. 224, pp. 435–443, 2019. [CrossRef]
[17] D. Demailly, and P. Quirion, "European Emission Trading Scheme and competitiveness: A case study on the iron and steel industry," Energy Economics, Vol. 30(4), pp. 2009–2027, 2008. [CrossRef]
[18] K. S. Rogge, M. Schneider, and V. H. Hoffmann, "The innovation impact of the EU Emission Trading System — Findings of company case studies in the German power sector," Ecological Economics, Vol. 70(3), pp. 513–523, 2011. [CrossRef]
[19] A. Engels, "The European Emissions Trading Scheme: An exploratory study of how companies learn to account for carbon," Accounting, Organizations and Society, Vol. 34(3–4), 488–498, 2009. [CrossRef]
[20] A. Anger, "Including aviation in the European emissions trading scheme: Impacts on the industry, CO2 emissions and macroeconomic activity in the EU," Journal of Air Transport Management, Vol. 16(2), pp. 100–105. [CrossRef]
[21] J. A. Leggett, B. Elias, and D. T. Shedd, "Aviation and the European Union's emission trading scheme," https://sgp.fas.org/crs/row/R42392.pdf Accessed on July 28, 2022.
[22] DEHSt. (2012). "Allocation of Emission Allowances to Aircraft Operators for Trading Periods 2012 and 2013-2020," https://www.dehst.de/SharedDocs/downloads/EN/aircraft-operators/Aviation_Allocation_report.pdf Accessed on July 28, 2022.
[23] J. Scheelhaase, S. Maertens, and W. Grimme, Options for improving the EU Emissions Trading Scheme (EU ETS) for aviation. Transportation Research Procedia, Vol. 59, pp. 193–202, 2021. [CrossRef]
[24] J. R. Crook, "Possible looming conflict with EU regulation of greenhouse gas emissions from civil aviation; United States prefers ICAO Action," American Journal of International Law, Vol. 102(1), pp. 171–173, 2008. [CrossRef]
[25] CJEU. (2011). "Court of Justice of the European Union," C-366/10. https://curia.europa.eu/juris/liste.jsf?language=en&num=C-366/10 Accessed on July 28, 2022. [CrossRef]
[26] EUR-Lex. (2013). "Decision No 377/2013/EU Of The European Parliament and of The Council. The European Parliament and The Council of The European Union," https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013D0377 Accessed on July 28, 2022.
[27] M. Efthymiou, and A. Papatheodorou, "EU Emissions Trading scheme in aviation: Policy analysis and suggestions," Journal of Cleaner Production, Vol. 237, pp. 1–10, 2019. [CrossRef]
[28] A. Sharma, S. K. Jakhar, and T.-M. Choi, "Would CORSIA implementation bring carbon neutral growth in aviation? A case of US full service carriers," Transportation Research Part D: Transport and Environment, Vol. 97, pp. 1–23, 2021. [CrossRef]
[29] R. Colantuono, (2021). "Market-based measures and aviation sustainability in the European Union: An assessment," http://www.sustainability-seeds.org/papers/RePec/srt/wpaper/0921.pdf Accessed on Aug 08, 2022.
[30] O. Schinas, and N. Bergmann, "Emissions trading in the aviation and maritime sector: Findings from a revised taxonomy," Cleaner Logistics and Supply Chain, Vol. 1, pp. 1–16, 2021. [CrossRef]
[31] W. Liao, Y. Fan, and C. Wang, (2022). "How does COVID-19 affect the implementation of CORSIA?" Journal of Air Transport Management, Vol. 99, pp. 1–8, 2022. [CrossRef]
[32] ICAO. (2021). "Over 100 States now participate in ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)," https://www.icao.int/Newsroom/Pages/Over-100-States-now-participate-in-ICAOs-Carbon-Offsetting-and-Reduction-Scheme-for-International-Aviation-CORSIA.aspx Accessed on July 28, 2022.
[33] Timperley, J. (2019). "Airlines around the world have recently begun to monitor their CO2 emissions as part of a UN climate deal," Carbon Brief. https://www.carbonbrief.org/corsia-un-plan-to-offset-growth-in-aviation-emissions-after-2020 Accessed on July 28, 2022.
[34] R. Qiu, J. Xu, H. Xie, Z. Zeng, and C. Lv, "Carbon tax incentive policy towards air passenger transport carbon emissions reduction," Transportation Research Part D: Transport and Environment, Vol. 85, pp. 1–16, 2020. [CrossRef]
[35] J. Larsson, A. Elofsson, T. Sterner, and J. Åkerman, "International and national climate policies for aviation: A review," Climate Policy, Vol. 19(6), pp. 787–799, 2019. [CrossRef]
[36] European Commission. (2019). "Taxes in the field of aviation and their impact," https://bevarjordforbindelsen.dk/wp-content/uploads/2020/03/EURapportjuni2019.pdf Accessed on July 28, 2022.
[37] Nippon Communications Foundation. "Japan to end aviation fuel tax cut as coronavirus reflief," https://www.nippon.com/en/news/yjj2021120400367/ Accessed on July 28, 2022

[38] R. González, and E. B. Hosoda, "Environmental impact of aircraft emissions and aviation fuel tax in Japan," Journal of Air Transport Management, Vol. 57, pp. 234–240, 2016. [CrossRef]
[39] Y. Li, and J. Song, "A comparative study of carbon tax and fuel tax based on panel spatial econometric model," Environmental Science and Pollution Research, Vol. 29(11), pp. 15931–15945, 2022. [CrossRef]
[40] J. B. Sobieralski, and S. M. Hubbard, (2020). "The effect of jet fuel tax changes on air transport, employment, and the environment in the US," Sustainability, Vol. 12(8), pp. 1–15, 2020. [CrossRef]
[41] S. Capoccitti, A. Khare, and U. Mildenberger, (2010). "Aviation industry - mitigating climate change impacts through technology and policy," Journal of Technology Management & Innovation, Vol. 5(2), pp. 66–75, 2010. [CrossRef]
[42] D. Chiaramonti, G. Talluri, G. Vourliotakis, L. Testa, M. Prussi, and N. Scarlat, "Can lower carbon aviation fuels (LCAF) really complement sustainable aviation fuel (SAF) towards EU aviation Decarbonization?" Energies, Vol. 14(19), Article 6430, 2021. [CrossRef]
[43] S. Gürçam. (2022). "The neoliberal initiative of the aviation industry to fight the climate crisis: Greenwashing," International Journal of Environment and Geoinformatics, Vol. 9(3), pp. 178–186, 2022. [CrossRef]
[44] Stay Grounded. (2021). "The troubling story of aviation's greenwashing - stay grounded," https://stay-grounded.org/the-troubling-story-of-aviations-greenwashing/ Accessed on July 28, 2022.
[45] UNEP. (2020). "Emissions Gap Report 2020," https://www.unep.org/emissions-gap-report-2020 Accessed on July 28, 2022.
[46] S. Altus, (2009). "AERO - Effective Flight Plans Can Help Airlines Economize," Boeing. https://www.boeing.com/commercial/aeromagazine/articles/qtr_03_09/article_08_1.html Accessed on July 28, 2022.
[47] M. Mazraati, & O. M. Alyousif, "Aviation fuel demand modelling in OECD and developing countries: impacts of fuel efficiency," OPEC Energy Review, Vol. 33(1), pp. 23–46, 2009. [CrossRef]
[48] H. Han, J. Yu, and W. Kim, "Investigating airline customers' decision-making process for emerging environmentally-responsible electric airplanes: Influence of gender and age," Tourism Management Perspectives, Vol. 31, pp. 85–94, 2019. [CrossRef]
[49] F. Mohammadi, "Research in the past, present and future solar electric aircraf," Journal of Solar Energy Research, Vol. 3(3), pp. 237–248, 2018.
[50] H. Han, B.-L. Chua, and S. S. Hyun, "Consumers' intention to adopt eco-friendly electric airplanes: The moderating role of perceived uncertainty of outcomes and attachment to eco-friendly products," International Journal of Sustainable Transportation, Vol. 14(9), pp. 671–685, 2020. [CrossRef]
[51] H. Han, M. J. Lee, B.-L. Chua, and W. Kim, "Triggers of traveler willingness to use and recommend eco-friendly airplanes," Journal of Hospitality and Tourism Management, Vol. 38, pp. 91–101, 2019. [CrossRef]
[52] B. Berseneff, S. Fiette, and A.L.B Van, "A reduced battery system model and sizing algorithm for future hybrid electric airplanes architectures studies," IOP Conference Series: Materials Science and Engineering, Article 03552217, 2021.
[53] I. P. Jain, "Hydrogen the fuel for 21st century," International Journal of Hydrogen Energy, Vol. 34(17), pp. 7368–7378, 2009. [CrossRef
[54] Airbus. (2021). "How to store liquid hydrogen for zero-emission flight," https://www.airbus.com/en/newsroom/news/2021-12-how-to-store-liquid-hydrogen-for-zero-emission-flight Accessed on July 28, 2022.
[55] UNEP. (2021). "Emissions Gap Report 2021," Birleşmiş Milletler. https://www.unep.org/resources/emissions-gap-report-2021 Accessed on July 28, 2022.
[56] R. C., Boehm, L. C., Scholla, and J. S. Heyne, "Sustainable alternative fuel effects on energy consumption of jet engines," Fuel, 304, Article 121378. [CrossRef]
[57] J. Hoelzen, D. Silberhorn, T. Zill, B, Bensmann, and R. Hanke-Rauschenbach, "Hydrogen-powered aviation and its reliance on green hydrogen infrastructure – Review and research gaps," International Journal of Hydrogen Energy, Vol. 47(5), pp. 3108–3130, 2022.
[58] EIA. (2021). "Biomass explained. U.S. Energy Information Administration," https://www.eia.gov/energyexplained/biomass/ Accessed on Aug 08, 2022.
[59] E.-M. Aro, "From first generation biofuels to advanced solar biofuels," Ambio, Vol. 45(S1), pp. 24–31, 2016. [CrossRef]
[60] A., Mohr, and S. Raman, "Lessons from first generation biofuels and implications for the sustainability appraisal of second generation biofuels," Energy Policy, Vol. 63, pp. 114–122, 2013. [CrossRef]
[61] B. D. Solomon, "Biofuels and sustainability," Annals of the New York Academy of Sciences, Vol. 1185(1), pp. 119–134, 2010. [CrossRef]
[62] N. Yilmaz, and A. Atmanli, "Sustainable alternative fuels in aviation," Energy, Vol. 140, pp. 1378–1386, 2017. [CrossRef]
[63] ICAO. (2022). "Sustainable aviation fuels," https://www.icao.int/environmental-protection/pages/SAF.aspx Accessed on July 28, 2022.W. Liao, Y. Fan, and C. Wang, (2022). "How does COVID-19 affect the implementation of CORSIA?" Journal of Air Transport Management, Vol. 99, pp. 1–8, 2022. [CrossRef]

[64] G. Seber, R. Malina, M. N. Pearlson, H. Olcay, J. I. Hileman, and S. R. H. Barrett, "Environmental and economic assessment of producing hydroprocessed jet and diesel fuel from waste oils and tallow," Biomass and Bioenergy, Vol. 67, pp. 108–118, 2014. [CrossRef]

[65] I. Ganguly, F. Pierobon, T. C. Bowers, M. Huisenga, G. Johnston, and I. L. Eastin, "'Woods-to-Wake' Life Cycle Assessment of residual woody biomass based jet-fuel using mild bisulfite pretreatment," Biomass and Bioenergy, 108, pp. 207–216, 2018. [CrossRef]

[66] E. S. K. Why, H. C. Ong, H. V. Lee, Y. Y. Gan, W.-H. Chen, and C. T. Chong, "Renewable aviation fuel by advanced hydroprocessing of biomass: Challenges and perspective," Energy Conversion and Management, Vol. 199, Article 112015, 2019. [CrossRef]

[67] S. Ahmad, and B. Xu, "A cognitive mapping approach to analyse stakeholders' perspectives on sustainable aviation fuels," Transportation Research Part D: Transport and Environment, Vol. 100, Article 103076, 2021. [CrossRef]

[68] ICAO. (2016). "ICAO environmental report 2016 aviation and climate change," https://www.icao.int/environmental-protection/pages/env2016.aspx Accessed on July 28, 2022.

[69] General Directorate of Civil Aviation. (2015). "2014 annual report," http://web.shgm.gov.tr/tr/kurumsal/4006-faaliyet-raporlarimiz Accessed on July 28, 2022.

[70] S. Gürçam. (2021a). "İklim değişikliği ile mücadele çerçevesinde Türkiye'nin sivil havacılık emisyonlarının: uluslararası sözleşmeler ve uygulamalar açısından analizi, Yayınlanmamış Doktora Tezi. İstanbul Yeni Yüzyıl Üniversitesi Sosyal Bilimler Enstitüsü, 2021

[71] General Directorate of Civil Aviation. (2020). "2019 annual report," http://web.shgm.gov.tr/tr/kurumsal/4006-faaliyet-raporlarimiz Accessed on July 28, 2022.

[72] ICAO. (2018). "Presentation of 2018 Air Transport statistical results," https://www.icao.int/annual-report-2018/Pages/the-world-of-air-transport-in-2018-statistical-results.aspx Accessed on July 28, 2022.

[73] ICAO. (2019). "Presentation of 2019 Air Transport statistical results," https://www.icao.int/annual-report-2019/Pages/the-world-of-air-transport-in-2019-statistical-results.aspx Accessed on July 28, 2022.

[74] ACI Europe. (2020). "European airports report slower passenger growth & declining freight in 2019," https://www.aci-europe.org/media-room/235-european-airports-report-slower-passenger-growth-declining-freight-in-2019 html Accessed on July 28, 2022.

[75] General Directorate of Civil Aviation. (2014). "2013 annual report," http://web.shgm.gov.tr/tr/kurumsal/4006-faaliyet-raporlarimiz Accessed on July 28, 2022.

[76] General Directorate of Civil Aviation. (2017). "2016 annual report," http://web.shgm.gov.tr/tr/kurumsal/4006-faaliyet-raporlarimiz Accessed on July 28, 2022.

[77] Pegasus Airlines. (2020). "Pegasus hava taşımacılığı anonim şirketi kurumsal sürdürülebilirlik raporu 2020," https://www.pegasusyatirimciiliskileri.com/medium/image/pgsus-2020-surdurulebilirlik-raporu_1070/view.aspx Accessed on July 28, 2022. [Turkish]

[78] Thinktech. (2021). "Sivil havacılıkta yakıt verimliliği," https://thinktech.stm.com.tr/uploads/docs/1616230696_stm-sivil-havacilik-yakit-verimliligi.pdf? Accessed on July 28, 2022. [Turkish]

[79] Turkish Airlines. (2016). "Çevre performans raporu," https://investor.turkishairlines.com/documents/surdurulebilirlik/cevre_raporu0161.pdf Accessed on July 28, 2022. [Turkish]

[80] Turkish Airlines. (2019). "Sürdürülebilirlik raporu," https://investor.turkishairlines.com/documents/surdurulebilirlik/surdurulebilirlik-raporu-turkce.pdf Accessed on July 28, 2022. [Turkish]

[81] Milliyet News. (2022). "THY çevreci yakıtla uçuşa geçti," https://www.milliyet.com.tr/ekonomi/thy-cevreci-yakitla-ucusa-gecti-6693109 Accessed on July 28, 2022. [Turkish]

[82] TRT News. (2021). "Türk Hava Yolları ilk kez çevreci yakıt kullanacak," https://www.trthaber.com/haber/ekonomi/turk-hava-yollari-ilk-kez-cevreci-yakit-kullanacak-640778.html Accessed on August 01, 2022

[83] Turkish Airlines. (2022). "Yepyeni bir proje: Paris'e sürdürülebilir havacılık yakıtıyla uçuyoruz!" https://blog.turkishairlines.com/tr/yepyeni-bir-proje-parise-surdurulebilir-havacilik-yakitiyla-ucuyoruz/ Accessed on July 28, 2022. [Turkish]

[84] T. Washington, and F. Watson, "Feature: EU review of ETS an opportunity for aviation decarbonization," https://www.spglobal.com/commodity-insights/en/market-insights/latest-news/agriculture/040921-feature-eu-review-of-ets-an-opportunity-for-aviation-decarbonization Accessed on July 28, 2022.

[85] A. Anger, and J. Köhler, "Including aviation emissions in the EU ETS: Much ado about nothing? A review," Transport Policy, Vol. 17(1), pp. 38–46. [CrossRef]

[86] Atmosfair. (2021). "Criticism of CORSIA, the aviation industry's offsetting scheme," https://www.atmosfair.de/en/criticism-of-corsia-aviation-offset-

ting-scheme/ Accessed on July 28, 2022. Thinktech. (2021). "Sivil havacılıkta yakıt verimliliği," https://thinktech.stm.com.tr/uploads/docs/1616230696_stm-sivil-havacilik-yakit-verimliligi.pdf? Accessed on July 28, 2022. [Turkish]

[87] Niranjan, A., & Schacht, K. (2021). "CORSIA: World's biggest plan to make flying green 'too broken to fix,'" https://www.dw.com/en/corsia-climate-flying-emissions-offsets/a-56309438

[88] International Energy Agency. (2021). "Net zero by 2050 A roadmap for the global energy sector," https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf Accessed on July 28, 2022.

[89] Y. Bicer, and I. Dincer, "Life cycle evaluation of hydrogen and other potential fuels for aircrafts," International Journal of Hydrogen Energy, Vol. 42(16), pp. 10722–10738, 2017.

[90] Airbus. (2020). "Airbus reveals new zero-emission concept aircraft," https://www.airbus.com/sites/g/files/jlcbta136/files/d82a792c20d166f4700d20c-013fead8a_EN-Airbus-unveils-ZEA-concepts.pdf Accessed on July 28, 2022.

[91] A. Baroutaji, T. Wilberforce, M. Ramadan, and A. G. Olabi, Comprehensive investigation on hydrogen and fuel cell technology in the aviation and aerospace sectors. Renewable and Sustainable Energy Reviews, Vol. 106, pp. 31–40, 2019

[92] Y. Y. Lai, E. Christley, A. Kulanovic, C. C. Teng, A. Björklund, J. Nordensvärd, E. Karakaya, and F. Urban, "Analysing the opportunities and challenges for mitigating the climate impact of aviation: A narrative review," Renewable and Sustainable Energy Reviews, Vol. 156, Article 111972, 2022. [CrossRef]

[93] IATA. (2015). "Sustainable aviation fuel roadmap," https://www.iata.org/contentassets/d13875e9ed-784f75bac90f000760e998/safr-1-2015.pdf Accessed on July 28, 2022.

[94] ATAG. (2011). "Powering the future of flight The six easy steps to growing a viable aviation biofuels industry," https://seors.unfccc.int/applications/seors/attachments/get_attachment?code=GRPR31ZA-287D3KAP5XOXQO2WP1JE9SQQ Accessed on July 28, 2022.

[95] IPCC. (2022). "Climate change 2022: Mitigation of climate change summary for policymakers," https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_SummaryForPolicymakers.pdf Accessed on July 28, 2022.