Addressing Global Warming: Challenges and Solutions in the Aviation Industry

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Abstract. The aviation industry faces significant challenges due to global warming. This article analyzes the specific impacts of global warming on aviation and explores potential mitigation measures. The industry contributes approximately 4% of human-induced global warming through CO_2 and non-CO_2 emissions, primarily from burning fossil fuels. The continuous rise in carbon emissions presents economic implications for airlines, exacerbating the climate crisis. Technological advancements aimed at reducing carbon emissions, such as sustainable aviation fuel (SAF) and electric flights, are discussed as promising solutions. Moreover, future trends and recommended policies in response to climate change are analyzed, showcasing the aviation industry's potential to address and mitigate climate-related issues. The adoption of these innovations and policies can significantly contribute to the global effort against climate change, ensuring a sustainable future for air travel. This comprehensive review highlights the urgent need for the aviation sector to embrace sustainable practices to mitigate its environmental impact while maintaining operational efficiency and economic viability.

Keywords: Aviation industry, global warming, carbon emissions, sustainable aviation fuel, electric flights.

1. Introduction

Greenhouse gases are the main cause behind global climate change and include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluoridated gases. Most human activities, such as burning fuels (including fossil fuels) for energy production and transportation, cutting down forests, etc., all emit very high concentrations of greenhouse gases. Carbon dioxide is the main greenhouse gas emitted by power stations, transportation and other types of production and services [1]. Jet engine combustion and contrails are the main greenhouse gases that cause the increase in global temperature. Aviation has a huge impact on global warming through carbon dioxide emissions, contrails and other complex factors. The aviation sector faces various challenges in a warming world. These include increased operating expenses and tighter environmental regulations and technology settings. Higher temperatures will lead to reduced aircraft performance – this is due to increased fuel consumption and, consequently, increased maintenance costs for flight operations. Moreover, pressure is mounting on governments to reduce the carbon footprint of the sector. This means the industry needs to invest in sustainable fuels, more fuel-efficient aircraft and better flight operations [1].

Furthermore, the industry is more vulnerable to interruption of services due to increased extreme weather events, which are becoming common and more devastating due to global climate change. The use of Jet A and Jet A-1, the form of kerosene that is derived from crude oil, is the main type of jet fuel for aviation. These fuels are employed in most airplanes in the civilian and military sectors worldwide [2]. Finally, the burning of jet fuel leads to increased CO_2, NOx, SOx and particulate matter, these being the fundamental sources of global warming and air pollution. Considering its effects on the environment, alternative fuels such as sustainable aviation fuels or biofuels are needed. The purpose of this assignment is to gauge the challenges in the aviation sector due to global warming and the possible solutions that might be adopted. It therefore becomes important to understand these problems for purposes of finding out how they can be mitigated given that it is a key carbon emitter among many sectors globally thereby necessitating urgent response towards climate change [2]. The significance of this study lies in the recognition that the aviation sector remains extremely important not only because it provides global transportation, economic development and connectivity but also because it has notable environmental impact. This study, therefore, intends to provide insights into the current status of the industry's future trends as well as provide workable recommendations for reducing its carbon footprint in order to balance its economic importance and environment [3].

2. Trends in Carbon Emissions and Their Impact on Global Warming

2.1. Trends in Carbon Emissions

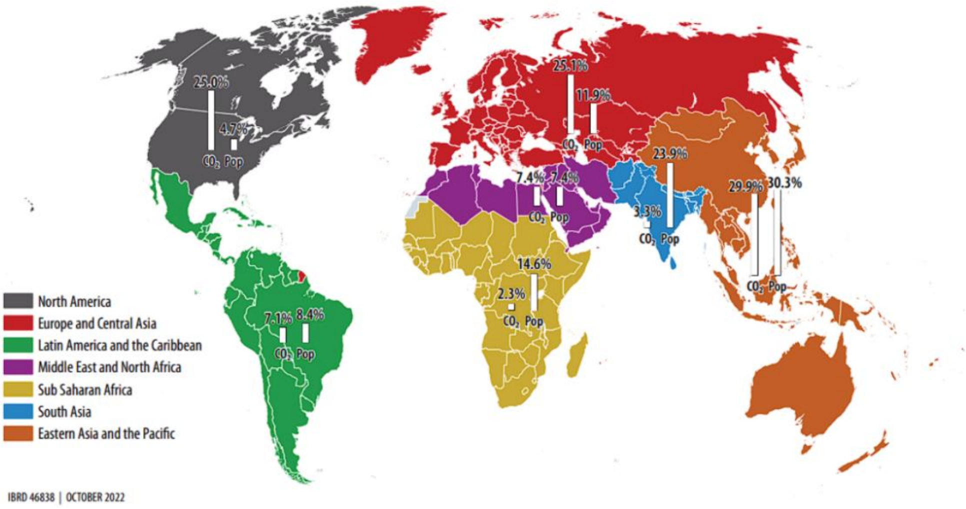

Figure 1. Combustion emissions of aviation and population by region, reproduced from the website: https://datatopics.worldbank.org/sdgatlas/archive/2017/the-world-by-region.html

Ballal et al. discuss global warming as majorly contributed to by the carbon emissions from the aviation sector. The burning of jet fuel brings forth CO_2 that retains heat in the Earth's atmosphere, thereby raising global temperatures [3]. Besides CO_2, NOx and water vapor are released into the air through aviation, which leads to the formation of ozone and contrails as well as cirrus clouds, which warm the earth even further [3]. Cumulatively, these gases have a substantial impact, with aviation being responsible for about 4% of human-induced global warming (Fig. 1). Bauen et al. discuss that the developed countries are mainly responsible for carbon dioxide emissions resulting from aviation activities, with combustion CO_2 emissions originating from these countries accounting for 62% in 2018 but only representing just 16% of the world's population [4]. In contrast, only 10% of CO_2 emissions arising from international flights come from low and middle-income countries whose share of the global population was roughly half or 49%. Nevertheless, despite the significant decrease in flights during the COVID-19 pandemic, predictions indicate that there will still be an increase in emissions by approximately seventy-one percent above those recorded in 2019 due to growth projected to occur in the airline business [4].

2.2. Costs and Challenges to the Aviation Industry

High costs and hurdles burden the aviation industry due to the impacts of global warming. This is because as temperatures rise, the air becomes less dense, resulting in poor performance of aircraft. Thus, due to increased fuel consumption and costs of maintenance, this leads to higher fuel consumption and maintenance costs [5]. Besides, extreme weather events are getting more frequent and intense, hence causing flight delays, cancellations and infrastructural damage that lead airlines to make massive financial losses. Regulatory challenges also pose significant obstacles. Governments worldwide are adopting stricter emissions standards and carbon pricing mechanisms for climate change mitigation purposes. Complying with such rules entails heavy investments in new technologies, sustainable fuels as well as operational improvements. Furthermore, the financial obligation is increased by the need for profitability and competitiveness within an industry transitioning towards low-carbon alternatives [5].

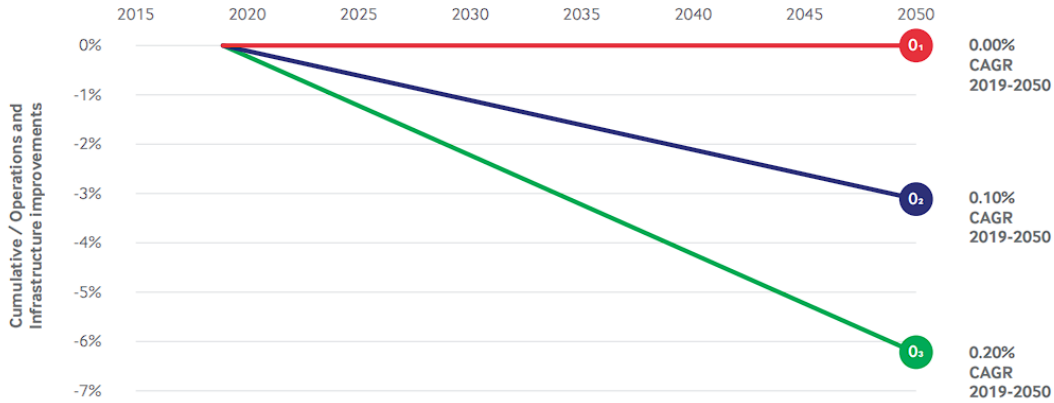

Figure 2. Operational efficiency scenarios for Waypoint 2050, reproduced from the website: https://www.ati.org.uk/wp-content/uploads/2022/07/insight-aviation-emissions-modelling.pdf.

The need for industry to invest in a multiple set of measures to cut its carbon footprint is one of the greatest challenges facing it [6]. These include shifts in air travel demand, better aircraft systems technologies, improved airline and ATM operations, as well as the adoption of sustainable aviation fuels (SAFs). SAFs have emerged as an important mitigation option, particularly because they can lead to significant reductions in greenhouse gas (GHG) emissions over the medium term. Although COVID-19 has led to a drastic reduction in air travel activities, forecasts indicate that aviation emissions could increase by 71% above 2019 levels by mid-century [6]. The year 2020 saw the global aviation sector affected like never before, with annual passenger traffic standing at only 34% of what was recorded in 2019.

Nonetheless, recent projections adjusted for COVID-19 impacts predict a huge surge in aviation activity up to 2050 (Fig. 2). On average, revenue passenger kilometers (RPKs) are projected to grow between 2.7% and 3.5% p.a. from 2019 through till mid-21st century [7]. This growth will, however, lead to increased GHG emissions unless further action is taken to reduce them significantly [7]. Consequently, it identifies possible areas where each country can produce SAFs given their level of development as well as the hurdles faced therein. Davis et al. also estimate emission reductions linked with these various scenarios and the associated capital investment, which is required thereof globally focused analysis aimed at addressing both international and domestic flight emissions considering the whole fuel cycle, from raw material extraction to fuel incineration. Moreover, such greening of aviation can only happen in concert with large investments and strong inventions that will achieve a sizeable reduction of GHG emissions by 2050 [8].

3. Ways to Reduce Carbon Emissions

Eisenhut et al. mention that doing this requires comprehensive, well-thought-out planning, as any particular part of the industry involves a large number of key strategies and stakeholders [9]. For example, one promising approach is to replace traditional fossil fuels with sustainable aviation fuels (SAF) and biofuels from renewable resources such as vegetable oils, waste oils and bio-based agricultural residues. Since such fuels significantly reduce lifecycle CO_2 emissions, their use can significantly improve the carbon footprint of aircraft [10]. However, these innovative fuels face the difficulties of high production costs and insufficient supply compared to fossil fuels, so large investments must be made in production capacity and technological improvements [10]. Another equally important point from an engineering perspective is that future flights need to adopt electric aircraft for all short-distance flights, with a range of fewer than 1,000km. Efficient use of air operations will also help reduce fuel consumption and, therefore, emissions: this means optimizing energy-saving flight plans and making full use of enhanced navigation systems, real-time weather, efficient air traffic management and other air traffic services available in everyone's sky around the world [11]. To successfully implement this goal, airlines, fuel supply companies, aircraft manufacturers, regulators, governments and other parties must work together. Major progress towards these and other sustainable measures include significant investments in infrastructure, supportive regulations, continued research and development, financial incentives, and public awareness programs. Solutions to all of these issues can indeed go a long way toward helping the aviation industry reduce its carbon footprint, thereby helping to achieve global climate goals [11].

3.1. Replacement of Fuel

3.1.1 Sustainable aviation fuel (SAF)

One option is Green Aviation Fuel (SAF), produced from plant oils, waste oil, agricultural residues, and even municipal solid waste - any organic source that stores solar energy [11]. Compared to fossil-based conventional jet fuel, lifecycle CO_2 emissions from SAF can be reduced up to even 80%, thanks to the fact that the feedstock accompanying CO_2 in their growth process is retracted back when burning [11]. While the reduction of lifecycle CO_2 emissions of SAF seems to be too good to be true, a significant challenge in the mass adoption of SAF remains. The biggest issue is the high production cost [12]. The current price point is much higher than fossil jet fuel, rendering itself to be less appealing to airlines that operate on slim profit margins. Gössling et al. discuss that the lack of large-scale production can explain this higher price point, the necessity of complex chemistry required to convert raw biomass to fuel, and other factors [13]. On top of that, the infrastructure required for large-scale SAF production has not fully been developed yet. Those existing facilities are too small to handle the potential scale of demand, causing supply shortage issues; large capital investments are necessary to set up new production plants, including the approval process with regulators, funding and new technology invention [13].

These barriers can be overcome by investing heavily in reducing costs and increasing green aviation fuel production capacity. Significant investments in R&D can lead to more efficient production methods and the discovery of new, cheaper precursor raw materials that can be used to make jet fuel [13]. The lower costs involved in converting the crude feedstock into SAF fuel make it more competitively priced. Pilots will then start using it on demand, similar to the fossil petroleum derivatives that airlines currently use when called upon. Policy can also play an important role in promoting the adoption of SAF [13]. Government agencies can use policies such as taxes or incentives to offset the additional costs involved in SF production so that commercial airlines can use green fuels. In addition, mandates requiring airlines to continue using SAF can ensure certainty of demand and thus the business case for investing in production facilities [14]. For example, blending regulations requiring SAF to be blended with traditional aviation fuel in a certain ratio can gradually increase SF's market share. In addition, unless it addresses this issue internationally, SAF will never be widely disseminated. International experts must coordinate regulations to make the widespread adoption of SAF easier. Cross-border trade in SAF can be smooth if all countries have similar specifications and certification requirements. Therefore, the government can either share the financial burden equally or work with aviation industry players, such as companies that deal in fossil oil and jet fuel [14]. Graham et al. also state that public awareness and corporate social responsibility initiatives will drive the uptake of SAF. Airlines can, therefore, win customers who are environmentally conscious by adopting sustainability measures as a marketing strategy [14]. An airline’s brand image could be enhanced by highlighting its efforts towards reducing its carbon footprint using SAF. This strategy could attract clients who are willing to participate in green initiatives when they go through an airport. Although Grewe et al. high production costs and limited availability are major setbacks to carbon emission reduction in air travel, Sustainable Aviation Fuel (SAF) offers itself as one of the ways out; this, however, necessitates collective action [15]. Thus, it requires investments in production capacity, technological advancements, supportive policy measures like taxation or subsidies, and global collaboration to make it a mainstream fuel for aviation. By overcoming these hurdles, the air transport sector will be closer to its objectives on sustainability, thus helping address global climate change concerns more effectively [15].

3.1.2 Biofuel

Biofuels are obtained from biological materials such as crops, algae and biomass waste. They can lower greenhouse gas emissions more than fossil fuels. There are two principal types of biofuels: first-generation ones, which are based on food crops, and second-generation ones made out of non-food biomass. As a result, second-generation biofuels are more viable than first-generation products because they do not compete with food production and can utilize waste. Nonetheless, the biofuel industry faces problems such as land and water resources management and the need for technological advances to improve yields and efficiency. Studies in genetically modified crops, algae cultivation and advanced bio-refining processes, however, can help overcome these challenges.

3.2. Technological Innovation and Development of Electric Flights

Biofuels are obtained from biological materials such as crops, algae and biomass waste. They can lower greenhouse gas emissions more than fossil fuels [16]. There are two principal types of biofuels: first-generation ones, which are based on food crops, and second-generation ones, made out of non-food biomass [17]. As a result, second-generation biofuels are more viable than first-generation products because they do not compete with food production and can utilize waste [17]. Nonetheless, the biofuel industry faces problems such as land and water resources management and the need for technological advances to improve yields and efficiency. Studies in genetically modified crops, algae cultivation and advanced bio-refining processes, however, can help overcome these challenges [18].

3.3. Improved Air Operations

This section will discuss how to improve air operations and the reduction of environmental impact with respect to air travel operations is a fundamental requirement. Significant savings in fuel and reduced emissions can be achieved through flight routes and altitude optimization [19]. It is possible to save energy on flight plans by employing new advanced navigation systems, real-time weather data, and air traffic management techniques that minimize the amount of fuel used. The adoption of Continuous Descent Operations, as well as Optimized Profile Descents will result in lesser fuel burn during landing [19]. Moreover, the introduction of Performance-Based Navigation has led to the creation of flight paths that are more likely to stay on track, reducing the distance that must be flown and, hence, the amount of fuel burned. High levels of operational efficiency rely on coordination between airlines, airports and ATC [20].

3.4. Implementation

Curbing the rapid growth of greenhouse gas emissions from aviation will require concerted action from all stakeholders, including airlines, fuel producers, aircraft manufacturers and governments. Acting now and making significant upfront investments in infrastructure such as SAF production plants, electric charging stations and integrated advanced air traffic management systems is essential. Public-private partnerships can play an important role in these investments, ensuring that sufficient gains are made in infrastructure to support green transportation. Regulators, in turn, can help by creating an environment conducive to the use of sustainable fuels and technologies. Through policies such as carbon pricing and emissions trading schemes, as well as fuel mandates, governments can steer the industry toward lower-emission routes. These regulations strengthen the economic incentives, forcing airlines to adopt fewer polluting modes of travel and reduce their carbon footprint. SAF relies on further RD to ramp up efficiency at acceptable cost as well as for further research and development into biofuels and electric propulsion [21].

There must be financial incentives and subsidies to remove economic barriers associated with new technologies or fuels adoption [22]. Besides this, increased public knowledge about the environmental effects of airplane activities, along with encouraging demand for cleaner alternatives, could lead to transformation in the industry towards sustainability [22]. Airlines should market themselves by highlighting their use of SAFs alongside hosting carbon offset programs to attract eco-conscious travelers who will further drive this paradigm shift. If the implementation challenges described above can be overcome, the aerospace sector could achieve substantial emissions reductions while still adhering to global climate targets. Providing more sustainable air transport requires exerted effort from stakeholders and large investments in support of conducive legal frameworks and continuous innovations [23].

4. Future

4.1. Future Global Warming Trends

Looking to future decades, global warming is likely to trend upward in terms of higher temperatures as well as increased frequency of violent climatic events. Indeed, predictions from the IPCC state that temperature could rise by 1.5 to 2°C above pre-industrial levels by 2050 if current emission trends continue as they are currently [24]. This spike in temperatures could come with drastic consequences in terms of weather patterns, rising sea levels and associated ecosystem changes [24]. More specifically, higher temperatures tend to have a detrimental effect on the performance of aircraft that, together with frequent and violent climatic changes, could lead to a significant increase in fuel consumption while simultaneously driving maintenance costs and margins up. This apparent productivity trap would also severely restrain the ability of air travel operations to continue to provide the high levels of service offered so far, as delays, cancellations, and potential damages to infrastructure (e.g., airport runways and terminals) are likely to become frequent [24]. For these reasons, they should develop more resilient infrastructures for their airlines and their operations, that is, investing in climate change resilient developments of the airport, further improving models on weather prediction and, above all, enhancing contingency plans for extreme climates. Alongside that, the same industry should continue working toward its carbon footprint reduction so it can contribute to the big effort that should be taken against global warming. Hence, by adopting sustainable practices with more resilient infrastructures, aviation might be able to manage climate change and contribute to wider efforts to curb global warming [24].

4.2. Policy Recommendations

Sovern policymakers must execute the policies on aviation for sustainability. One of these is tightening up on emission limits and concentrating on sustainable fuels, leading to lower release of carbon dioxide from aircraft emissions [25]. This must include setting targets for neutral growth in terms of carbon as well as incorporation of SAF and other types of green fuel. At the same time, these can act as important economic incentives to cut emissions, thus leading to higher prices in pollution activities, thereby pushing individuals to move to more energy efficient technology. Governments can help speed up the shift by subsidizing SAF production, by giving grants in researching electric flight techs coupled with tax credits on green investments. Just as important is the international cooperation in addressing climate change impacts [25]. Raising awareness amongst the public about the environmental impacts of flying might also be crucial. Governments could do this by running campaigns teaching customers to travel more sustainably and, at the same time, ensuring more demand for green methods of transferring [26]. Lastly, encouraging the creation and use of programs designed to offset any carbon release while flying can benefit a great deal to reduce environment degeneration resulting from such activity. Creating these approaches is capable of moving such pertinent policymakers much closer to a more sustainable and green aviation sector while aiding the broader global climate targets at large.

5. Conclusion

In conclusion, since global warming is causing major and multifaceted issues for the aviation industry, this plays a vital role in climate change. However, in terms of greenhouse gas emissions, the sector has become a central component in the climate debate since it relies on fossil fuels. Despite the significant challenges, there are big chances to lessen the environmental footprint and for the sector to be compliant with global climate objectives, which include carbon reductions by using these alternatives through renewable sources and modern production processes. In addition, electric aircraft development and deployment can have transformative prospects, for instance, short haul flights, thereby serving as a zero-emission substitute capable of significantly reducing the carbon printout generated from this sector. Re-optimization of air operations also provides immediate impacts comprising significant fuel savings, and such an aircraft can be built with better design and technology, such as lightweight construction material, which reduces fuel consumption and waste. However, for these strategies to bear fruits, huge investments are needed in infrastructure as well as ongoing research and development (R&D). For instance, building adequate facilities to allow for SAFs and biofuel uses requires huge amounts of finance, while developing reliable electric aircraft technology demands huge investments in research so does updating air traffic management systems since this requires financial resources as well as new technologies. Policymakers here play critical roles since linear modal shift alone will not propel the transition to a green sky as a wave of greenwashing with airlines issuing corporate quotes and presenting green practices.

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