Global Tourism, Climate Change and Energy Sustainability: Assessing Carbon Reduction Mitigating Measures from the Aviation Industry

Walter Leal [1], Artie W Ng,[2 *] Ayyoob Sharifi [3], Jitka Janová [4], Pınar Gökçin Özuyar [5], Chinmai Hemani [6], Graeme Heyes [7], Dennis Njau [8], Izabela Rampasso [9]

[1] Department of Natural Sciences / Manchester Metropolitan University, Chester Street, Manchester M1 5GD, UK & International Climate Change Information and Research Programme, Research and Transfer Centre "Sustainable Development and Climate Change Management", Hamburg University of Applied Sciences, Germany. E-mail: walter.leal2@haw-hamburg.de ORCID: 0000-0002-3993-8974

[2] * Corresponding author: Artie W Ng, Centre for Sustainable Business, International Business University, Toronto, Canada; Waterloo Institute for Sustainable Energy, University of Waterloo, Waterloo, Canada; Research Centre for Green Energy, Transport and Building, The Hong Kong Polytechnic University, Hong Kong SAR. Email: ang@ibu.ca ORCID: 0000-0002-1388-5835

[3] Ayyoob Sharifi, Graduate School of Humanities and Social Sciences, and Network for Education and Research on Peace and Sustainability, Hiroshima University, Higashi-Hiroshima 739-8530, Japan, E-mail: Sharifi@hiroshima-u.ac.jp ORCID 0000-0002-8983-8613

[4] Jitka Janová, Department of Statistics and Operational Analysis, Faculty of Business and Economics, Mendel University in Brno, Zemedelska 1, Brno, Czech Republic, Email: janova@mendelu.cz

[5] Pınar Gökçin Özuyar, Department of Business Administration, Bahçeşehir University, Faculty of Economics, Administrative and Social Sciences, Turkey, Email: pinar.ozuyar@eas.bau.edu.tr

[6] Chinmai Hemani, RuChiNi ESP, India, Email: chinmayhemani@gmail.com ORCID: 0000-0002-4326-7456

[7] Graeme Heyes, Centre for Enterprise, Faculty of Business and Law, Manchester Metropolitan University Business School, All Saints, Manchester, UK , Email: g.heyes@mmu.ac.uk ORCID: 0000-0002-8073-1975

[8] Dennis Njau, Prime Research Division – Palme Research & Training Consultants, Nairobi, Kenya, Email: dennis@palmeconsultants.com ORCID 0000-0003-4946-452X

[9] Izabela Simon Rampasso, Departamento de Ingeniería Industrial, Universidad Católica del Norte, Antofagasta, Chile., Email: izarampasso@gmail.com

Abstract

As many business activities - especially those associated with the energy-intensive industries- continue to be major sources of greenhouse gas emissions, and hence significantly contributing to global warming, there is a perceived need to identify ways to make business activities eventually carbon neutral. This paper explores the implications of a changing climate for the global tourism business and its intertwining global aviation industry that operates in a self-regulatory environment. Adopting a bibliometric analysis of literature in the domain of global tourism and climate change (772 articles), the paper reveals the underlying sustainability issues that entail unsustainable energy consumption. The aviation industry as a significant source of carbon emission within the sector is then examined by analyzing the top 20 largest commercial airlines in the world with respect to its ongoing mitigating measures in meeting the Paris Agreement targets. While self-regulatory initiatives are taken to adopt Sustainable Aviation Fuels (SAF) as alternative fuel production and consumption for drastically reducing carbon emission, voluntary alignment and commitment to long-term targets remain inconsistent. A concerted strategic approach to building up complementary sustainable infrastructures among the global network of airports based in various international tourist destination cities to enable a measurable reduction in carbon emission is necessary to achieve a transformational adaptation of a business sector that is of essence to the recovery of the global economy while attempting to tackle climate change in a post-COVID-19 era.

Keywords: Climate change, Tourism business, Aviation industry, Energy sustainability, Paris Agreement, Self-regulation, International airports

1. Introduction

Global efforts to combat climate change revolved around debates on who should take responsibility for carbon emission reductions; nonetheless, the significance of business and its potential impacts have been widely asserted (Dessens, et.al. 2016, Sivapuram and Shaw, 2020; Johnstone et.al. 2021). While there are still differences among governments on how to advance with the Paris agreement (Gunfaus and Waisman, 2021), the business sectors have already begun evaluating measures to take in order to claim their role. Despite a decrease in the global greenhouse gas emissions during the Covid-19 period (Le Quere et.al., 2021), businesses will have to step up their efforts to maintain this momentum. The urgency for businesses to take long-term measures in boosting sustainability can be elucidated with respect to nominal, legislative, or market-based drivers (Kara, et.al. 2013; Santa-Maria et.al.2021; Hao and Renneboog, 2020).

The discourse to mitigate global warming and adapt to climate change creates a major agenda item, especially for some of the material sectors, which are largely business sectors or industries that depend heavily upon the use of various raw materials, particularly fossil fuels. Due to the risks posed by climate change, it is expected that businesses have to bear increased operating costs, and only a few companies are prepared for such challenges under a major transformation in the supply of raw materials and related logistics processes (Arnell et.al. 2021; Wang et.al. 2020, Gerlak et.al. 2018; Sun et.al. 2020). Since climate change mitigation and adaptation measures have the potential to affect the future livelihood of businesses, a well-calculated, negotiated and mutually agreeable implementation mechanism must be set in place.

Market-based green finance mechanisms for emissions trading and climate change have long been discussed (Chevallier 2009), and various tools have been presented (Ng, 2018). Among the earlier ones were carbon or emissions trading schemes, an outcome of the Kyoto Protocol for the undersigned governments to take part in the mandatory emissions market. Other countries have formed a voluntary market, a more relaxed but also less efficient system. Others followed, from carbon taxes to climate bonds, all forming a set of financing mechanisms in line with the principle of ‘common but differentiated

responsibility and respective capabilities', as set out in the United Nations Framework Convention on Climate Change and the 1.5 ^{o}C target set in place by the Paris Agreement (IPCC, 2018). However, with respect to adopting the Paris agreement targets, specific strategies aligned with independent scientific reviews and developing countries to cap carbon emissions are not yet in place (Schumacher, 2020; Roberts et al., 2021). Among others, Kotchen (2020) provided a framework for evaluating the feasibility of climate finance to facilitate international agreement, and based on a conceptual model, showed that complementary financial transfers are feasible if they are bounded by the net benefits of avoided climate damages and forgone economic growth.

Businesses are a key part of this concentrated effort towards this transformation. While this mobilization will be significant to most business sectors, certain sectors, such as tourism, are considered relatively more impactful in terms of materializing environmental sustainability. In the discussion of climate change mitigation and adaptation, the global tourism sector and its comprising aviation industry call for much attention; while there are global targets from the Paris Agreement, specific strategies to cap carbon emissions from specific material sectors/industries are not in place yet despite the emerging efforts of climate finance. A number of prior studies have pointed out the cruciality of developing green transport infrastructures to enhance sustainability within the tourism sector and the aviation industry (Monsalud et al. 2015; Erdogan et al., 2020; Santa et al., 2020; Kazancoglu et al., 2021). In this relation, there are studies noting the importance of adopting cleaner energy to transform the unsustainability of local economies that rely on tourism (Rizzo, 2017, Lin et al., 2018; Jea, 2019). Interdisciplinary studies on such transformation for smart and sustainable tourism are desirable, as the world is to undergo a challenging period of recovery from COVID-19 (Casado-Aranda et al., 2021).

Against this background, this paper first provides an extended literature review on the underlying issues connecting global tourism business, climate change, and the aviation industry, which are complemented by a bibliometric analysis of literature in the domain of climate change and tourism (772 articles) as well as an analysis of 20 representative cases in the global aviation industry, taking into consideration the industry's mitigating measures through a self-regulatory approach to reducing carbon emission

systematically by 2050. It aims to investigate the industry's current approach to reducing carbon emissions in alignment with the Paris Agreement and to the limitations of a self-regulatory environment. It contributes to the existing literature by examining the relevance of adopting cleaner energy and green infrastructures to the sustainability of global tourism as key possible ways to augment carbon reduction through such innovative and transformative measures.

2. Climate Change and Tourism as a Business Sector

2.1 Global Tourism and Climate Change

The global tourism industry has been rapidly expanding over the past decades into a significant contributor to many national economies. During the last 25 years, worldwide international tourism more than doubled, from 1,025 billion international arrivals in 1995 to 2,28 billion in 2019 (WDG, 2021). In 2019, national and international tourism accounted, directly or indirectly, for 10.3% of global GDP and 330 million jobs (WTTC, 2020). The World Travel and Tourism Council (WTTC) and the UN World Tourist Organization (UNWTO) have been promoting tourism as a means to reduce poverty and preserve cultural heritage. Yet, there has also been substantial criticism of international tourism due to its negative impact on the environment and its contribution to climate change (Scott et al., 2012). Alongside this criticism, the immediate negative influence of 'over-tourism' on the tourist destinations and the local habitants' well-being is increasingly discussed and considered by policymakers (Hoogendoorn & Fitchett, 2018; Kajan & Saarinen, 2013; Saeporsdottir & Hall, 2020).

Theoretically, there is a two-way interaction between climate change and global tourism (Hewer & Gough, 2018; Hoogendoorn & Fitchett, 2018; Njoroge, 2015) (see Figure 1). Tourism has a significant impact on the environment and climate (Lenzen et al., 2018; Scott et al., 2012; Scott & Becken, 2010). Nature-based tourism, particularly along the coastline and in winter destinations, is vulnerable to weather and climate change (Morrison & Pickering, 2013; Spandre et al., 2019). On the other hand, tourists' perceptions and responses to this environmental change are yet to be fully understood (Dube & Nhamo, 2020; Hindley & Font, 2017; Morrison & Pickering, 2013). The assessment of tourism development and climate change

interconnections has been given much attention and intensively studied in developing countries that are potentially vulnerable to climate change, and yet economically dependent on tourism (Chapagain et al., 2020; Le, 2020; Scott et al., 2012).

As illustrated in Figure 1, we can see the current complex, overall interconnections of global tourism and climate change. Tourism contributes to climate change via greenhouse gas emissions, while climate change impacts tourism in multiple ways (UNWTO, 2008):

i. directly, by the weather changes resulting in, e.g., severe weather conditions or less snow in winter sports destinations,
ii. indirectly, through reduced landscape aesthetics, loss of biodiversity, lower water availability, or increased incidence of diseases,
iii. through mitigation policies that may result in changing tourists' travel patterns; and
iv. through societal impacts, possibly resulting in social unrest and political instability.

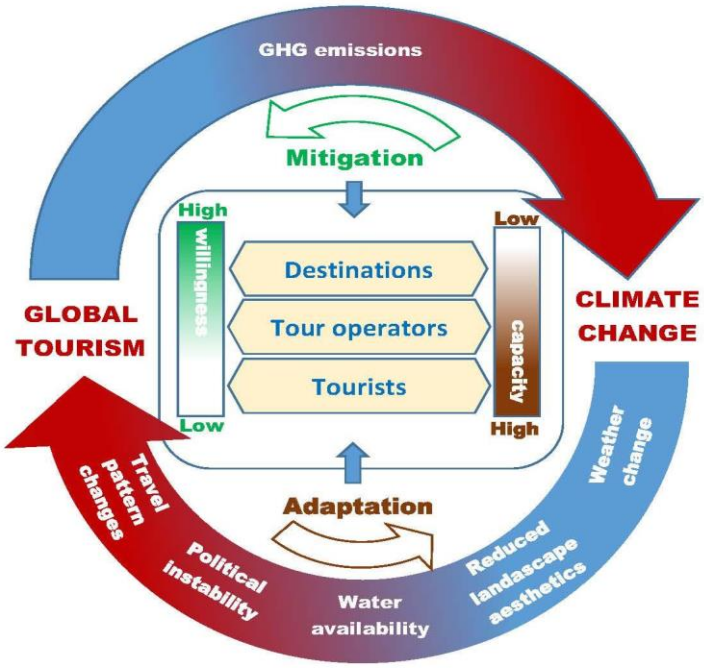

Figure 1: Global tourism and climate change: interrelations

The tourism industry stakeholders are tourists, tour operators, and the destinations where the services are provided. Mitigation strategies aim to lower the impact of tourism on climate change, as the industry simultaneously adapts to the new climate conditions. While tourists and tour operators have a high adaptation capacity for climate change (shifting timing or destination, product, and market diversification, respectively), the destinations face a limited adaptation capacity. Even though it was found that consumers identify air travel as a cause of climate change (Bonini & Oppenheim, 2008; Brouwer et al., 2008), other studies have evidenced that there is little willingness among air passengers to change their behavior to limit oneself in flying (Cohen and Higham, 2011; Hall et al., 2015; Lassen, 2010; Xu et al., 2021). Consumers are considered to have the most flexibility, i.e., having the highest capacity to adapt, as compared to destinations and tourism operators (Njoroge, 2015). The willingness to apply mitigation actions is relatively more observable among the destinations, but the willingness of tourists to voluntarily change

their travel behavior to reduce environmental impacts was evidently rather low (Higham & Cohen, 2011; McKercher et al., 2010; Xu et al., 2021).

2.2 Mitigating Measures and Significance of the Aviation Industry

The impacts of tourism on the environment in general, and specifically on the climate, have been receiving significant attention in the past decades since the essential tourism components of traveling are considered carbon intensive. Moreover, tourism is expected to account for an increasingly larger share of global greenhouse gas emissions, even if other sectors manage to achieve absolute emission reductions (Gossling et al., 2013). Based on the analysis of traveler habits in 160 countries between 2009-2013, a study (Lenzen et al., 2018) showed that tourism's impact on global emissions is four times higher than previously thought. Tourism contributes to about 8% of global greenhouse gas (GHG) emissions, resulting mainly from the transport and consumption of goods and services, including food and accommodation. Its findings suggest that tourism has turned into a carbon-intensive sector and would continue to accelerate local carbon emissions. Another study warns that at least 15% of global tourism-related emissions associated with global aviation are under no binding reduction targets in the Paris Agreement (Lenzen, 2018).

The possible impact of tourism on climate change has raised debates and induced studies during the last decades of the 20th century, and since then, related research has intensified considerably (Hall et al., 2015; Kajan & Saarinen, 2013; Scott, 2010; Scott & Becken, 2010). The need for the reduction of emissions in the aviation sector and for imposing appropriate policies has been declared (Gossling & Hall, 2008; Scott et al., 2010). In 2008, the UNWTO proposed particular mitigation actions that would improve the situation: to encourage travelers to choose a closer destination, use more public transportation and less aviation, and provide incentives for tourism operators to improve their energy and carbon efficiency (UNWTO, 2008). The tourism industry has continued to face pressure from the growing awareness of the carbon footprint of travel (Becken and Hay, 2007; Dawson et al., 2010).

In fact, the aviation industry has long been recognized for its adverse impact on environmental sustainability and climate change (Lee et al, 2009; Fahey and Lee; 2016). Such concerns have been addressed by calls

for demand-side management of aviation (Larkin, 2014), owing to the fact that pre-COVID the aviation sector was predicted to continue growing at a rate of 4.8% to 2030, a figure far greater than the technological and operational efficiencies the industry has been able to demonstrate in recent decades (Lee et al, 2020). This has led to airlines seeking ever more radical efficiency savings that impede the customer experience, such as weight-saving measures that include unpainted aircraft, removal of in-flight safety jackets, and seeking the reduction of weight from the sale of duty-free products (Heyes, 2019). Baumeister (2020) points out that there are five general mitigation strategies for the aviation industry, namely technological changes, market-based changes, operational changes, regulatory changes, and behavioral changes. In particular, technological innovation has reached the point of incremental returns on investment, whilst operational savings are complex and subject to a range of competing environmental interdependencies, not least air quality and noise, both of which are typical of a greater priority to airport communities (Hoolhorst, 2022; Heyes, 2021).

2.3 Advancing Mitigation Strategies in a Post COVID-19 Era for Energy Sustainability

In 2011, the WTTC position paper issued carbon reduction targets of 25% by 2020 and 50% by 2035 when compared to 2005 levels (Scott et al., 2012; UNWTO, 2011). However, from 2005 to 2019 worldwide tourism continuously expanded. The number of national and international aviation-related tourists has almost doubled, while the number of international arrivals has risen by 50% and the amount of total tourism has increased by 125% worldwide (WDG, 2021). During the pre-COVID era, the mitigation strategies had yielded limited success. Neither responsible travel behavior nor technological improvements have alleviated the increase in tourism's footprint (Lenzen et al., 2018). Carbon-intensive tourism at its current scale remains unsustainable. Until 2019, tourism was producing an increasing share of GHG emissions each year, and simultaneously, tourists are generally not willing to apply any mitigation strategies to their traveling habits. The burden of a shift to sustainable practices is placed upon destinations and tour operators, including tourist offices and long-haul transport services, particularly the aviation industry.

Due to the COVID-19 pandemic, international tourist arrivals in 2020 dropped by 74% worldwide in comparison to 2019 figures (UNWTO, 2021). With the start of vaccination in 2021, the tourism sector looks ahead for better days and believes in recovery. The 2020 decrease in traffic and pollution supports the voices of those who call for the regulation of tourism due to its high impact on carbon emissions, which is considerably attributed to vehicles and aviation (Rume & Didar-Ul Islam, 2020). Others have suggested promoting low carbon tourism through regional certifications (Baumber et al., 2021), and marketing propagation (D'Souza et al., 2021). To complement this development, carbon reporting and public disclosure are increasingly expected from companies in the pertinent industries on any enhanced application of climate mitigation measures as demonstrated in other business sectors (Tang and Demeritt, 2018; Bui et al., 2021).

The suggestions of mitigation policies and strategies to reduce emissions systematically for a transition into global sustainability in a post-COVID-19 era have been elaborated in recent scientific literature (Duflot et al, 2021; Ranjbari et al., 2021). It is advocated that green infrastructures and systems can be built within the airport facilities to enhance the energy sustainability of their operations as a significant part of the carbon emission mitigation strategies (Santa et al., 2020; Ng et al., 2021; Bragge, 2022). With respect to drastically reducing carbon emissions, Sustainable Aviation Fuel (SAF) as cleaner energy has been considered an imminent solution for commercial aircraft (Abrantes et al., 2021).

2.4 Further Mitigating Measures from the Aviation Industry to Reduce Carbon Emissions

Targets for CO_2 emissions from the aviation industry are considered relevant within the Paris Agreement, which aims to restrict increases in temperature to under 2°C by 2100 (Lee, 2018). In order to meet the Paris Agreement's goals, a significant reduction in global greenhouse gas emissions is necessary for the industry on a global basis. Its emissions of CO_2 are overseen by the International Civil Aviation Organization (ICAO), which has taken measures to adopt the "Carbon Offsetting and Reduction Scheme for International Aviation" (CORSIA) and has a carbon-neutral growth goal for international aviation emissions of CO_2 to not surpass 2020 levels (ICAO, 2021a). On the other hand, the International Air Transport Association (IATA), the trade association representing 290 airlines in 120 countries, has

stepped up to support the development of environmental standards and recommended practices in ICAO. IATA is the entity that advocates and collaborates with airlines to identify policies to mitigate the sector's impact on climate change (IATA, 2021). IATA reckons its members need to tackle the global challenge of climate change and has adopted three targets and four pillars to mitigate CO_2 emissions from air transport, as summarized in Table 1.

Targets to Reduce Emissions:
● T1: Past Performance: An average improvement in fuel efficiency of 1.5% per year from 2009 to 2020
● T2: Near-term Performance: A cap on net aviation CO_2 emissions from 2020 (carbon-neutral growth)
● T3: Long-term Performance: A reduction in net aviation CO_2 emissions of 50% by 2050, relative to 2005 levels
Four Pillars of Strategy to Achieve Environmental Sustainability:
● P1: Improved technology, including the deployment of Sustainable Aviation Fuels
● P2: More efficient aircraft operations
● P3: Infrastructure improvements, including modernized air traffic management systems
● P4: A single global market-based measure, to fill the remaining emissions gap

Table 1 Adopted framework of targets and pillars for sustainability in the global aviation industry (Source: adjusted from IATA, 2021)

3. Methods

This study aims to explore the implications of the changing climate for businesses, with a focus on

tourism as a business sector and its intertwining global aviation industry, and to examine the initiatives taken by the pertinent industry actors to reduce the carbon footprint of the business activities. It adopts a mixed-method approach to examine the underlying relationship between business and climate change in the sector. First, text mining is performed to reveal the research landscape of prior studies, based on the bibliometric analysis method. Of different bibliometric analysis techniques, this study mainly relies on co-occurrence analysis to examine issues related to climatic impacts and sustainability implications of tourism. Subsequently, being informed by the results of the text analysis, the research team identify and examine representative cases of 20 of the largest commercial airline operators from the global aviation industry which disclose their commitment to a global framework approach embraced by the industry. This mixed-method approach enables an external validation of the underlying research landscape by examining in-depth the current practice of these representative cases by analyzing their disclosures, thereby mitigating the possible limitation of merely reviewing prior studies considering the evolving climate change issues.

3.1 Bibliometric Analysis Method

The rapid rate of scientific publication has made it challenging to obtain knowledge about the overall structure of a field using traditional methods based on manual analysis. To solve this issue, several software tools for bibliometric analysis of the literature have been developed in the past decade that can provide an overview of the research landscape by using text mining methods. VOS viewer is a frequently used bibliometric analysis tool that, among other things, allows one to identify major thematic focus areas in a research field by using the term co-occurrence analysis (van Eck & Waltman, 2010). The input data for term co-occurrence analysis can be downloaded from scientific databases such as the Web of Science (WoS) and Scopus. In a recent study on human mobility behavior in COVID-19 by Benita (2021), bibliometric analysis is adopted to conduct a systematic literature review.

In this study, we have used WoS for its broad coverage of quality peer-reviewed articles related to the topic. A broad-based search string that includes different variants of terms related to climate change mitigation and tourism was used to retrieve relevant articles (see the Appendix for the complete search string). The terms used in the search were selected in a way to cover multiple issues related to climate change and tourism. The literature search was conducted on February 28, 2020, with 850 returned articles. Titles and abstracts of these articles were screened to select those that are within the scope of the paper. In the end, 772 articles were selected for final analysis using the VOSviewer. The output of the term co-occurrence analysis (see Figure 2) is a network of nodes and links. Each node represents a term, and node size is proportional to its frequency of occurrence. Terms that have co-occurred are linked to each other, and link width is proportional to the strength of the connection between two terms. In other words, terms that have co-occurred more frequently are connected by wider links. The frequently co-occurred terms establish clusters that represent major thematic focus areas.

3.2 Multiple-Case Study

Complementing the bibliometric analysis, a multiple-case method is adopted to examine the global aviation industry, with individual airlines as units of analysis (Yin, 2003). The top 20 largest commercial airlines in the world, in terms of aircraft size, are selected to assess their above-mentioned performance, based on their public disclosures in February/March 2021 (Airportcodes, 2021). Under supervision for a systematic approach to data collection and analysis, five independent researchers reviewed such disclosures and evaluated their performance against the adopted framework of sustainability strategies for the industry presented in Table 1. Each researcher was initially assigned to assess four airlines regarding compliance and performance; subsequently, the results were compared to ensure consistency in terms of basis.

4. Results and Discussion

4.1 Bibliometric Analysis

Through the bibliometric analysis, two major clusters can be identified in Figure 2. The cluster on the left has a clear focus on emissions and mainly focuses on terms and issues related to climatic impacts and sustainability implications of tourism, while the one on the right focuses on key economic issues related to tourism. The cluster on the right has a clear focus on economic issues and has links between tourism-led growth and environmental degradation. The top 10 articles related to each cluster are listed in Table 2a and 2b, respectively. The term tourism has co-occurred frequently with CO_2 emissions and climate change, indicating ample research on and evidence of tourism's impacts on climate change and mitigation policies (Akadiri et al., 2020; Lenzen et al., 2018; Rico et al., 2019). In addition, there are relatively strong connections between tourism and terms such as ecological footprint (total link strength value of 201), pollution (total link strength value of 196), and environmental sustainability (total link strength value of 318). This is indicative of the ecological impacts of the tourism sector that have been discussed in the literature (Lee & Chen, 2021; Ozturk et al., 2016). As for issues related to the nexus between tourism and CO_2 emissions/climate change, strong connections with transportation-related terms (e.g., mobility, transport, aviation) and terms related to energy consumption and renewable energy demonstrate the significant roles of the energy and transportation sectors in contributing to tourism-related emissions (Spasojevic et al., 2018). Tourism-related air and land transportation accounts for about 10% of the annual global CO_2 emissions (Bella, 2018). Accordingly, sustainable tourism initiatives should enhance the efficiency of these sectors in contributing to climate change mitigation.

In addition, promoting travel to closer destinations and further investment in public transportation networks may also contribute to reducing travel-related emissions. Another likely influential actor is the hospitality industry, which could be water and energy intensive (Cazcarro et al., 2014; Chen, 2019). The term "water resources" has relatively co-occurred less frequently with other terms. This may indicate that existing research is mainly focused on energy-related issues. In addition to their significance for climate change adaptation, water resources also have links to energy resilience (through the water-energy nexus) and deserve further attention. Therefore, both energy and water consumption should be considered in

studying enhanced management practices for optimizing the sustainability performance of hotels. Overall, it is evident that sustainable and responsible tourism is needed to reduce CO_2 emissions, to ensure the conservation of ecosystem services, and to minimize the ecological footprint.

The cluster on the right revealing the causality between tourism flow and different variables such as economic growth, financial development, income growth, energy consumption, and environmental pollution has been studied in the literature using various economic methods, such as co-integration and time series analysis (Bella, 2018; Ozturk et al., 2016). There is consensus in the literature that tourism development can lead to economic growth, but this could have significant impacts on the environment (Ozturk et al., 2016; Zaman et al., 2016). Figure 2 shows that the term "Kuznets curve" has occurred frequently in the tourism literature. Indeed, there is a vast body of research from different countries that examines the validity of the environmental Kuznets curve hypothesis in the context of tourism-led development (Bella, 2018; Ozturk et al., 2016; Zaman et al., 2016).

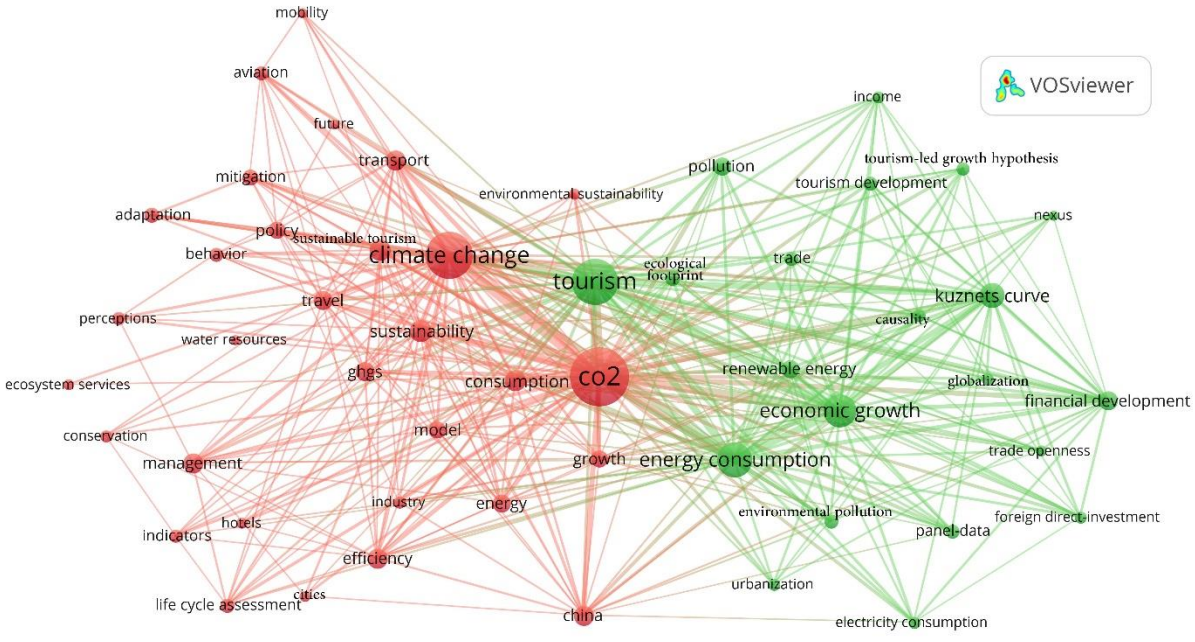

Figure 2 The output of the term co-occurrence analysis.

These studies often validate the hypothesis, indicating that responsible tourism development policies in the context of economic growth will eventually result in reduced environmental degradation. It is essential to further prioritize sustainable tourism in environmental and climate policies that aim to meet ambitious decarbonization targets (Bella, 2018). Climate-friendly and sustainable tourism can also provide sustainable livelihood options for many communities, especially those in developing countries that are economically dependent on tourism (Chapagain et al., 2020; Le, 2020; Scott et al., 2012). All in all, the carbon emission is perceived to be the central issue for tourism sustainability as demonstrated in this bibliometric analysis which needs to be mitigated by the industry.

Table 2a Most Cited Papers of the Green Cluster

No.	Paper title	Ref.
1	Investigating the influence of tourism on economic growth and carbon emissions: Evidence from panel analysis of the European Union	Lee, J.W. and T. Brahmasrene, *Investigating the influence of tourism on economic growth and carbon emissions: Evidence from panel analysis of the European Union.* Tourism Management, 2013. **38**: p. 69-76.
2	Estimating tourism-induced energy consumption and CO2 emissions: The case of Cyprus	Katircioglu, S.T., M. Feridun, and C. Kilinc, *Estimating tourism-induced energy consumption and CO_2 emissions: The case of Cyprus.* Renewable and Sustainable Energy Reviews, 2014. **29**: p. 634-640.
3	International tourism, energy consumption, and environmental pollution: The case of Turkey	Katircioglu, S.T., *International tourism, energy consumption, and environmental pollution: The case of Turkey.* Renewable and Sustainable Energy Reviews, 2014. **36**: p. 180-187.
4	Testing the tourism-induced EKC hypothesis: The case of Singapore	Katircioğlu, S.T., *Testing the tourism-induced EKC hypothesis: The case of Singapore.* Economic Modelling, 2014. **41**: p. 383-391.
5	Tourism development, energy consumption, and Environmental Kuznets Curve: Trivariate analysis in the panel of developed and developing countries	Zaman, K., et al., *Tourism development, energy consumption, and Environmental Kuznets Curve: Trivariate analysis in the panel of developed and developing countries.* Tourism Management, 2016. **54**: p. 275-283.
6	The carbon footprint of global tourism	Lenzen, M., et al., *The carbon footprint of global tourism.* Nature Climate Change, 2018. **8**(6): p. 522-528.
7	The Effects of Tourism on Economic Growth and CO2 Emissions: A	Paramati, S.R., M.S. Alam, and C.-F. Chen, *The Effects of Tourism on Economic Growth and CO_2 Emissions: A Comparison between Developed and*

	Comparison between Developed and Developing Economies	*Developing Economies.* Journal of Travel Research, 2016. **56**(6): p. 712-724.
8	Revisiting the environmental Kuznets curve hypothesis in a tourism development context	de Vita, G., et al., *Revisiting the environmental Kuznets curve hypothesis in a tourism development context.* Environmental Science and Pollution Research, 2015. **22**(21): p. 16652-16663.
9	Tourist arrivals and macroeconomic determinants of CO2 emissions in Malaysia	Solarin, S.A., *Tourist arrivals and macroeconomic determinants of CO_2 emissions in Malaysia.* Anatolia, 2014. **25**(2): p. 228-241.
10	Investigating the impacts of energy consumption, real GDP, tourism, and trade on CO2 emissions by accounting for cross-sectional dependence: A panel study of OECD countries	Dogan, E., F. Seker, and S. Bulbul, *Investigating the impacts of energy consumption, real GDP, tourism and trade on CO_2 emissions by accounting for cross-sectional dependence: A panel study of OECD countries.* Current Issues in Tourism, 2017. **20**(16): p. 1701-1719.

Table 2b Most Cited Papers of the Red Cluster

No.	Paper title	Ref.
1	Global environmental consequences of tourism	Gössling, S., *Global environmental consequences of tourism.* Global Environmental Change, 2002. **12**(4): p. 283-302.
2	Can tourism deliver its "aspirational" greenhouse gas emission reduction targets?	Scott, D., P. Peeters, and S. Gössling, *Can tourism deliver its "aspirational" greenhouse gas emission reduction targets?* Journal of Sustainable Tourism, 2010. **18**(3): p. 393-408.
3	Measuring National Carbon Dioxide Emissions from Tourism as a Key Step Towards Achieving Sustainable Tourism	Becken, S., and M. Patterson, *Measuring National Carbon Dioxide Emissions from Tourism as a Key Step Towards Achieving Sustainable Tourism.* Journal of Sustainable Tourism, 2006. **14**(4): p. 323-338.
4	Estimating the carbon footprint of Australian tourism	Dwyer, L., et al., *Estimating the carbon footprint of Australian tourism.* Journal of Sustainable Tourism, 2010. **18**(3): p. 355-376.
5	The eco-efficiency of tourism	Gössling, S., et al., *The eco-efficiency of tourism.* Ecological Economics, 2005. **54**(4): p. 417-434.
6	Energy use is associated with different travel choices	Becken, S., D.G. Simmons, and C. Frampton, *Energy use associated with different travel choices.* Tourism Management, 2003. **24**(3): p. 267-277.

7	National emissions from tourism: An overlooked policy challenge?	Gössling, S., *National emissions from tourism: An overlooked policy challenge?* Energy Policy, 2013. **59**: p. 433-442.
8	The greenhouse gas intensity of the tourism sector: The case of Switzerland	Perch-Nielsen, S., A. Sesartic, and M. Stucki, *The greenhouse gas intensity of the tourism sector: The case of Switzerland.* Environmental Science & Policy, 2010. **13**(2): p. 131-140.
9	Analysing International Tourist Flows to Estimate Energy Use Associated with Air Travel	Becken, S., *Analysing International Tourist Flows to Estimate Energy Use Associated with Air Travel.* Journal of Sustainable Tourism, 2002. **10**(2): p. 114-131.
10	Quantifying energy use, carbon dioxide emission, and other environmental loads from island tourism based on a life cycle assessment approach	Kuo, N.-W. and P.-H. Chen, *Quantifying energy use, carbon dioxide emission, and other environmental loads from island tourism based on a life cycle assessment approach.* Journal of Cleaner Production, 2009. **17**(15): p. 1324-1330.

4.2 Multiple-Case Analysis

As reflected in the literature overview using the term co-occurrence analysis, tourism-related air travel is identified as a major contributor to global emissions (Lenzen et al., 2018; Lee et al., 2021). The multiple-case analysis is undertaken to examine actions taken by the aviation industry towards reducing emissions. Against the adopted framework (Table 1), the multiple-case analysis of the aviation industry reveals four main observations of the 20 leading operators in their implementation approach to sustainability strategy. Firstly, it reveals that more than half of them have recognized the target of achieving a reduction in net aviation CO_2 emissions by 50% by 2050 (T3) (see Figure 3). European airlines have shown to be disclosing the most commitments to the 50% reduction target. Secondly, improvement in immediate and near-term efficiency in aircraft operations is a pillar (P2) embraced by most the airlines, cultivating the economic incentives driven by lowered operating costs and enhanced profitability (see Figure 4). Thirdly, Sustainable Aviation Fuel (SAF) is widely adopted among airlines as an innovative approach or pillar (P1) that improves sustainability among top airlines from advanced economies, particularly in North America and Europe. Fourthly, infrastructure improvement, such as the synergistic role of the airport facilities and systems for sustainability, appears to be lagging as a pillar (P3).

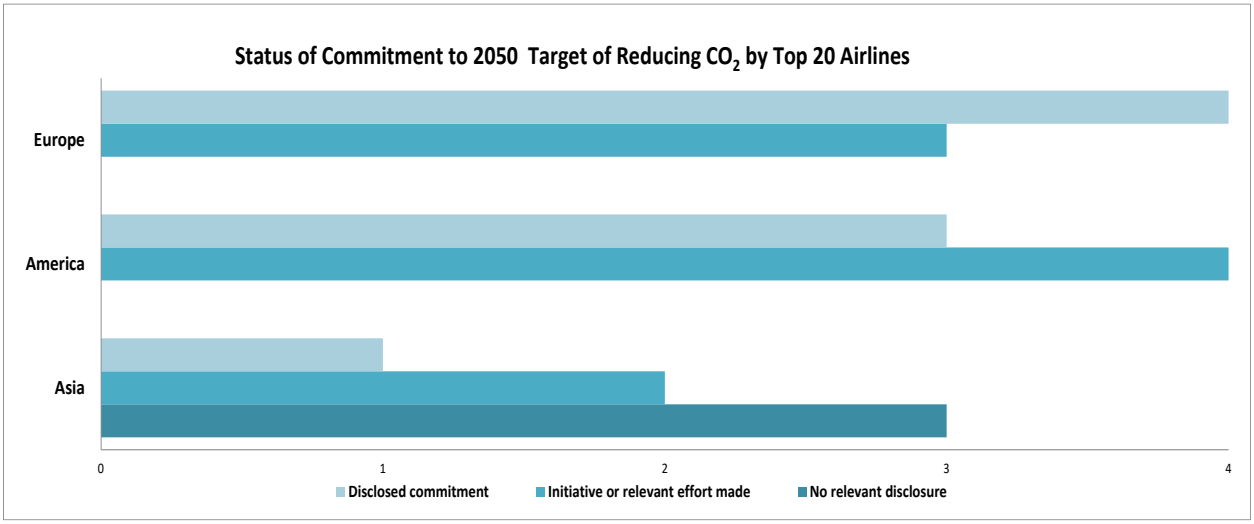

Figure 3 Commitments to 2050 Target by Region

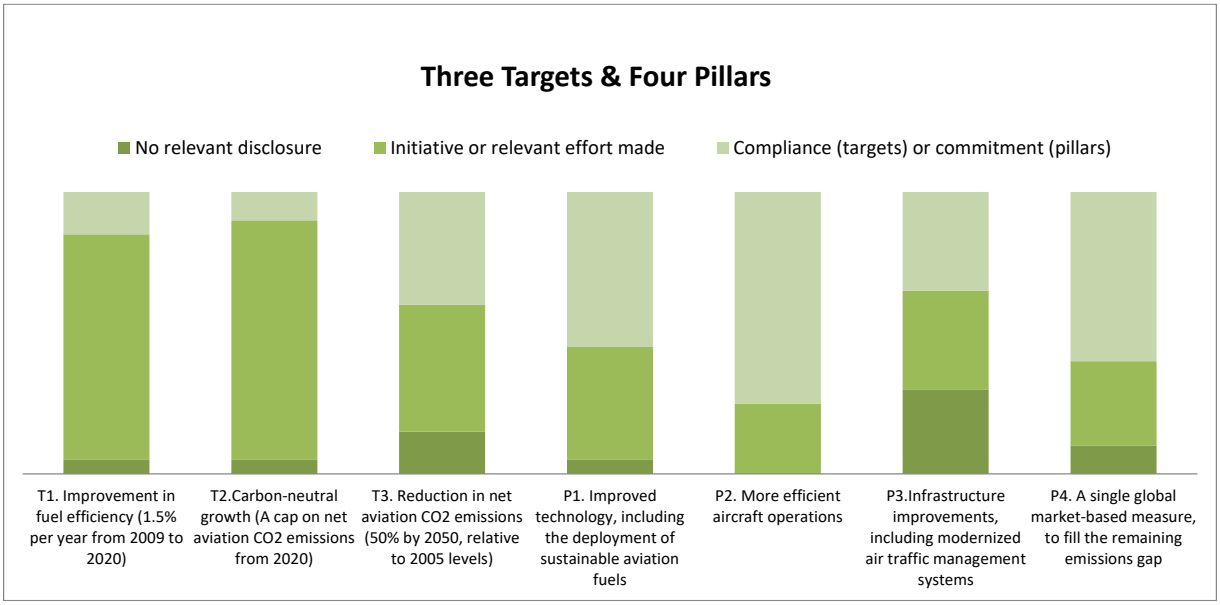

Figure 4 Top 20 Airlines' Compliance and Performance

While complementary green infrastructure is considered critical for transforming the sustainability performance of the airlines, airports that enable the supply of SAF and pertinent technological infrastructure are integral to the aviation industry in this respect. As depicted in Figure 5 and summarized in Table 3, there are currently 22 international airports that can deliver SAF, concentrated in Europe and

North America (ICAO, 2021b). Despite the increasing market share of tourism and aviation activities among the emerging economies, SAF delivery infrastructure is missing in these regions. To complement the data in Figure 5, Table 3 presents a list of the airports using SAF, based in various international tourist destination cities around the world.

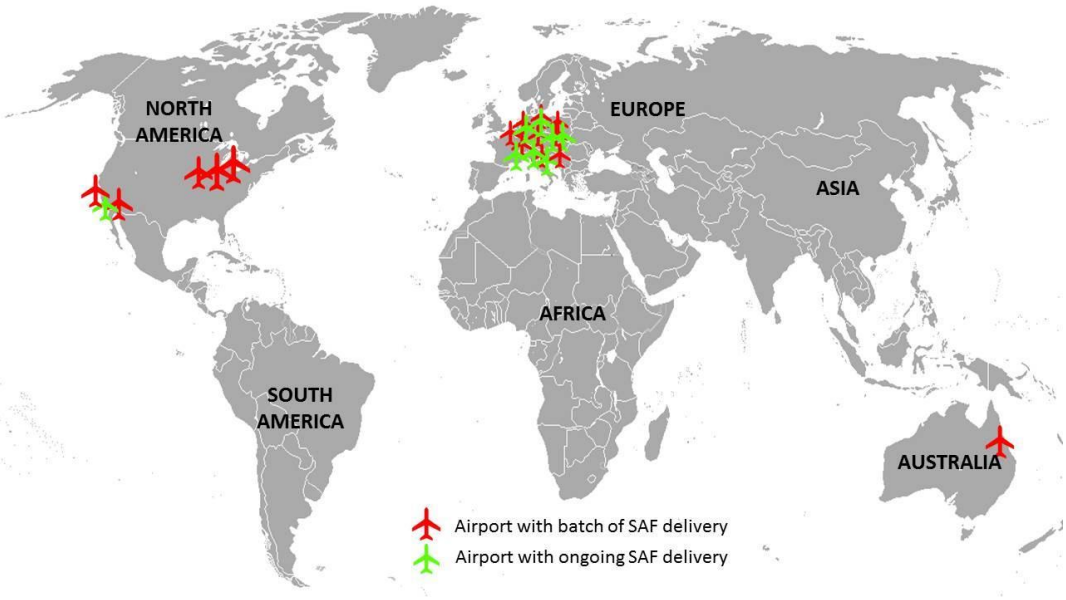

Figure 5 International airports with batch or ongoing delivery of Sustainable Aviation Fuel (SAF) (Source: Adaptation from ICAO 2021b)

Batch Delivery of SAF	**Ongoing Delivery of SAF**
Karlstad Airport (Europe)	Los Angeles Airport (N. America)
Chicago O'Hare Airport (N. America)	Oslo Airport (Europe)
Brisbane Airport (Australia)	San Francisco Airport (N. America)
Toronto-Pearson Airport (N. America)	Stockholm Arlanda Airport (Europe)
Montreal Trudeau Airport (N. America)	Bergen Airport (Europe)
ÅreÖstersund Airport (Europe)	VaxjoSmaland Airport (Europe)
Göteborg Landvetter Airport (Europe)	Halmstad City Airport (Europe)
Visby Airport (Europe)	Stockholm Broma Airport (Europe)
Luleå Airport (Europe)	Kalmar Öland Airport (Europe)
Van Nuys Airport (Europe)	

Jackson Hole Airport (N. America)
Umeå Airport (Europe)
Malmö Airport (Europe)

Table 3 List of International Airports with SAF Supply (Source: ICAO 2021b)

It is worth noting that most airports using SAF are in Europe and North America, illustrating a notable disparity in such fuel supply infrastructures across geographical regions that have yet to be effusively developed.

5. Conclusions

This paper has provided an overview of the extent to which the global tourism business contributes to the production of carbon emissions and, inter alia, to climate change as demonstrated in the bibliometric analysis. Because of the significant impacts of the aviation industry in association with global tourism, its sustainability status has been examined as the focus. Emphasis was given to reveal the industry's ongoing adoption of different sustainable approaches, the development of building capacity for drastically improving operational efficiency, as well as the utilization of cleaner energy sources among a set of the largest international commercial airlines.

First, carbon-intensive tourism, at the pre-pandemic scale, has been evidently unsustainable, largely based on a self-regulatory approach. Until 2019, i.e., prior to the COVID-19 pandemic, its share of global GHG emissions increased year by year. As it is expected that travel will gradually resume over time, GHG emissions levels are likely to grow again. This "rebound" effect is already being seen now, as some airlines are slowly returning more and more of their aircraft back to business. This trend is compounded by the fact that not all tourists are accustomed to or willing to engage in mitigation strategies associated with their traveling (e.g., purchase of carbon credits to offset the emissions associated with their travel), due to the additional costs.

Second, whereas a considerable portion of the shift towards sustainable practices is mostly placed upon the aviation industry, its key operators are not yet fully prepared to handle it. Based on the results of our analysis of the top 20 global aviation operators, their targets, and their activities towards CO_2 emissions reductions, it is apparent that specific strategies and particular attempts to establish sustainable practices are mostly ad hoc and not part of a consistent strategy. Moreover, as discussed by Lenzen et al. (2018), each of the historically formulated mitigation strategies has yielded only limited success so far. Neither responsible travel behavior nor technological improvements have led to significant reductions in the carbon footprint of the tourism industry.

This state of affairs suggests that unless more effective measures to address the current trends associated with the tourism sector are implemented, the goal to reduce GHG emissions by 50% by 2050 will be endangered. In addition to the existing self-regulatory approach being adopted by the industry, some other carbon reduction measures initiated among airlines could include the following:

i. Providing resources and incentives to operate more efficient aircraft and to scale up the production and consumption of Sustainable Aviation Fuel (SAF) across various geographical regions around the world, based on the success achieved in the places where it has been implemented. This approach is considered by the International Air Transport Association (IATA) as a promising way to reduce the carbon footprint and, to some extent, the environmental impacts of the aviation sector. Airports of international tourist destination cities situated among the emerging economies, as key components of the global travel network, would need to consider providing the availability of SAF by investing in complementary facilities and infrastructures to supply such a cleaner fuel.

ii. The set-up or – where it is available - upscaling of complementary green infrastructures at airports and hotels to cater to the many land-based sources of GHG emissions systematically (e.g., renewable energy use, energy savings means, food processing, and waste, etc). Such infrastructures for facilitating direct or indirect sustainable consumption by the sector ‘s stakeholders are expected to enable more comprehensive carbon neutrality solutions while reducing operating costs.

iii. Encouraging operators to enhance and promote the usefulness of carbon offset schemes among travelers, with the objective to reduce unnecessary long-haul travels.

On the consumer front, the promotion of more responsible travel behavior to support the efforts to improve the sustainability of the overall tourism sector does not suffice on its own. A complementary global regulatory strategy that aligns with the goal of GHG emissions reductions, as stated in the Paris Agreement, to revive the global tourism sector would be necessary for reinforcing capital investments in pertinent green infrastructures, particularly in the aviation industry, which will facilitate sustainable energy consumption. Such an investment strategy to redirect the allocation of resources into such infrastructures would harmonize with the advocated climate finance mechanism deployed to meet the targets set under the Paris Agreement.

Appendix

Search string:

TS= ((“climate change mitigation” OR “climate mitigation” OR “carbon footprint*” OR “carbon dioxide” OR “CO_2” OR “greenhouse gas emission*” OR “GHG*” OR “carbon flow*”) AND (“tourism” OR “tourist*”))

Indexes=SCI-EXPANDED, SSCI, A&HCI, ESCI Timespan=All years

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