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"Problematizing" carbon emissions from international aviation and the role of alternative jet fuels in meeting ICAO's mid-century aspirational goals

Mónica Soria Baledón*, Nicolás Kosoy

Department of Natural Resource Sciences, McGill University, 21,111 Lakeshore Road, Ste.-Anne-de-Bellevue, Quebec, H9X 3V9, Canada

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ABSTRACT

Alternative jet fuels are one of the four mechanisms by the United Nations International Civil Aviation Organization (ICAO) to limit and reduce carbon emissions from international aviation. By using Carol Bacchi's *what's the problem represented to be?* method of discourse analysis, the objective of this paper was to identify and understand the premises and effects of the problem-solving paradigm underlying ICAO's alternative jet fuel strategy. As a result, three problem representations were identified, from which two out of four underlying assumptions have reinforced ICAO's weak sustainability approach to international aviation's growth and have led to a number of discursive, subjectification and lived effects. The selected method also allowed the authors to identify several options to disrupt those premises in favor of the implementation of more aggressive mitigation and adaptation strategies without constraining air travel demand, including: (i) raising awareness of the environmental impacts of aviation beyond the tailpipe emissions, (ii) improving the understanding of the effects of climate change on the air transport sector, and (iii) reassessing the sectoral approach to the Sustainable Development Goals so as to gain consistency with the aims of the UN *2030 Agenda for Sustainable Development.*

1. Introduction

In 2014, the aviation sector contributed with 3.5 percent of the global gross domestic product (GDP), supported 62.7 million direct, indirect, induced and catalytic jobs, and in 2017, transported over 4 billion passengers (ICAO, 2018; WEF, 2017; ATAG, 2016a). Conversely, domestic and international flights currently account for ~2 percent of the total carbon dioxide (CO_2) emissions from anthropogenic origin (IATA, 2015; Penner et al., 1999), a contribution that can be as high as 4.9 percent when the radiative forcing effect of greenhouse and non-greenhouse gas emissions at cruise altitude are accounted for (Moore et al., 2017; Novelli, 2011; Lee et al., 2009; Penner et al., 1999). Although aviation's contribution to climate change appears to be small, the lower end is comparable to the total greenhouse gas emissions (GHGs) of Germany, ranked within the top ten largest global emitters (FCCC/CP/2015/10).

Whereas the emissions reductions from domestic aviation are governed by the Paris Agreement, emissions from international aviation are addressed by Member States to the United Nations International Civil Aviation Organization (ICAO) through their national Action Plans, to operationalize the targets adopted in 2010 in ICAO's 37th Assembly resolution A37-19 (ICAO, 2014); consisting of:

I An average 2% annual improvement in fuel efficiency from 2009 until 2020[1],
II Carbon-neutral growth[2] from 2020, and
III Halving the sector's CO_2 emissions by 2050 relative to 2005 levels.

Although these aspirational targets are ambitious, they are insufficient to meet those of the Paris Agreement, as they do not appropriately account for the required carbon reductions to limit global warming to 1.5–2 °C. According to Pidcock and Yeo (2016), by 2050 carbon emissions from international aviation will still represent 12% of the 205Gt remaining global CO_2 budget even if technological and operational efficiencies are maximized and the total demand for conventional jet fuel is met with alternatives.

This contribution can rise up to 20% should alternative jet fuels not become available in sufficient quantities to replace the demand for conventional jet fuel in its entirely (Staples et al., 2018; Pidcock and Yeo, 2016). In the past, the EU has suggested more aggressive carbon reduction targets for international aviation to be consistent with the 1.5–2 °C global aspirational goal, with sectoral reductions needed

* Corresponding author.
E-mail addresses: monica.soriabaledon@mail.mcgill.ca (M. Soria Baledón), nicolas.kosoy@mcgill.ca (N. Kosoy).

[1] The original target set in 2009 by IATA was a 1.5 percent average annual increase in fuel efficiency (ATAG, 2012).
[2] The international aviation community defines carbon-neutral growth as an absolute decoupling of greenhouse gas emissions from economic sectoral growth.

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between 64% and 91% by 2050 compared to 2005 levels (Cames et al., 2015).

By using Carol Bacchi's (2009) *what's the problem represented to be?* (WPR) method of discourse analysis (a detailed description is presented in Section 3), this paper aims to contribute to a better understanding of ICAO's strategy on alternative jet fuels (AJF), as they are perceived by the aviation community to hold the greatest potential to meet ICAO's international goals (CAAF/2-SD3; ATAG, 2012).

The WPR is a six-step method to examine the premises and effects of the problem-solving paradigm underlying ICAO's work on environmental protection so as to identify its material and symbolic impacts on people and the environment. Most importantly, it is a useful method to challenge current problem representations in favor of policy interventions more consistent with the goals of the Paris Agreement and of the United Nations *2030 Agenda for Sustainable Development.*

2. Background

In addition to the aspirational targets adopted in 2010, ICAO's 37th General Assembly endorsed the *Program of Action on International Aviation and Climate Change* to develop a global framework consisting of operational, technological, market-based measures, and the use of alternative fuels to address CO_2 emissions from international aviation (ICAO, 2013a).

Emissions from international aviation are calculated based on fuel consumption, thus the proposed framework has aimed at increasing jet fuel savings. Carbon reductions from technological measures include: the use of lighter and recyclable materials, higher engine performance, fleet renewals, compliance with emissions certification standards – including ICAO's aircraft CO_2 standard –, improvements in aircraft aerodynamics, etc. Fuel savings from operational measures include improvements in air traffic flow management, dynamic and flexible routing, airport design and operations, performance-based navigation, etc. (ICAO, 2013b).

Whereas the fuel efficiency target has been met over the past years mainly as a result of technological and operational measures (ATAG, 2017), ICAO's assessments on fuel consumption and emissions show that the aggregate environmental benefit achieved by a combination of the technological and operational measures will be insufficient to attain carbon-neutral growth from 2020 (A39-WP/55). This, coupled with other factors analyzed later in this paper, make international aviation reliant on the use of alternative jet fuels to achieve greater carbon reductions.

Presently, there are five certified conversion pathways for alternative jet fuel production under ASTM D7566, four airports regularly distributing AJF and over 100,000 commercial flights that have used alternative fuels (ICAO GFAAF, accessed on October 24th and November 20th, 2017). However, regular production of alternative jet fuels remains limited, and volumes supplied through off-take agreements between airlines and fuel producers account for 0.9Mt per year (less than 0.006 percent of total jet fuel consumption by international aviation in 2010), making it difficult to predict their future contribution to meeting ICAO's aspirational goals (CAAF/2-WP/06).

In an effort from ICAO to accelerate the development and adoption of alternative jet fuels, Member States convened in Mexico City at the Second Conference on Aviation and Alternative Fuels (CAAF/2) in October 2017 to set short-to-long term volumetric targets for alternative jet fuels. However, no consensus amongst participant States on specific targets was reached and the Conference endorsed the *2050 ICAO Vision for Sustainable Aviation Fuels* without any quantitative goals for substituting conventional jet fuel nor any quantifiable carbon reductions resulting from the use of alternative jet fuels (CAAF/2-SD3).

Although ICAO's market-based measure was originally envisioned in 2010 as a complementary measure to further the CO_2 reductions achieved through improvements in technology and operations, in October 2016, ICAO's 39th General Assembly approved the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) to address *any annual increase* in the total CO_2 emissions from international aviation that exceed the 2020 baseline (Resolution A39-3).

3. Understanding policy governance as “problem” representations

Carol Bacchi's (2009) *what's the problem represented to be?* (WPR) methodological approach consists of a six-step method to examine how “problems” are represented in public policy to identify the material and symbolic impacts that problem representations have on the subjects of those policies.

Bacchi's method builds on much of the work by Michel Foucault on discourse analysis, the history of thought and the process by which thoughts are “problematized” or reflected in the form of socially-constructed “problems” and addressed in public policy (Foucault, 1984). According to Foucault, the nature, scope and type of solutions articulated through public policy will inevitably result from a specific form of “problematization” (Foucault, 1984).

Bacchi goes beyond the Foucauldian approach by proposing a method that challenges problematizations that have negative effects on policy subjects at the expense of others (Bacchi, 2009). Although her original scope is limited to the problem-solving paradigm underlying public policy in Western industrialized nations and international organizations, Bacchi's WPR approach is suitable for the analysis of policies in a variety of political regimes and institutions. Also, notwithstanding that it was originally designed and has been applied ever since for public policy analysis, the WPR is equally useful to analyze ICAO's alternative jet fuel strategy, where the novelty of this research paper rests.

The WPR method follows a set of six questions: [Q1] What is the “problem” represented to be in a given policy? [Q2] What assumptions underlie this problem representation? [Q3] How has this representation of the problem come to prominence? [Q4] What does this representation of the problem take for granted and leave unquestioned? [Q5] What effects are produced by this representation? [Q6] How and where is this representation of the problem produced, disseminated and defended? And how could it be challenged?

4. Debriefing the problem-solving paradigm underlying ICAO's alternative jet fuel strategy

ICAO's alternative jet fuel strategy supports and promotes the development and consolidation of supply chains of alternative fuels for international aviation through its Member States. It was originally developed within ICAO's *Program of Action on International Aviation and Climate Change* and it encompasses a broad range of activities including R&D, certification, financial assistance, monitoring, verification and evaluation (MRV), technology transfer, capacity building, etc. (CAAF/09-WP/24).

The exchange of information, worldwide initiatives, actions and best practices is facilitated by ICAO's Global Framework for Aviation Alternative Fuels (GFAAF), an online platform created in 2009 to help Member States accelerate the development and adoption of alternative jet fuels (CAAF/2-WP/4; CAAF/09-SD/3).

The following figure (Fig. 1) summarizes the findings for questions Q1-Q5, each of which is analyzed in separate sections. The findings and respective analysis for Q6 are presented later in the manuscript (Fig. 2).

[Q1] What is the“problem” represented to be? Three problem representations were identified in ICAO's alternative jet fuel strategy: (1) A *main* “problem” represented by the current and future

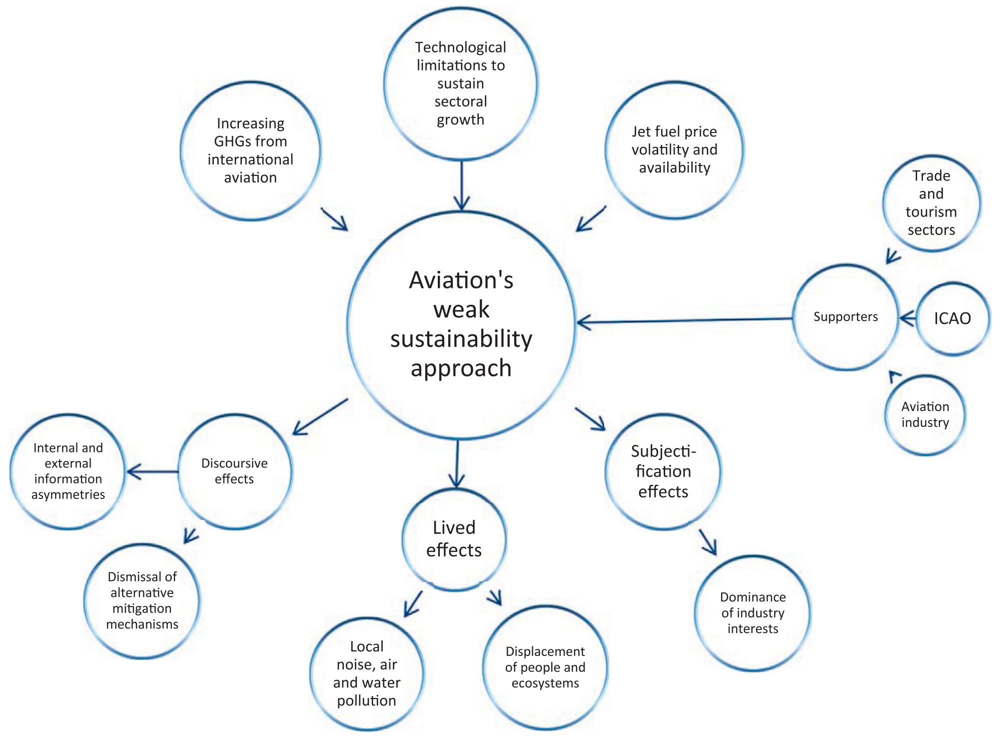

Fig. 1. Problem representations, premises and effects underlying ICAO's jet fuel strategy.

contribution of GHGs[3] emissions from international aviation to global warming and climate change (Resolution A37-19). (2) A *secondary* "problem" represented by the technological limitations to attain the necessary CO_2 reductions to sustain the five percent annual growth in air traffic projected by the industry (IATA, 2015; AEF, 2014).

The secondary problem is implicit in several ICAO documents where the use of alternative jet fuels aims to close "the mitigation gap" between ICAO's aspirational goals and the carbon reductions attained with conventional fuel savings resulting from the implementation of operational and technological measures (CAAF/09-WP/23).

(3) An *incidental* "problem" represented by the uncertainty around jet fuel price volatility and supply shortages. Although the focus on energy security progressively shifted towards the sustainability of alternative jet fuels as a result of the oil price crash in 2014, ICAO's strategy originally intended to mitigate airlines financial risk by diversifying the fuel market (CAAF/09-WP/23; Palmer, 2015).

[Q2] What assumptions underlie these problem representations? There are two assumptions underlying the *main* problem representation: the first one is that anthropogenic emissions from aviation cause interference with the climate system by contributing to the greenhouse gas effect (Penner et al., 1999). The second assumption is the incontestability of international aviation's growth as sine qua non to support "global social and economic development and inclusion" (ATAG, 2016a); a governing principle in ICAO's work as delegated by the *Convention on International Civil Aviation* (*Chicago Convention,* 1944).

The assumption underlying the *secondary* problem representation is the nature of carbon emissions from aviation as strictly a technological problem that should, in consequence, be addressed through technological and market-based solutions. Last, the assumption underlying the *incidental* problem representation is the need to diversify international aviation's fuel portfolio in face of an uncertain future of finite fossil resources, as world production from conventional oilfields has been slowly but steadily declining since 2005, and the oil industry faces steeper production costs for lower resource quality and a slower supply growth (Heinberg, 2014).

[Q3] How have these problem representations come to prominence? All three problem representations have similar roots in the context of an increasing awareness of resource scarcity and the global ecological crisis. The acknowledgement of the increasing contribution of international aviation to climate change (*main* problem representation) came about as the result of ICAO's progressive involvement in addressing the environmental impacts of air transport since the 1960s (Pelsser, 2017; Piera, 2015).

But according to Piera (2015), ICAO's engagement in climate change discussions was mainly brought about by "the possibility that the United Nations Framework Convention on Climate Change (UNFCCC) [could] take over the regulation of GHGs emissions from international aviation and the threat posed by unilateral EU action" by incorporating foreign aircraft operators into the European Union's Emissions Trading Scheme (ETS). Also, several international organizations and non-governmental organizations have strongly criticized ICAO's lack of progress on climate mitigation in the past couple of decades, and have advocated to impose financial sanctions on the international air transport sector so as to generate revenue for climate mitigation and adaptation in developing countries (Piera, 2015; Palmer, 2015).

The recognition of the technological limitations to attain carbon-neutral growth of international aviation (*secondary* problem representation) arose as a result of the increasingly marginal fuel efficiency gains in the last couple of decades. Historic trends claim that aircraft are presently 80% more fuel efficient than they were in the 1960s (ATAG, 2010), and although the average annual efficiency improvement of 2.4% between 2009 and 2014 exceeded ICAO's 2% target (ATAG, 2016b), aircraft manufacturers acknowledge that cumulative efficiency gains will not be enough to halve international aviation emissions by 2050 alone (Epstein, 2017).

[3] Although ICAO acknowledges the effects of other GHGs emissions on global warming and climate change, the aspirational targets explicitly aim at reducing CO_2 emissions as it is released in greater quantities than others and it has a longer atmospheric persistence (Resolution A37-19). Furthermore, there are areas of scientific uncertainty about the effects of other GHGs (NO_x, SO_x, CH_4, O_3, PM and H_2O) released at cruise altitude (8–13 km AMSL) that have limited the development of a more comprehensive approach from ICAO to GHGs mitigation (Moore et al., 2017; Novelli, 2011; Lee et al., 2009; Penner et al., 1999; Piera, 2015).

The uncertainty around jet fuel price volatility and supply shortages (*incidental* problem representation) first became prominent with the Organization of the Petroleum Exporting Countries (OPEC) embargo of 1973 and the economic recession that followed it (Du Pisani, 2006). Yet, the international aviation industry has continued to grow since the post-WWI era in spite of the oil peak prices triggered by the Iranian Revolution (1978), the Iran-Iraq War (1980), the first Persian Gulf War (1990) and the oil price spike of 2007–2008 (Hamilton, 2011).

On this, a study by Kasarda (2010) showed a positive correlation between jet fuel prices and the number of passengers and cargo between 1987 and 2008, and found no evidence that oil peak prices had curbed international aviation's growth. According to Lee et al. (2009), this was also the case for major geopolitical events such as the terrorist attack of 9/11, the severe acute respiratory syndrome (SARS) epidemic of 2003, and the global financial crisis of 2008, where the international passenger traffic between 2000 and 2007 increased by 38% as a result of an average annual traffic growth rate of 5.3%.

Notwithstanding the dynamism and adaptation capacity of international aviation to price shocks and global crises, global efforts to adopt alternative energy sources remain driven by the potential threat of conventional fuel price volatility and supply shortages (ATAG, 2017; ICAO, 2012).

Coincidentally, the idea of using alternative fuels to replace conventional jet fuel gained momentum around the years of the oil price spike of 2007–2008, when several test flights demonstrated the use of alternative fuels as convenient and safe replacements of fossil fuel (CAAF/09-WP/23; ASTM 7566; IATA, 2009). Preference for alternative jet fuels was reinforced overtime by the following factors:

First, the current technological barriers to power aircraft with cleaner energy carriers make air transport reliant exclusively on liquid fuels. Second, even if a technological breakthrough would become commercially available before 2050, new technological developments in the aviation sector usually take up to a couple of decades before reaching maturity (IATA, 2013). Third, aircrafts in service can only be phased-out gradually as they reach the end of their service life, which is estimated between 20 and 25 years on average (Jiang, 2013).

[Q4] What do these problem representations take for granted and leave unquestioned? All three problem representations leave unquestioned the notion of *progress*, a key concept that historically preceded those of sustainability, development, and sustainable development (Du Pisani, 2006), and that underlies the sectoral approach of international air transport. Whereas an in-depth discussion about the history and development of the concept of sustainable development goes beyond the purpose of this paper and prolific scholarly discussions can be found elsewhere (Munda, 2008; Du Pisani, 2006; Luke, 2005; Redclift, 2005), it is nonetheless essential to clarify the epistemological principles underpinning the mitigation strategies of the international air transport sector in order to gain a better understanding of their material and symbolic impacts on society and the environment.

The *Chicago Convention* (1944) was drafted close to the end of WWII, preceding by nearly two decades the environmental movements that gave birth to the notion of sustainable development. The original text mandated ICAO to guarantee the "safe, regular, efficient and economical" development of air transport to "meet the needs of the peoples of the world" (Article 44d), and at the time it was drafted it did not contain any provisions related to the environment.

With the unprecedented economic thriving of the 1950s and over the course of the second half of the 20th century, lower air transport fares prompted a considerable growth in demand for air travel services, which had become more accessible as a result of higher disposable incomes and the progressive economic liberalization that enhanced global market access and trade (WEF, 2017; ATAG, 2016a; Piera, 2015; Macintosh and Wallace, 2009). From 1960 to 1997, passenger traffic grew at an annual rate of 9 percent, and since the 1980s, air traffic has doubled every 15 years, reaching 4.1 billion people in 2017 and expecting to reach 7.8 billon by 2036 (ICAO, 2018; Airbus, 2017; IATA, 2017).

ICAO's regulations on environmental protection were incorporated to the *Chicago Convention* in 1971 under Annex 16 *Environmental Protection* (Pelsser, 2017), and since then, ICAO has increasingly allocated financial resources to *minimize* the adverse environmental effects of civil aviation activities as stated in the organization's Strategic Objectives (2017) (Piera, 2015). However, there is no specific reference to the principle of "environmental protection" in ICAO's constitutional framework and governing structure, leading to an understanding of *progress* that legitimizes and promotes the expansion of international aviation in pursuance to the original mandates of the *Chicago Convention*.

This understanding of *progress* is rooted in the positivist thinking of the 18th and 19th centuries that linked the idea of human advancement and well-being to the economic and material growth brought about by the Industrial Revolution (Du Pisani, 2006; Von Wright, 1997; Nisbet, 1980). The neoliberal approach to sustainable development builds on this notion of progress, where environmental degradation and social inequality are considered market externalities (Du Pisani, 2006; Luke, 2005; Redclift, 2005; Euractiv, 2002) and where economic growth justifies the replacement of natural capital for human capital, the latter amounting to the concept of *weak* sustainability (Munda, 2008; Du Pisani, 2006).

Ever since the Rio Declaration (*Agenda 21*) in 1992, the weak sustainability approach has underpinned the work of governments and international organizations alike (Redclift, 2005) and has provided them with the legitimacy to mobilize around policies that advocate for mass consumption (Du Pisani, 2006). Particularly, the weak sustainability approach underlying ICAO's work on environmental protection, including its alternative jet fuel strategy, was reinforced in 2015 with the endorsement of the United Nations Sustainable Development Goals (SDGs), a global framework consisting of 17 overarching goals and 169 targets over the next 15 years to end poverty, protect the planet and ensure world peace and prosperity (A/RES/70/1). Both ICAO and the aviation industry have asserted that the international air transport *significantly* contributes to 15 out of the 17 SDGs (A39-WP/374; ATAG, 2017 and 2016a), and have urged governments worldwide to prioritize and encourage the development of aviation as a driver for sustainable development (A39-WP/25).

Whereas external restrictions for further sectoral expansion have been warned by ICAO to be detrimental to the attainment of the SDGs and for the advancement of humankind (A39-WP/374), advocates of a *strong* sustainability approach (natural capital and human capital are not interchangeable (Munda, 2008)) have remarked the role of international aviation in undermining the realization of sustainable development as a whole should unrestrained sectoral growth be encouraged and sustained (A39-WP/427; WWF & Care Intl., 2016).

[Q5] What effects are produced by these problem representations? The symbolic and material impacts of a public policy can be positive and negative, and the WPR classifies them into discursive, subjectifying and lived effects. The discursive effects result from the limits imposed on what can be said or thought; the subjectification effects involve how subjects are constituted within problem representations, and the lived effects consist of the material impacts of those representations on people and the environment (Bacchi, 2009).

This section focuses only on the negative effects of ICAO's alternative jet fuel strategy because the objective of the WPR is to scrutinize and clarify a policy's problem representations and their underlying assumptions so as to identify potential interventions to reduce or eliminate those effects (Bacchi, 2009). Also, whereas the benefits of air travel have been widely documented by ICAO, the industry and other sectors highly reliant on the air transport sector (WEF, 2017; ATAG, 2016a; ICAO, 2012), most of its negative effects have currently no visibility.

Q5.1 Discursive effects

The assumptions underpinning the foregoing problem representations have encouraged ICAO and the industry to historically underplay the sector's environmental impacts while overemphasizing the social and economic benefits brought about by aviation (Piera, 2015; Ghosh, 2014; Bridger, 2013; Shaw and Thomas, 2006). This has led to a number of discursive repercussions:

First, it creates information asymmetries between air transport service providers (i.e. airlines and airports), and users – including cargo –, who *experience* the advantages of aviation but remain largely unaware of its environmental impacts (Ghosh, 2014; Bridger, 2013; Shaw and Thomas, 2006). Second, it creates information asymmetries between ICAO and its Member States that have resulted in a generalized understating of the urgency to implement more ambitious mitigation and adaptation strategies through their State Action Plans (Piera, 2015).

Third, ICAO's definition of environmental impacts as technological in essence, rejects mitigation approaches that could contravene the aims of the *Chicago Convention*. For example: regulations to constraint demand for air transport services, carbon-pricing mechanisms such as levies on conventional jet fuel and on carbon emissions, restrictions on airport expansion projects, etc. (Piera, 2015; Bridger, 2013; Macintosh and Wallace, 2009).

Q5.2 Subjectification effects

The subjectification effect created by ICAO's alternative jet fuel strategy is not exclusive to it and can be generally identified in ICAO's policies on environmental protection. By promoting sectoral growth while addressing environmental issues through technology, ICAO has recurrently placed the interests of the aviation industry ahead of the environment, of the needs from its Member States that are the most vulnerable to climate change and from those that do not hold membership in the Council and the Committee on Aviation Environmental Protection (CAEP).

Whereas ICAO's *weak* approach to sustainable development has resulted in great exogenous and endogenous pressure in the last couple of decades to reduce the environmental impacts of international aviation (Palmer, 2015; Piera, 2015; ICAO, 2012), the prominence of the industry could drive more ambitious climate goals. As Piera (2015) has remarked, the role of the International Air Transport Association (IATA) was instrumental in ICAO's adoption of the aspirational targets to reduce the sectoral carbon emissions, and in the agreement and development of CORSIA.

Q5.3 Lived effects

Much of the research conducted since the 1960s on the impacts of aviation have widely covered the most prominent lived effects, particularly its contributions to global warming, to noise and to local air pollution. Less visible lived effects from ICAO's weak sustainability approach include: water pollution from de-icing operations and fuel leaks and spills, the displacement of vulnerable groups entailed by the expansion of airport infrastructure, the loss of wildlife and ecosystem damage, and the spread of invasive species (Bridger, 2013; Kolmes, 2011).

The great expectations placed by ICAO and the industry on the use of alternative jet fuels to meet the aspirational targets are not exempt from additional lived risks, particularly from emerging bioenergy crops and large-scale production. For example, the preference of dedicated bioenergy feedstocks over edible and non-edible agronomic crops does not eliminate the issues of land use, as they can also displace forests, grazing land and directly compete with agricultural land for food production (Rude et al., 2017; Mondou and Bognar, 2017). Furthermore, certain traits that make emerging bioenergy feedstocks desirable for alternative fuels production, are also found in invasive plants that could spread through a variety of vectors such as the movement of equipment and goods, livestock, packaging, regional and international trade and tourism, and natural events such as floods and winds (IUCN, 2009; Crosti, 2009).

In consequence, large-scale production of alternative jet fuels could aggravate the direct and indirect environmental impacts linked to intensive agriculture of dedicated bioenergy feedstocks (Novelli, 2011; Giampietro and Mayumi, 2009), result in an absolute increase of carbon emissions from international aviation (Staples et al., 2018), and reduce the potential social spillovers from small-to-medium farming operations.

[Q6] How and where are these problem representations produced, disseminated and defended? And how can they be questioned, disrupted and replaced? ICAO and the industry are not the only stakeholders to have historically understated the sector's environmental impacts while overemphasizing its social and economic benefits. This discourse has also been endorsed, disseminated and defended by international organizations that represent the interests of the trade and tourism sectors, including UN World Trade Organization, the World Economic Forum, and the World Travel & Tourism Council (WEF, 2017; Becken, 2006).

Conversely, factions within the European Union and the non-governmental organizations (NGOs) that conform the International Coalition for Sustainable Aviation (ICSA) have for a few decades challenged ICAO's weak sustainability approach and continue to strongly advocate for more aggressive policies and regulations to more effectively address the environmental impacts of international aviation (Girling, 2017; A39-WP/427).

Although the narrative of ICAO and the industry has not changed much since the adoption of the Paris Agreement and the Sustainable Development Goals in 2015, the increasing global awareness around aviation's future contribution to climate change, the technological limitations to compensate for the progressive sectoral growth, and the reduced availability of sustainable alternative fuels at present, have all prompted a shift in the discourse of international organizations such as the OECD International Transport Forum (ITF) towards more aggressive carbon reduction strategies (ITF, 2017).

In its Transport Outlook 2017, the ITF encourages developed and developing countries to support R&D in conjunction to the implementation of "*avoid* (travel) and *shift* (mode)" policies to influence demand through behavioural change (ITF, 2017). At the moment, *avoid* and *shift* policies have mainly been applied to road transport as part of the Nationally Determined Contributions (NDCs) submitted by Member States to the United Nations Framework Convention on Climate Change (UNFCCC) to operationalize the goals of the Paris Agreement, but they are expected to include air transport as they gain momentum amongst policy-makers globally (ITF, 2017).

Further disruptions to the current problem representations can be encouraged through several measures. For example, Piera (2015) has suggested regulatory amendments to the *Chicago Convention* and the adoption of pragmatic strategies to increasingly engage developing, least developed countries and more NGOs in ICAO's environmental protection deliberations and negotiations.

Also, public awareness, international discussions and future mitigation and adaptation efforts would greatly benefit from incorporating alternative approaches to the current understanding of ICAO's problem representations (Fig. 2).

The first approach consists of incorporating the full life-cycle analysis of air transport infrastructure and supply chains (manufacturing, operation, maintenance, etc.) into the environmental impact assessment of international aviation, which according to a study from Chester and Horvath (2009), contribute with at least an additional 31% to the tailpipe emissions from jet fuel combustion. This would provide a more comprehensive understanding of the carbon contributions of international aviation to climate change beyond the "two percent" tailpipe

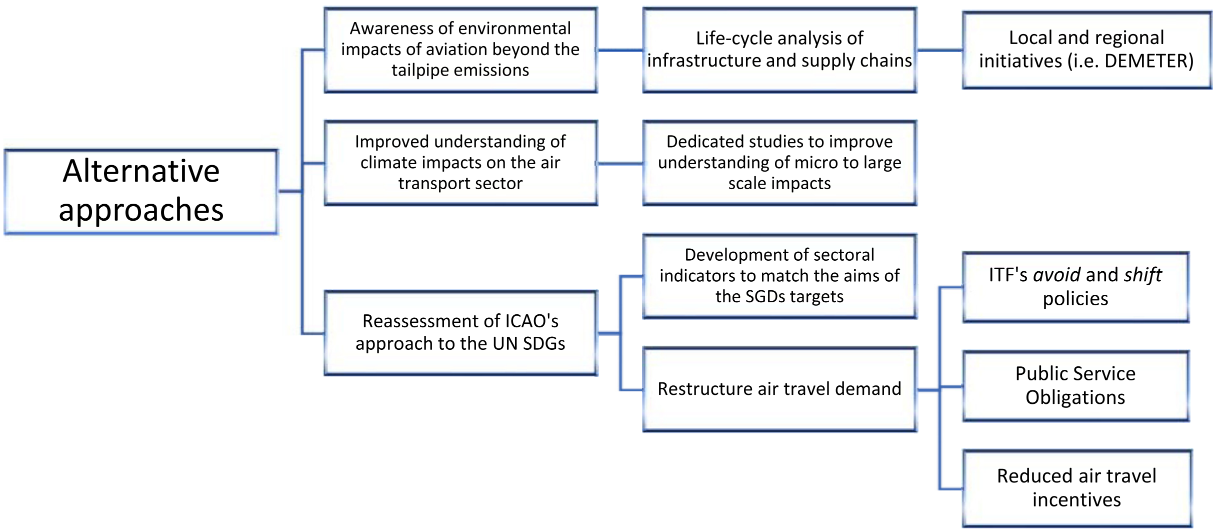

Fig. 2. Alternative approaches to ICAO's work on environmental protection.

emissions from flight, and a better chance to effectively mitigate the environmental impacts of air transport.

For example, project DEMETER (Démonstrateur des Engagements Territoriaux pour la Réduction des émissions) was launched in October 2017 as the first of its kind to address the individual and collective environmental impacts of air transport operations throughout the supply chain around the airport of Toulouse-Blagnac, in France (Eychenne, 2017; Bousquet, 2017).

The second approach includes raising awareness and improving the understanding of the current and future impacts of climate change on aviation within ICAO, its Member States, the aviation industry and the public in general. Although not yet fully understood, higher air temperatures and sea-level rise are expected to increase airlines and airports' operating costs and the risk of incurring in liabilities as a result of more severe and recurring disruptions on the ground and during flight (Haines, 2017; Morad, 2017; WMO, 2016; Wienert, 2010). For example, higher air temperatures affect take-off performance, the usability of short-runways at airports, the recurrence of clear-air turbulence (CAT), and even a flight's length (Karnauskas et al., 2015). Sea-level rise can damage airports, increase the recurrence of runway flooding, prompt flight delays and cancellations due to extreme weather events, and increase the frequency of icing during the fall and winter (Haines, 2017; Morad, 2017; WMO, 2016; Wienert, 2010).

Furthermore, climate change could significantly exacerbate the environmental impacts of aviation. To illustrate this point, Karnauskas et al. (2015) found a positive correlation between return journey times of long-haul flights and an increase in the variation of the atmospheric mid-latitude jet stream, suggesting that:

> "For an average change in total round-trip flying time by route (*T*) of one minute, commercial [aircraft] would be in the air ~300,000 h longer per year, amounting to ~1 billion additional gal jet fuel (~US$3 billion fuel cost) and 10,000 million kg CO_2 emitted per year. Such and additional CO_2 emission is equivalent to 1.5% of [the total] CO_2 emissions [from commercial aviation worldwide]" (Karnauskas et al., 2015:1071).

The third approach involves the reassessment of the international aviation's contributions to the SDGs. Whereas ICAO and the aviation industry have asserted the *significant* contributions of air transport to 15 out of the 17 SDGs (A39-WP/374; ATAG, 2017 and 2016a), members of the European Union and ICSA have remarked the need for greater consistency in ICAO's work to address climate change in support of the aims of the UN *2030 Agenda for Sustainable Development* (A39-WP/427).

But greater consistency will require reorienting some of ICAO's climate efforts. For example, SDG.12 on responsible consumption and production has been mainly approached by the aviation sector from a technological perspective (i.e. waste reduction and treatment throughout the supply chain, reductions in the energy and material intensity of aircraft manufacturing, material recycling and responsible disposal of aircraft components at their end-of-life, etc.) (Boeing, 2017; ATAG, 2017; Bombardier, 2016). But as it has been remarked by others in the past (A39-WP/427; Palmer, 2015; Piera, 2015; Bridger, 2013) technological efficiencies introduced over the years would have taken place regardless of the sector's climate commitments and as a result of cost-reduction strategies and compliance with local regulations.

SDG.12 is particularly relevant to the aviation sector because it emphasizes the need for governments, international organizations and the private sector to raise public awareness on sustainable development and to encourage the adoption of "lifestyles [that are] in harmony with nature" (SDG.12.8). Also, SDG.12 urges governments to adopt regulatory and policy measures to phase-out fossil-fuel subsidies so as to reduce the environmental externalities of wasteful consumption (SDG.12.8.c) (A/RES/70/1). However, there are no initiatives from ICAO, its Member States or the industry to address these targets and they are not mentioned in their official reports (ATAG, 2017; ICAO, 2016; A39-WP/374).

While the implementation of "*avoid* (travel) and *shift* (mode)" policies at the national level gains global momentum and terrain (ITF, 2017), reorienting ICAO's climate efforts could focus on restructuring air travel demand. One way to do this is by deflecting highly saturated air transport routes to expand the coverage of public service obligation (PSO) routes so as to provide air transport services to communities that would otherwise not be served commercially (Smyth et al., 2012). Within the context of the SDGs, doing so could play a significant role in contributing to the targets of SDG.8 (sustained, inclusive and sustainable economic growth, full and productive employment) and SGD.10 (reduced inequalities within and among countries), as documented by Smyth et al. (2012) apropos of the implementation of the Route Development Fund (RDF) in Scotland.

Member States could also contribute to SDG.12.8 by progressively reshaping air transport demand through the regulation of frequent flyers' programs and by framing frequent travel as a policy issue so as to reduce the economic and psychological incentives to fly (Cohen et al., 2011).

5. Conclusions

This research paper aimed at improving the understanding of ICAO's alternative jet fuel strategy by using Carol Bacchi's (2009) *what's the problem represented to be?* (WPR) methodological framework to analyze the premises and effects of the problem-solving paradigm underlying ICAO's work on environmental protection. In consequence, some of the findings of this exploratory exercise could be equally applied to the analysis of ICAO's market-based CORSIA insofar as they both build on the same problem representations and their underlying assumptions (Q1,2). However, a separate analysis would be required for an in-depth understanding of the rationale and the material and symbolic impacts of CORSIA as an indirect carbon mitigation strategy.

Three problem representations were identified in ICAO's alternative jet fuel strategy: (1) the increasing contribution of international aviation to climate change, (2) the technological limitations to constraint and reduce the necessary carbon emissions to sustain the continued sectoral expansion, and (3) the uncertainty around future jet fuel prices and availability. However, two out of the four assumptions underlying the foregoing problem representations have encouraged ICAO and the industry to historically underplay the sector's environmental impacts, leading to a number of discursive, subjectification and lived effects. The first conflicting assumption is that air transport growth is considered by ICAO and the industry as a condition sine qua non for social inclusion and economic development, while the second one is that the environmental impacts from aviation are regarded as strictly technological issues that should be addressed through technological and market-based solutions.

Whereas the social and economic benefits brought about by aviation in the course of over a century are undeniable, the adoption of the Paris Agreement in 2015 and the approval of CORSIA in 2016 have intensified the external and internal pressure on ICAO towards the implementation of more aggressive carbon reduction strategies, some of which challenge the foundational assumptions of the problem representations analyzed in this paper. Also, climate efforts could greatly benefit from incorporating aspects into the international discussions that have received little to no attention, such as: (1) raising awareness of the environmental impacts of aviation beyond the tailpipe emissions, (2) improving the understanding of current and future climate impacts on the air transport sector, and (3) reassessing the sectoral approach to the SDGs so as to gain consistency with the aims of the UN *2030 Agenda for Sustainable Development*.

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Declarations of interest

None.

References

AEF, 2014, August 8. Demand for air travel will have to be limited to meet industry CO_2 targets. Retrieved from: https://www.aef.org.uk/2014/08/08/demand-for-air-travel-will-have-to-be-limited-to-meet-industry-co2-targets/.

Airbus, 2017. Growing horizons: global market forecast 2017-2036. Retrieved from: http://www.airbus.com/content/dam/corporate-topics/publications/backgrounders/Airbus_Global_Market_Forecast_2017-2036_Growing_Horizons_full_book.pdf.

ATAG, 2010. Beginner's guide to aviation efficiency. Retrieved from: http://www.atag.org/component/downloads/downloads/59.html.

ATAG, 2012. Powering the future of flight. Retrieved from: http://www.atag.org/component/downloads/downloads/152.html.

ATAG, 2016a. Benefits beyond borders. Retrieved from: http://www.atag.org/component/downloads/downloads/346.html.

ATAG, 2016b. Fact sheet: delivering fuel efficiency. Retrieved from: http://www.atag.org/component/downloads/downloads/297.html.

ATAG, 2017. Flying in formation. Retrieved from: http://www.atag.org/component/downloads/downloads/355.html.

Bacchi, C.L., 2009. Analysing Policy: What's the Problem Represented to Be? Pearson, Frenchs Forest.

Becken, Susanne, 2006. Tourism and transport: the sustainability dilemma. J. Sustain. Tourism 14 (2), 113–116.

Boeing, 2017. Environment Report: build something cleaner. Retrieved from: http://www.boeing.com/resources/boeingdotcom/principles/environment/pdf/2017_environment_report.pdf.

Bombardier, 2016. CS100 environmental product declaration. Retrieved from: http://gryphon.environdec.com/data/files/6/12107/epd921_Bombardier_C_SERIES100.pdf.

Bousquet, Gil, 2017, October 5. Un 'pack' autour de l'aéroport pour réduire l'effet de serre. La Dépêche Retrieved from: https://www.ladepeche.fr/article/2017/10/05/2659260-pack-autour-aeroport-reduire-effet-serre.html.

Bridger, Rose, 2013. Plane Truth: Aviation's Real Impact on People and the Environment. Pluto Press, London.

Cames, M., Graichen, J., Siemons, A., Cook, V., 2015. Emission Reduction Targets for International Aviation and Shipping. report prepared for the European Parliament's Directorate General for International Policies, IP/A/ENVI/2015-11, Brussels Retrieved from: http://www.europarl.europa.eu/RegData/etudes/STUD/2015/569964/IPOL_STU(2015)569964_EN.pdf.

Chester, Mikhail V., Horvath, Arpad, 2009. Environmental assessment of passenger transportation should include infrastructure and supply chains. Environ. Res. Lett. 4 (2), 1–8.

Cohen, S.A., Higham, J.E.S., Cavaliere, C.T., 2011. Binge flying: behavioural addiction and climate change. Ann. Tourism Res. 38 (3), 1070–1089.

Crosti, Roberto, 2009. Invasiveness of Biofuel Crops and Potential Harm to Natural Habitats and Native Species. report prepared for the Convention on the Conservation of European Wildlife and Natural Habitats of the Council of Europe Retrieved from: http://www.globalbioenergy.org/uploads/media/1012_CE_-_Invasiveness_of_biofuel_crops_and_potential_harm_to_natural_habitats_and_native_species.pdf.

Du Pisani, Jacobus A., 2006. Sustainable development: historical roots of the concept. Environ. Sci. J. Integr. Environ. Res. 3 (2), 83–96.

Epstein, Alan, 2017, October 4. Session 3: meeting the 2050 goal to reduce net aviation CO_2 emissions through technology. In: ATAG Global Sustainable Aviation Summit, October 3-4, Geneva.

Euractiv, 2002, August 19. Sustainable development: introduction. Retrieved from: http://www.euractiv.com/section/sustainable-dev/linksdossier/sustainable-development-introduction-archived/.

Eychenne, Frederic, 2017, November 17. Session 4: global and regional initiatives. In: IATA Alternative Fuel Symposium, November 16-17, Vancouver.

Foucault, Michel, 1984. Polemics, politics and problematizations. In: In: Rabinow, Paul (Ed.), (1998), Essential Works of Foucault, Vol. 1 "Ethics" The New Press., New York Retrieved from: https://foucault.info/doc/foucault/interview-html.

Ghosh, Arup, 2014. Plane truth: aviation's real impact on people and the environment [book review]. Int. J. Environ. Stud. 71 (6), 888–898.

Giampietro, M., Mayumi, K., 2009. The Biofuel Delusion: the Fallacy of Large-scale Agro-biofuel Production. Earthscan, London.

Girling, Julie, 2017, October 4. Session 4: the big picture and future challenges. In: ATAG Global Sustainable Aviation Summit, October 3-4, Geneva.

Haines, Gavin, 2017, October 4. More Turbulence and Longer Runways: Seven Ways Climate Change Will Affect Air Travel. The Telegraph Retrieved from: http://www.telegraph.co.uk/travel/news/ways-climate-change-could-affect-flying/.

Hamilton, James D., 2011. Historical Oil Shocks. NBER Working Paper 16790, Cambridge Retrieved from: http://www.nber.org/papers/w16790.pdf.

Heinberg, Richard, 2014, December 19. The Oil Price Crash of 2014. Post Carbon Institute Retreived from: http://www.postcarbon.org/the-oil-price-crash-of-2014/.

IATA, 2009, December 8. Halving emissions by 2050: aviation brings its targets to Copenhagen. Press release no. 54. Retrieved from: http://www.iata.org/pressroom/pr/Pages/2009-12-08-01.aspx.

IATA, 2013. Technology Roadmap, fourth ed. Retrieved from: https://www.iata.org/whatwedo/environment/Documents/technology-roadmap-2013.pdf.

IATA, 2015. Sustainable aviation fuel roadmap. Retrieved from: https://www.iata.org/whatwedo/environment/Documents/safr-1-2015.pdf.

IATA, 2017, October 24. 2036 forecast reveals air passengers will nearly double to 7.8 billion. Press release no. 55. Retrieved from: http://www.iata.org/pressroom/pr/Pages/2017-10-24-01.aspx.

ICAO, 2012. Global aviation and our sustainable future. Retrieved from: https://www.icao.int/environmental-protection/Documents/Rio+20_booklet.pdf.

ICAO, 2013a. Destination Green: driving progress through action on aviation and the environment. The ICAO Journal 68 (2) Retrieved from: https://www.icao.int/publications/journalsreports/2013/6802_en.pdf.

ICAO, 2013b. Basket of measures to reduce aviation CO_2 emissions: progress since the 37th Session of the ICAO Assembly. Retrieved from: http://cfapp.icao.int/tools/38thAssyiKit/story_content/external_files/Flyer_US-Letter_ENV_Basket-Measures_2013-08-28.pdf.

ICAO, 2014. Overview of alternative jet fuels in 2014, published in IATA. Report on alternative fuels. Retrieved from: https://www.icao.int/environmental-protection/GFAAF/Documents/Overview%20of%20Alternative%20Jet%20Fuels%20in%202014.pdf.

ICAO, 2016. Environmental Report: on board a sustainable future. Retrieved from: https://www.icao.int/environmental-protection/Documents/ICAO%20Environmental%20Report%202016.pdf.

ICAO, 2018, January 17. Continued passenger traffic growth and robust air cargo demand in 2017. Retrieved from: http://www.unitingaviation.com/strategic-objective/economic-development/continued-passenger-traffic-growth-robust-air-cargo-demand-2017/.

ITF, 2017. ITF Transport Outlook 2017. OECD Publishing, Paris.

IUCN, 2009. Guidelines on biofuels and invasive species. Retrieved from: https://

cmsdata.iucn.org/downloads/iucn_guidelines_on_biofuels_and_invasive_species_.pdf.
Jiang, Helen, 2013. Key Findings on Airplane Economic Life. Boeing Retrieved from: http://www.boeing.com/assets/pdf/commercial/aircraft_economic_life_whitepaper.pdf.
Karnauskas, K.B., Donnelly, J.P., Barkley, H.C., Martin, J.E., 2015. Coupling between air travel and climate. Nat. Clim. Change 5 (12), 1068–1073.
Kasarda, John D., 2010, December 22. Are rising jet fuel prices leading to the end of aviation? Retrieved from: http://aerotropolisconcepts.blogspot.ca/2010/12/are-rising-jet-fuel-prices-leading-to.html.
Kolmes, Steven A., 2011. Ground-level pollution, invasive species and emergent diseases. In: Hoppe, Elizabeth A. (Ed.), Ethical Issues in Aviation. Ashgate, Burlington, pp. 257–265.
Lee, D.S., Fahey, D.W., Forster, P.M., Newton, P.J., Wit, R.C.N., Lim, L.L., Owen, B., Saucen, R., 2009. Aviation and global climate change in the 21st century. Atmos. Environ. 43, 3520–3537.
Luke, Timothy W., 2005. Neither sustainable nor development: reconsidering sustainability in development. Sustain. Dev. 13 (4), 228–238.
Macintosh, A., Wallace, L., 2009. International aviation emissions to 2025: can emissions be stabilised without restricting demand? Energy Pol. 37, 264–273.
Mondou, M., Bognar, J., 2017. Policy Approaches and Lessons for Biofuel Policy in Canada, in BFN, *What Role for Advanced Biofuels in Canada?. A Q&A of policy impacts and options*, the BiofuelNet Canada, Retrieved from: http://www.biofuelnet.ca/nce/wp-content/uploads/2013/02/Biofuel-QA-Report-KTF-Apr-6-Final.pdf.
Moore, R.H., Thornhill, K.L., Weinzierl, B., Sauer, D., D'Ascoli, E., Kim, J., Lichtenstern, M., Scheibe, M., Beaton, B., Beyersdorf, A.J., Barrick, J., Bulzan, D., Corr, C.A., Crosbie, E., Jurkat, T., Martin, R., Riddick, D., Shook, M., Slover, G., Voigt, C., White, R., Winstead, E., Yasky, R., Ziemba, L.D., Brown, A., Schlager, H., Anderson, B.E., 2017. Biofuel blending reduces particle emissions from aircraft engines at cruise conditions. Nature 543, 411–415.
Morad, Azlan, 2017, May 19. Climate Change Impact on Aviation: what You Need to Know. New Airport Insider Retrieved from: https://newairportinsider.com/climate-change-impact-on-aviation/.
Munda, Giuseppe, 2008. Social Multi-criteria Evaluation for a Sustainable Economy. Springer, Barcelona.
Nisbet, Robert, 1980. History of the Idea of Progress. Basic Books, New York.
Novelli, Philippe, 2011. Sustainable way for alternative fuels and energy in aviation (SWAFEA), report prepared for the European Commission's directorate general for mobility and transport. Retrieved from: https://www.icao.int/environmental-protection/GFAAF/Documents/SW_WP9_D.9.1%20Final%20report_released%20July2011.pdf.
Palmer, Walter J., 2015. Will Sustainability Fly? Aviation Fuel Options in a Low-carbon World. Routledge, New York.
Pelsser, Albert, 2017, August 17. The postal history of ICAO: Annex 16. Environmental protection. Retrieved from: https://www.icao.int/secretariat/PostalHistory/index.html.
Penner, J.E., Lister, D.H., Griggs, D.J., Dokken, D.J., McFarland, M. (Eds.), 1999. Aviation and the Global Atmosphere: a Special Report of the Intergovernmental Panel on Climate Change, UK. Cambridge University Press.
Pidcock, Roz, Yeo, Sophie, 2016. Analysis: aviation could consume a quarter of 1.5C carbon budget by 2050". Retrieved from: https://www.carbonbrief.org/aviation-consume-quarter-carbon-budget.
Piera, Alejandro J., 2015. Greenhouse Gas Emissions from International Aviation: Legal and Policy Challenges. Eleven International Publishing, The Hague.
Redclift, Michael, 2005. Sustainable development (1987-2005): an oxymoron comes of age. Sustain. Dev. 13 (4), 212–227.
Rude, J., Luckert, M., Campbell, H., 2017. Advanced biofuels and macro-economic impacts, in BFN. In: What Role for Advanced Biofuels in Canada? A Q&A of policy impacts and options. the BiofuelNet Canada Retrieved from: http://www.biofuelnet.ca/nce/wp-content/uploads/2013/02/Biofuel-QA-Report-KTF-Apr-6-Final.pdf.
Shaw, S., Thomas, C., 2006. Social and cultural dimensions of air travel demand: hyper-mobility in the UK? J. Sustain. Tourism 14 (2), 209–215.
Smyth, A., Christodoulou, G., Dennis, N., Al-Azzawi, M., Campbell, J., 2012. Is air transport a necessity for social inclusion and economic development? J. Air Transport. Manag. 22, 53–59.
Staples, M.D., Malina, R., Suresh, P., Hileman, J.I., Barrett, S.R.H., 2018. Aviation CO_2 emissions reductions from the use of alternative jet fuels. Energy Pol. 114 (C), 342–354.
Von Wright, Georg H., 1997. Progress: fact and fiction. In: Burgen, A., McLaughlin, P., Mittelstrab, J. (Eds.), The Idea of Progress. Walter de Gruyter, Berlin, pp. 1–18.
World Economic Forum, 2017. The travel and tourism competitiveness report 2017: paving the way for a more sustainable and inclusive future, Geneva. Retrieved from: https://www.weforum.org/reports/the-travel-tourism-competitiveness-report-2017.
Wienert, Uwe, 2010. Climate change and its possible impact on aviation. In: EASA International Air Safety & Climate Change Conference, September 8–9. [PowerPoint slides], Cologne Retrieved from: https://www.easa.europa.eu/conferences/iascc/doc/Workshop%201%20Presentations/Workshop1_DAY%201/2_Wienert_DWD/Aviation%20&%20Climate%20Change300710_TD.pdf.
WMO, 2016. Climate change impacts on aviation: an interview with Herbert Puempel. World Meteorol. Organ. Bull. 65 (2) Retrieved from: https://public.wmo.int/en/resources/bulletin/climate-change-impacts-aviation-interview-herbert-puempel.
WWF, Care International, 2016. Twin tracks: developing sustainably and equitably in a carbon-constrained world (3rd ed.). Retrieved from: http://careclimatechange.org/wp-content/uploads/2016/04/CARE-WWF_Twin-Tracks-3rdEdition.pdf.

United Nations regulations, documents, resolutions, working papers and information papers

United Nations General Assembly (UN).

Transforming our world: the 2030 agenda for sustainable development, A/RES/70/1. 21/10/2015. Retrieved from: http://www.un.org/ga/search/view_doc.asp?symbol =A/RES/70/1&Lang=E.

United Nations Framework Convention on Climate Change (UNFCCC).

Annex I. Information provided in accordance with paragraph 104 of decision 1/CP.21 related to entry into force of the Paris Agreement (Article 21), FCCC/CP/2015/10. Retrieved from: http://unfccc.int/files/paris_agreement/application/pdf/10e.pdf.

International Civil Aviation Organization (ICAO).

Convention on International Civil Aviation, 7 December 1944, 15 UNTS 295, ICAO doc 7300/06. [Chicago convention]. Retrieved from: https://www.icao.int/publications/Documents/7300_orig.pdf.

39th Assembly Resolution A39–3: Consolidated statement of continuing ICAO policies and practices related to environmental protection – Global Market-based Measure (MBM) scheme, October 2016. Retrieved from: https://www.icao.int/environmental-protection/Documents/Resolution_A39_3.pdf.

37th Assembly Resolution A37–19: Consolidated statement of continuing ICAO policies and practices related to environmental protection – Climate Change, October 2010. Retrieved from: https://www.icao.int/environmental-protection/37thAssembly/A37_Res19_en.pdf.

Aviation's contribution towards the United Nations 2030 Agenda for sustainable development, A39-WP/25 [presented by ICAO], 05/07/2016. Retrieved from: https://www.icao.int/Meetings/a39/Documents/WP/wp_025_en.pdf.

Present and future aircraft noise and emissions trends, A39-WP/55. 17/06/2016. Retrieved from: https://www.icao.int/Meetings/a39/Pages/WP_Num.aspx.

Aviation's Contribution towards the United Nations 2030 Agenda for sustainable development, A39-WP/374 [presenteAviation's contributiond by ACI, CANSO, IATA, IBAC and ICCAIA]. Retrieved from. https://www.icao.int/Meetings/a39/Documents/WP/wp_374_en.pdf.

ICAO's climate change measures and the sustainable development goals, A39-WP/427 [Information paper presented by ICSA], 14/09/2016. Retrieved from: https://www.icao.int/Meetings/a39/Documents/WP/wp_427_en.pdf.

Appendix B. Declaration of the Conference on Aviation and Alternative Fuels, CAAF/09-SD/3. 18/11/2009. Retrieved from: https://www.icao.int/Meetings/caaf2009/Documents/CAAF-09_SD003_en.pdf.

Appendix. Declaration of the Second Conference on Aviation and Alternative Fuels, CAAF/2–SD3. 13/10/2017. Retrieved from: https://www.icao.int/Meetings/CAAF2/Documents/CAAF2%20SD%20day%203.Final.pdf.

Follow up con CAAF/1 recommendations, CAAF/2-WP/04. 27/07/2017. Retrieved from: https://www.icao.int/Meetings/CAAF2/Documents/CAAF.2.WP.004.1.en.pdf.

Trends and scenarios on alternative fuels, CAAF/2-WP/06. 07/09/2017. Retrieved from: https://www.icao.int/Meetings/CAAF2/Documents/CAAF.2.WP.006.4.en.pdf.

Global Framework for Aviation Alternative Fuels, CAAF/09-WP/23. 18/11/2009. Retrieved from: https://www.icao.int/Meetings/caaf2009/Documents/CAAF-09_WP023_en.pdf.

Declaration and recommendations, CAAF/09-WP/24. 18/11/2009. Retrieved from: https://www.icao.int/Meetings/caaf2009/Documents/CAAF-09_WP024-Rev_en.pdf.

Strategic Objectives. 2017. Retrieved from: https://www.icao.int/about-icao/Council/Pages/Strategic-Objectives.aspx.

ICAO Global Framework for Aviation Alternative Fuels GFAAF, 2017. Retrieved from: https://www.icao.int/environmental-protection/GFAAF/Pages/default.aspx.

ASTM International standards.

ASTM D7566, 2016b (2009), Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons, West Conshohocken: ASTM International. Retrieved from: http://www.astm.org.