ALTERNATIVES FOR MITIGATING CO_2 EMISSIONS IN THE AIR TRANSPORTATION SECTOR IN BRAZIL

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Abstract

The purpose of this study is to discuss the participation of Brazilian air transportation within the context of global climate changes. It first briefly presents an inventory of CO_2 emissions caused by airborne activities in Brazil, an then shows a Trend Scenario through to 2022 indicating the progress of these emissions, with ten possible mitigation strategies. The abatement potential for each of these strategies is also investigated. It is estimated that the joint implementation of all these strategies within a typical scenario of broad-based sustainability (based on renewable energy sources with fair social, economic and technological development) could result in an annual reduction in CO_2 emissions caused by airborne activities in Brazil of up to 45% (compared to the Trend Scenario for 2022). It is also estimated that the emissions avoided through the joint implementation of the mitigation alternatives analyzed may well reach some 102,000 Gg CO2 from 2002 through to 2022.

Keywords: Climate change; Energy consumption; Mitigation strategies for CO_2 emissions.

1 Introduction

Vital to today's globalized economy, the transportation sector have contributed most significantly to speeding up environmental degradation, basically through burning fossil fuels and releasing pollutant gases into the atmosphere. Carbon dioxide emissions generated by the transportation sector have been causing much concern among the scientific community worldwide, due to rapid growth rates and the fact that CO_2 is the main greenhouse gas. At the moment, the transportation sector accounts for 13% of global warming (IPCC, 2001).

Since the early 1990s, some of the highest growth rates for these emissions have been posted for air transportation which currently accounts for around 3.5% of anthropogenic carbon dioxide contributions to global warming through burning fossil fuels, equivalent to around 0.3 giga-tons/year of CO_2 (IPCC, 1999). Particularly in the industrial-based developing countries, such as Brazil, extremely high growth rates have been posted in the demand for air transportation and the associated CO_2 emissions (IPCC, 1999). This study consequently discusses the contribution of Brazil's air transportation sector to greenhouse gases emissions, presenting possible mitigation alternatives.

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2 Air Transportation in Brazil and the Associated CO_2 Emissions

In this paper, CO_2 emissions caused by Brazil's air transportation sector (Figure 1) are calculated through the use of the top-down methodology suggested by the IPCC (IPCC, 1994).

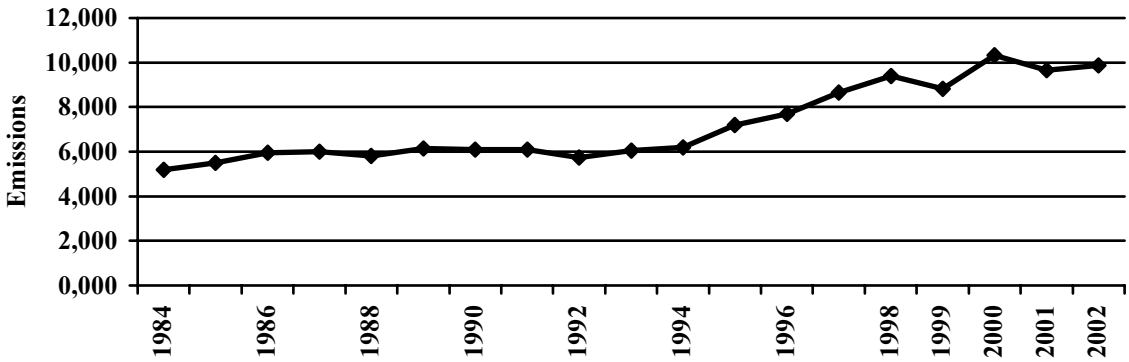

Figure 1: Development of Total CO_2 Emissions by the Air Transportation Sector in Brazil, 1984-2002 (Gg CO_2)

3 Development of CO_2 Emissions in the Trend Scenario

Basic characteristics adopted for building up the Trends Scenario for the development of CO_2 emissions by Brazil's air transportation sector (showed in Table 1): continuation of current trends (lack of development incentives introduced by government policies for the Brazilian air transportation sector); rising participation of private enterprise in the planning and expansion of the Brazilian air transportation sector ≈ deregulation ≈ lower air-ticket prices and a wider variety of routes; continuation of economic stability in order to reduce external vulnerability; and cargo shipments expanding faster than passenger transportation (spurred by government policies) ≈ diversification and keener competitive edge for Brazilian exports.

Table 1: Trend Scenario for the Development of CO_2 Emissions (Gg CO_2) due to air transportation activities in Brazil, 2003-2022

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Emissions Gg CO_2	10,190	10,530	10,870	11,230	11,600	12,270	12,990	13,740	14,540	15,380
Year	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Emissions Gg CO_2	16,530	17,770	19,100	20,540	22,080	24,110	26,330	28,750	31,390	34,280

4 Alternatives for Mitigating CO_2 Emissions Due to Air Transportation in Brazil

Wide-Ranging Use of Low-Density Aeronautical Alloys

The average tare weight of an aircraft operating in the Brazilian air transportation sector is around seventy tons (DAC, 1997). Taking into account the IPCC analysis, this indicates that the reduction in the tare weight of an aircraft may reach 2,000 Kg due to the widespread use of low-density alloys (such as those belonging to the aluminum-lithium system) (IPCC, 1999). This reduction in the tare weight for an aircraft operating in Brazil would be around 2.86%. It is estimated that this reduction in the tare weight of an aircraft would be directly proportional to the resulting reduction in annual fuel consumption of around 2.8%. Within

this context, the reduction in CO_2 emissions through widespread use of low-density alloys by the Brazilian and global aircraft industries would be proportional to the reduction in fuel consumption (meaning 2.8% p.a. compared to the Trend Scenario). Taking into account the relatively mature stage of the development of light aviation alloys today, this reduction would take place from 2015 onwards.

Introduction of Alternative Fuels / Vegetable Kerosene

A pioneer in the development of alternative energy sources – such as fuel alcohol during the 1980s – Brazil has backed research and production (on a pilot scale) of a vegetable-based type of aviation kerosene through the Air Ministry. Consisting of a blend of linear esters obtained from vegetable oils (soy, canola, castor, colza and sunflower, among others), the PROSENE alternative fuel was obtained in late 1982 through a reaction known as transesterification, using methanol in this process. Within this context, this paper suggests that Brazil should relaunch the PROSENE Project as soon as possible. It is estimated that this strategy could result in a drop in CO_2 emissions by Brazil's air transportation sector of around 7.8% a year (compared to the Trend Scenario, should the blend used be 90% aviation kerosene and 10% PROSENE), rising to 15.6% p.a. (compared to the Trend Scenario should the blend used be 80% aviation kerosene and 20% PROSENE). It is estimated that PROSENE would be phased onto the Brazilian aircraft fuels market gradually.

Introduction of Alternative Fuels / Hydrated Alcohol

Accepting the hypothetical substitution of aviation gasoline by hydrated alcohol in all crop-dusters operating in Brazil, and assuming that the 100% reduction could be applied to this entire fleet, this would mean that the abatement in CO_2 emissions due to this substitution might well reach 26.22 Cg of CO_2, equivalent to 0.3% of total CO_2 emissions caused by airborne activities in Brazil in 2001. However, introducing hydrated alcohol as an aircraft fuel should be phased in slowly and gradually, according to EMBRAER specialists (EMBRAER, 2003). Within this context, it is estimated that the entire Brazilian crop-duster fleet would be flying on alcohol only by 2011. The successful introduction of alcohol as a fuel for crop-duster aircraft would be so marked that, still hypothetically, hydrated alcohol would gradually replace aviation gasoline during the subsequent years for the entire Brazilian fleet of aircraft fitted with piston engines, which in 2002 accounted for 3.7% of all energy consumed by the Brazilian aeronautical sector.

Introduction of Alternative Fuels / Liquid Hydrogen

Burning renewable liquid hydrogen does not generate any CO_2 emissions, which is undoubtedly an extremely positive aspect from the standpoint of mitigating the greenhouse effect. Due to current technological stumbling-blocks hampering the use of liquid hydrogen as an aircraft propellant (such as the high risk of explosions should an aircraft fuelled by liquid hydrogen crash), it is estimated that aviation kerosene/aviation gasoline would be replaced by liquid hydrogen only in 2020, at the modest rate of 5% p.a., continuing at this level through to at least 2022, by hypothesis. Within this context, the reduction in CO_2 emissions due to the mitigation strategy under analysis would be around 5% p.a., compared to the Trend Scenario from 2020 through 2022.

Introduction of the Broad-Ranging Integrated Air Traffic Control System

Based on the success of the Air Traffic Flow Management (ATFM) system in the USA, Brazil has been developing its own version (GTFA - *Gerenciamento de Fluxo de Tráfego Aéreo*). Through sophisticated computerized methods for processing data, this would result in fine-tuning the use of aviation kerosene and aviation gasoline. Based on the percentage of 10% estimated by the Air Ministry as the amount of fuel saved each year through introducing this System into the Brazilian air transportation sector, estimated CO_2 emission reductions due to the introduction of a broad-based, integrated air traffic control system (similar to the GFTA or some other) would reach around 10% p.a., compared to the Trend Scenario from 2005 through to 2020.

Taxing Aviation Kerosene Consumption in Brazil

Based on the international examples (USA, Sweden, Norway and UK) it is suggested that Brazil adopts a tax similar to the Air Passenger Duty (APD) in the UK, which is included in air ticket costs and whose value would vary by the distance traveled, as follows: the longer the trip, the higher the value of the tax. It is estimated that this tax would result in a drop in the demand for airborne services in Brazil of around 2.5% between 2005 and 2022. It is also estimated that this percentage reduction in demand due to the IADS tax would be reflected in a certain reduction in energy consumption, with lower CO_2 emissions due to air transportation in Brazil. It is felt that this reduction would not be negligible, as a drop in energy consumption and CO_2 emissions of around one percent a year from 2005 through 2022 would be quite feasible, or at least within the possible value margins.

Intermode Substitution Between Rio de Janeiro and São Paulo

The air shuttle between Rio de Janeiro and São Paulo (373 kilometers) is among the five busiest flights worldwide in terms of both passengers and cargo. All this movement results in high energy consumption: some 170 million liters of aviation kerosene were consumed by the Rio de Janeiro-São Paulo route in 2000. For all these reasons, as well as the geographical characteristics of the Rio de Janeiro-São Paulo leg, the prospect of implementing intermode options along this route is currently under study (Aircraft x High Speed Trains) as a way of minimizing energy consumption and greenhouse gases emissions caused by airborne activities in Brazil. Over a similar distance, a high-speed train (HST) produces only around one third of the emissions of a commercial aircraft.

The proposed intermode transportation option could result in potential reductions for both direct and indirect demands, meaning that not only would flights between Rio de Janeiro and São Paulo flights be less heavily used, but automobiles, inter-city diesel trains and buses would also be less in demand. Specifically with regard to air transportation, it is estimated that the intermode option proposed would result in a 4% reduction a year in CO_2 emissions caused by airborne activities in Brazil (compared to the Trend Scenario).

Lower Average Flight Speeds

According to engineers at Brazil's Civil Aviation Institute (IAC - *Instituto de Aviação Civil*), a reduction of around 12% in the average speed of aircraft operating in Brazil (cruising at altitudes of over 11,000 meters) may result in fuel savings of around twenty million liters of aviation kerosene a year (around one percent of the total consumption posted in 2000)

(IAC, 2003). Taking the analyses drawn up by the IAC engineers as a basis, it is estimated that aviation kerosene consumption could be cut by around one percent a year through implementing this mitigation strategy in actual practice, with CO_2 emissions caused by airborne activities in Brazil reduced by a similar level.

Higher Aircraft Occupancy Rates

Studies indicate a global occupancy rate of around 80% worldwide in 2015, which would boost the energy efficiency of air transportation by around 12%, compared to 2001 (Schell, B.; Sledsens, T. and Johnson, T. ,1999). Assuming an occupancy level of 80% for the air transportation sector in 2015, it seems likely that a considerable reduction in energy consumption could be achieved in the Brazilian aviation industry, in parallel to lower associated CO_2 emissions. A conservative reduction of around 1% a year is assumed here from 2015 onwards for CO_2 emissions (compared to the Trend Scenario), through the introduction of the mitigation strategy under analysis.

Application of Specific Regulations

Analyzing the regulations implemented in Netherlands, Norway, Sweden and the UK, as well as the characteristics of the Brazilian air transportation sector, it is suggested that two rules be introduced by the government for the busiest airports : (1) aircraft with occupancy rates of less than 50% would not be released for take-off; and, (2) depending on local air pollution conditions, large aircraft would not be allowed to take off when using outdated technology (particularly related to pollutant gas emissions and noise). It is estimated that implementing these regulations would result in a reduction of around two percent a year in CO_2 emissions by Brazil's air transportation sector from 2006 onwards (taking 2006 as Year 1 for the broad-ranging introduction of specific regulations focused on Brazil's air transportation sector). Table 2 summarizes the potential CO_2 emissions reductions for each of the mitigation strategies analyzed in this paper, as well as the associated total potential.

Table 2: Alternatives for Mitigating and Reducing CO_2 Emissions Caused by Airborne Activities in Brazil

Alternatives	Time Period	Accumulated Reduction in CO_2 Emissions (compared to the Trend Scenario, Gg CO_2)
Widespread Use of Low Density Alloys (2015-2022)	2015-2022	5,910
Alternative Fuels: - Vegetable Kerosene	2015-2022	25,530
- Hydrated Alcohol	2011-2022	6,070
- Liquid Hydrogen	2020-2022	4,720
Broad-Ranging Integrated Air Traffic Control System	2005-2022	34,350
Tax on Aviation Kerosene Consumption in Brazil	2005-2022	3,440
Intermode Substitution Rio de Janeiro- São Paulo	2013-2022	9,640[a]
Lower Average / Flight Speeds	2010-2022	2,850
Higher Aircraft / Occupancy Rates	2015-2022	2,850
Introduction of Specific Regulations	2006-2022	6,650
Total ≈ 102,000 Gg CO_2 Avoided Emissions (2002 – 2022)		

Note: [a] An indirect accumulated reduction is estimated of around 315,000 Gg CO_2 due to the introduction of a high-speed train system running between Rio de Janeiro and São Paulo.

5 Trend Scenario x Ample Mitigation Scenario

Figure 4 presents the Ample Mitigation Scenario, drawn up on the basis of adopting all the assumptions and considerations included in the description of each of the ten CO_2 emissions mitigation strategies under analysis, in terms of reducing CO_2 emissions compared to the Trend Scenario.

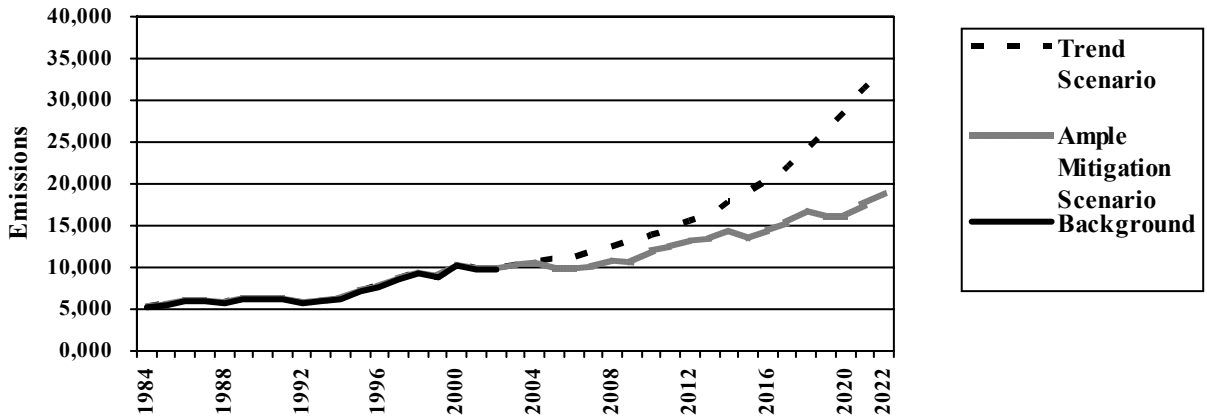

Figure 4: CO_2 Emissions by the Brazilian Air Transportation Sector: Background (1984-2002) and Trend Scenario x Ample Mitigation Scenario (2003-2022) (Gg CO_2)

6 Final Remarks and Recommendations

Comparing the Ample Mitigation Scenario with the Trend Scenario, the percentage reduction in CO_2 emissions varies from 11% in 2005 (when the mitigation strategies begin to take effect) through to 45% in 2022. It is also noted that the accumulated reduction prompted by the joint implementation of the ten mitigation strategies analyzed from 2002 through 2022 reaches 102,000 Gg CO_2 – equivalent to the total CO_2 emissions by Brazil's air transportation sector over the past twelve years (1990 - 2002).

It should be noted that there are factors specific to Brazil that will tend to provide leverage for aviation demands, which are already expanding. These factors include: heavy repressed demand, a continent-sized county and a good airport infrastructure. The IPCC itself forecasts an "explosion" in the demand for airborne services in the developing countries with industrialized bases, such as Brazil, from 2015 onwards (IPCC, 1999). Within this context, it is essential to implement alternatives that lead to lower CO_2 emissions by the Brazilian air transportation sector, helping avoid any worsening of environmental problems at the global level. However, the estimated reduction of 45.16% of CO_2 emissions by Brazil's air transportation sector by 2022 (compared to the Trend Scenario) generated by the ten mitigation alternatives under analysis in this paper is clearly most opportune.

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