CHALLENGES IN EUROPEAN AEROSPACE

5TH CEAS AIR & SPACE CONFERENCE

CEAS

CEAS 2015

ENVIRONMENTAL PROSPECTS IN AVIATION: A STUDY FROM THE AIR & SPACE ACADEMY

Alain Joselzon
Air & Space Academy
Aeronautic Expert-Consultant
73 rue Barrau 31400 Toulouse - France
alain.joselzon@wanadoo.fr

ABSTRACT

Environmental issues (noise, local emissions and air quality, greenhouse gases and global warming), closely linked to technical, economic and social issues, involve multiple interacting, fast-evolving factors making the 2050 horizon uncertain. Significant efforts are required to address them, with efficient, balanced, globally optimised, equitable and viable solutions, acting in technological and operational fields and calling cross-disciplinary expertise.

Noise reductions have been spectacular, as a result of intensive research and technological progress, stimulated by regularly updated standards limits are (perceived noise reduced by 75%, cumulative noise, noise exposure areas reduced). The overall trend is expected to continue, with a decrease in total acoustic energy between 2010 and 2050 despite the air traffic growth. Local situations will however need to be watched on critical platforms, where all applicable regulations will have to be enforced.

The situation of local emissions and air quality, regarding nitrogen oxides (NO_x) in particular, is similar to that of noise, with relatively stable emissions between 2010 and 2050, thanks to technological advances, also stimulated by regularly updated standard limits for engine certification. There also, local situations will need to be monitored.

Particulate Matter emitted by aircraft/engines will be a major issue in the future due to their growing impact on air quality and human health, as emissions grow. Scientific knowledge, including the contribution of PM to the greenhouse effect is still lacking. Research should be intensified, and a new ICAO standard is envisioned in coming years.

Aircraft fuel consumption and CO_2 emissions have benefited from spectacular improvements in the past, thanks to engine and aircraft performance improvements. Industry and ICAO have set ambitious goals for the future. The analysis made by the Air & Space Academy (Foresight Commission) of the fuel consumption and CO_2 emissions drivers between 2010 and 2050 (including the air traffic growth), has estimated results that fall short of the Industry/ICAO goals and of the European objective by a large amount, and concluded that technical progress is unlikely to fill the gap. Carbon compensation (Emission Trading Systems) may contribute to closing in, providing that it is managed on a worldwide basis and ensures equal access, non-discriminatory treatment, unbiased competition and viable costs.

There are key environmental interdependencies and trade-offs between noise, local and global emissions, inherent to physical parameters, which result in crucial technical and configuration choices, in particular regarding future propulsion systems.

1 INTRODUCTION

Considering the unique role of air transport in the world and in Europe in particular, its vital contribution to its welfare and to the mobility of its citizens, while recognizing the tough challenges involved for securing those benefits in the long term, the Air & Space Academy (Foresight Commission) has undertaken the task to evaluate those challenges, develop a vision and derive key recommendations aimed at best addressing them, with a 2050 time horizon. A fully coherent, multidisciplinary, holistic and iterative approach was deployed, covering altogether: worldwide demographics, market volume evolution in connection with economic welfare level and exchanges within and between states, energy availability, environmental effects, expected quality of service, air navigation services, airline and airport operating structures, use of spatial means.

This exceptional exercise, which represented three years of intensive, tightly coordinated work, carried out by a team of leading experts sharing a large and deep field of experience, culminated in a well-attended, successful international colloquium: “Flying in 2050”, held in Toulouse in May 2012. It was followed in 2013 by a full report, a dossier and several presentations made since then by the Air & Space Academy. The paper herewith contains the essential findings reached under one of the themes: the environment, completed and updated as applicable and as necessary.

The environmental challenges, combined with those relative to energy, are indeed to-day among the most critical challenges in European aerospace and beyond, and they will mark out an even more critical path in the future. The high levels of uncertainties, linked with the complexity and multiple entanglements inherent to the subject, the fast evolving context, make it very important to keep track of the prospects and to keep them updated. Year after year, they will deserve and rightfully receive increased attention from the aviation community - as it does from the whole community, in Europe as well as worldwide: the aim is to be as proactive as possible, anticipating and taking adequate, timely decisions and measures, at all required levels, in all the fields concerned. A special focus is expected and justified, at the time the 2015 CEAS conference is organised, a few months ahead of the Paris world climate summit and of the next ICAO / CAEP triannual meeting (early 2016), to be followed by the next ICAO Assembly session (39th session, fall of 2016).

The above remarks explain the study update provided at the end of this paper.

2 THE ENVIRONMENTAL CONTEXT

Environmental issues (noise, local emissions and air quality, greenhouse gas and global warming), which are closely linked to scientific, energy, geopolitical, economic and social questions, involve multiple interactions between innumerable factors and actors and are therefore rapidly evolving. As a result, the 2050 horizon is clouded by uncertainty. The underlying stakes are growing fast and matching efforts are needed in order to address them, reduce the level of uncertainty, take adequate measures and implement efficient solutions.

In the technological and operational fields, efforts need to be reinforced and the correct balance found between the different disciplines and between upstream and downstream research.

Cross-disciplinary expertise should be developed, in order to better apprehend the multidisciplinary nature of environmental issues.

Implementation of proposed solutions, including those aimed at curbing the growth of air transport-related CO_2 emissions or keeping them within certain limits, must be properly tuned and regulated, with a view to ensuring global optimisation, promoting equal treatment and protecting the viability of the sector.

A global assessment of needs, assets and interactions should make it easier to manage interlinked problems.

Finally, communication on the environmental aspects of air transport should be enhanced, in an unbiased, professional way, so as to keep it robust, coherent and credible.

3 NOISE

A strong, proven framework at national and international levels (ICAO standard[1]) sets noise limits, which contribute to stimulate technical progress and to reduce noise nuisance significantly (perceived noise reduced by 75%, cumulative noise, reduced noise contours and exposure areas). Stiffer limits have been introduced on a periodic basis, and certification procedures have been regularly reviewed and refined within ICAO. The last occurrence was at CAEP/10, in 2013, where a new chapter 14 was introduced, lowering the cumulative noise

1 ICAO - Convention on International Civil Aviation - Environmental Protection - Annex 16 - Volume I - Aircraft Noise.
ICAO - Environmental Technical Manual - Volume I (Doc 9501 - vol.I)

limit at the three certification points by 7 EPNdB, which was endorsed at the 38th session of the ICAO Assembly. This applies to Aircraft weighing 55 tons and above, starting from 2017, and the others from 2020.
The overall improvement trend should continue, despite the growth in air traffic, thanks to fleet renewal with enhanced aircraft. Thus, total acoustic energy could decrease by 15 to 20% between 2010 and 2050, taking into account the air traffic growth and the technological benefits as analysed by the Air & Space Academy Foresight Commission.
The decoupling of noise and traffic therefore appears plausible, even for the type of aircraft equipped with noisier counter-rotating open rotors (see figure 1 below).
A similar improvement can be expected for rotary wing aircraft, based on intensive research efforts to reduce their noise.

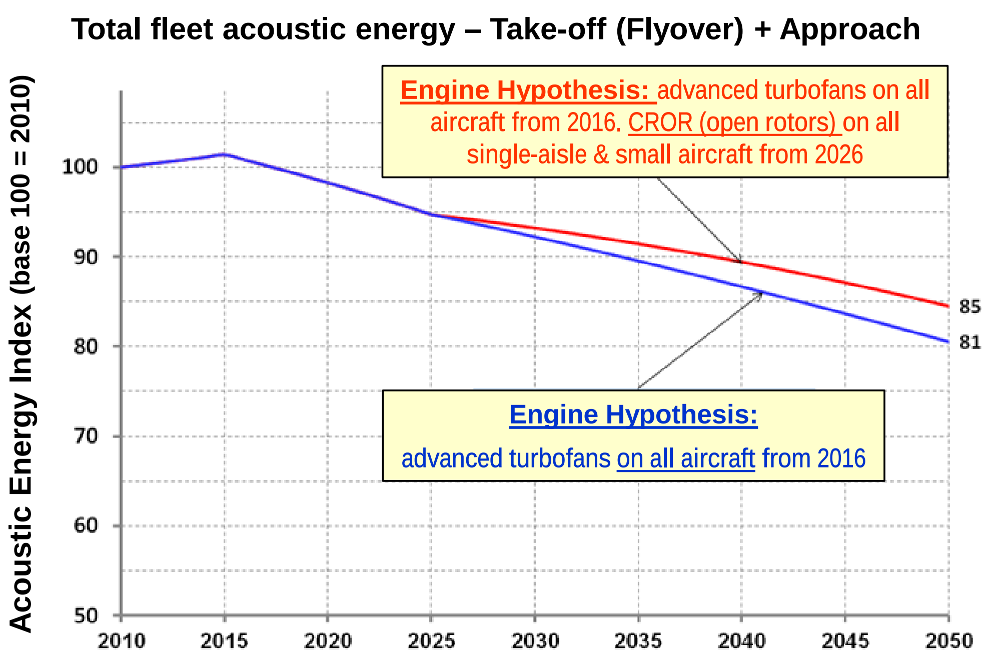

Figure 1: Evolution of the Total Acoustic Energy 2010-2050 (Projection based on FC estimations)

Those results would seem to indicate some room for manoeuvre on the noise side in the trade-off between noise and CO_2 (see thereafter). They do not however take account of local situations and should therefore be placed in context. In fact, on some potentially critical platforms with high traffic, noise will remain a major issue and will have to be closely monitored, factoring into the analyses and the regulatory framework all elements contributing to acoustic nuisance, especially:

- acoustic spectrum characteristics that could impact perceived noise in the airport vicinity and possibly en route;
- the risk of noise disturbance generated by an isolated event[2];
- the exacerbating effect produced by cumulative/repetitive events.

2 The limit of the zone authorised for building construction - noise insulation included - must be adjusted to ensure that the noisiest recurring aircraft in the traffic does not exceed the acceptable noise intensity threshold.

Asia presents a different situation to Europe and to the US; on the one hand, it has a faster growth rate in traffic but, on the other, a growing number of airports in which preventive measures can still be put in place.

The ICAO Balanced Approach principle[3] should be applied everywhere, so as to efficiently manage noise issues around airports, both from an environmental standpoint and from an economic perspective. Four main pillars must be considered: noise reduction at source, land use planning and management, noise abatement procedures and operational restrictions.

Noise reduction at source, a fundamental step in this approach, requires continued intensive research and development, with proper funding[4].

In order to derive full advantage from technologies and operational procedures, an authority should be set up, and reinforced whenever necessary, responsible for managing and controlling urban development plans as well as implementing the full set of applicable regulations[5], while preventing any undue building construction.

4 LOCAL EMISSIONS AND AIR QUALITY

4.1 NO_x

The overall situation of nitrogen oxides (NO_x) is similar to that of noise, in the sense that total emissions will be relatively stable between 2010 and 2050 - according to FC forecasts for traffic growth, reductions in fuel consumption and NO_x emissions - thanks to dedicated technological advances. The corresponding standard is thus periodically reinforced with an updating of the relevant engine certification procedures (ICAO[6]).

As is the case for noise, local situations concerning low altitude NO_x emissions need to be carefully monitored, especially in places where air quality limits can be exceeded under the combined effect of various contributors. Although aviation is a minor offender when compared with surface access transport, the issue can put a curb on airport development (e.g. London Heathrow). It is also important to ensure that the results of research and development efforts into NO_x emissions meet expectations.

Operationally-driven reductions in NO_x emissions at low altitude through operational procedures can only remain minimal, in as much as procedures currently in use already restrict engine power, and therefore NO_x emissions[7].

4.2 Particulate Matter

Particles emitted by aircraft/engines are the object of growing concern, due to their impact on air quality and human health.

In aeronautics, scientific knowledge on particulate matter and the means to measure, quantify and assess its impact remain limited. Research should be intensified, possibly leading to a new specific ICAO standard in coming years.

The involvement of particulates in cirrus cloud formation at altitude (therefore also impacting the greenhouse effect) is still very poorly understood. Further scientific progress is needed in order to improve our knowledge on this effect.

---

3 ICAO - Guidance on the Balanced Approach to Aircraft Noise Management (Doc 9829 AN/451- 2nd Edition - 2008).

4 Should the worldwide fleet significantly exceed the forecast, noise limitation constraints might stimulate a reshaping of the fleet (e.g. bigger aircraft, limited flight frequencies, more radical application of noise reduction technologies and operational procedures).

5 Appropriate grants to aid noise insulation, or even air conditioning, could fall within the responsibilities of such authority.

6 ICAO - Convention on International Civil Aviation - Environmental Protection - Annex 16 - Volume II – Aircraft Engine Emissions. ICAO - Environmental Technical Manual - Volume II (Doc 9501 - vol.II).

7 The correlation between NOx emissions at low altitude and during climb and cruising is such that the benefits of low altitude regulations and emissions reductions also reflect on total NO_x emissions.

The quantities of particulates emitted will benefit from reductions in fuel consumption and from an improved understanding of associated phenomena. Nevertheless, the combination of their impact and of the growth in total emissions will make particulates a major issue in the future.

5 GREEN HOUSE EFFECT AND GLOBAL WARMING

5.1 Global CO2 emissions

Aircraft fuel consumption and CO_2 emissions have benefited from spectacular improvements in the past (more than 75%), thanks to concerted efforts to improve engines and aircraft performance, in response to growing mobility needs and a competitive, exacting market.

The aeronautics industry and ICAO have set ambitious goals for the coming years[8]: a 1.5% increase in fuel efficiency per year until 2020 (2% for ICAO), carbon neutral growth from 2020, and a halving of total CO_2 emissions by 2050 relative to 2005 (industry only). These objectives rely on strong governmental support, technological progress, optimised operations, air traffic and infrastructures, use of sustainable biofuels, and finally economic instruments.

The Air & Space Academy (Foresight Commission, hereunder abbreviated as FC) has analysed the various factors that will drive fuel consumption and CO_2 emissions between 2010 and 2050, and has forecast the following cumulative gains in fuel consumption per passenger.km: 25% from technology and new aircraft introduced, 31% when air traffic and operational improvements are factored in and 37% due to increased load factor. To this can be added a decrease in CO_2 production of 40% (cumulative) due to biofuels, and 47% thanks to various types of carbon compensation effects. These cumulative gains are summarised on the left-hand side of figure 2 below.

Since air traffic (expressed in number of passengers x km, under the acronym: PKT) is growing at a faster pace than improvements (multiplier 3.1 in the time period), the total fuel consumption is expected to double during the period, with total CO_2 emissions growing by a factor of 1.6 as shown in figure 2 below.

[8] Air Transport Action Group (ATAG) - www.atag.org

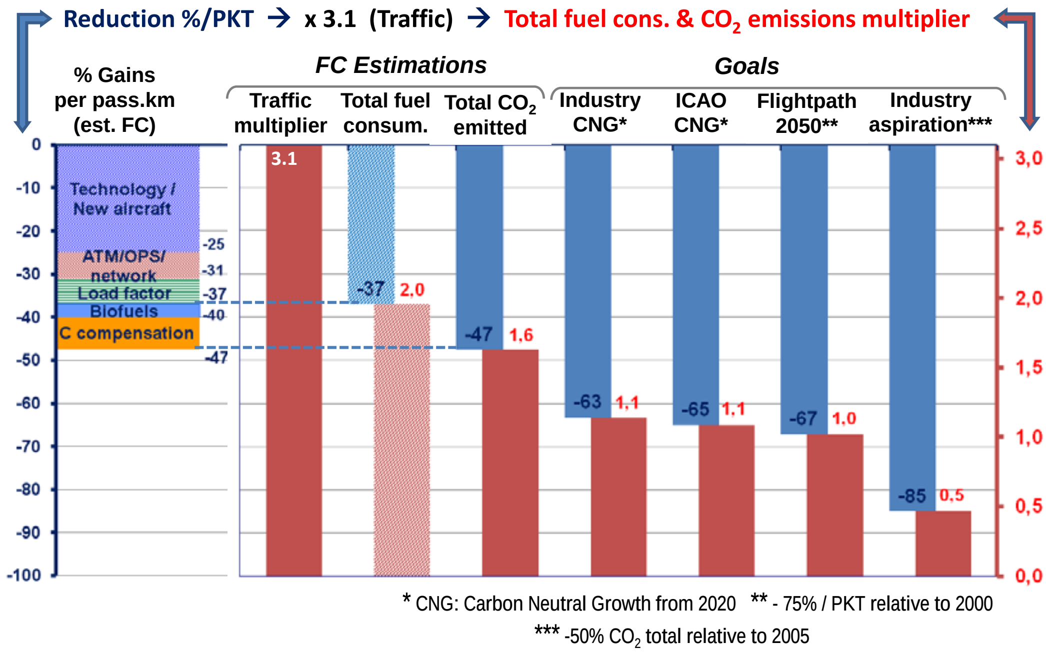

Figure 2: Fuel Consumption & CO_2 Emissions 2050 / 2010
Comparison: FC Forecasts vs Industry / ICAO / EU Goals

The results shown in figure 2 above are significantly short of industry and ICAO goals, notably as far as “carbon neutral growth from 2020” is concerned (including biofuels). The FC's 47% compares with 63%/65% industry/ICAO goals, with a multiplier on total emissions of 1.6 (FC) as against 1.1 (industry/ICAO). The objective of halving total CO_2 emissions by 2050 relative to 2005 implies an even more drastic reduction: - 85% per passenger.km, taking into account growth in air traffic. The European objective of Flightpath 2050 (-75% in CO_2 emissions per passenger.km relative to 2000[9]) is close to industry/ICAO objectives in terms of carbon neutral growth[10].

So, in spite of an air traffic growth hypothesis well below the one considered by industry, it seems that there is a low likelihood that technical progress will fill the gap in order to reach the required objectives. It remains a key factor however in reducing the sector's CO_2 emissions; intensive research efforts will be needed in particular to develop new biofuels and innovative technologies.

Carbon compensation[11] may contribute to closing in on objectives. However, in order to avoid damaging effects on air transport, it is vital that “compensation” measures, such as emissions trading systems, be managed on a worldwide basis, in order to ensure equal access, non-discriminatory treatment and unbiased competition, and control of costs so they are compatible with the sector’s viability, taking into account the socio-economic role of air transport[12]. The Authorities are considering other forms of carbon compensation. In any case, all possible means will have to be combined, and ICAO should play a major role.

9 European Commission Europe’s Vision for Aviation - Report of the High Level Group on Aviation Research.

10 -75 % relative to 2000 is equivalent to -67 % relative to 2010

11 It consists of subtracting from the CO_2 emissions attributable to air transport, the quotas purchased from outside the sector within the framework of emissions cap-and-trade emissions trading schemes.

12 This is a point of contention between the European Union and almost the rest of the world, due to the integration of aviation into the European CO_2 emissions trading scheme (European Directive 2003/87/EC of 13/10/2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC European Directive 2008/101/EC of

5.2 Effect of Contrails - Possible actions for aviation?

The direct effect of contrails is negligible. The only significant indirect effect might be their contribution to cirrus cloud formation, a phenomenon that is still poorly understood to-day.
The feasibility and efficacy of operational measures must be confirmed, in terms of the overall greenhouse effect.

6 THE IMPORTANCE OF ENVIRONMENTAL INTERDEPENDENCIES

Environmental interdependencies and trade-offs between noise, local and global emissions are inherent to the cross-disciplinary nature of the subject and intrinsic to all phases of design, from initial selection of overall goals to choices as to configurations and technologies. They impact propulsion system design, integration and operation and also influence regulatory processes.
There are many environmental trade-offs, linked to physical principles and factors such as engine internal temperatures, bypass ratio, specific fuel consumption, aerodynamic drag and nacelle acoustic treatment area, with varying impacts on noise, fuel consumption and NO_x/CO_2 emissions.
These trade-offs concern all new aircraft and are based on the overarching requirements adopted, in close connection with economic performance drivers. Interdependencies and trade-offs are difficult to analyse due to the complexity, uncertainties and evolving characteristics of the phenomena involved, and their different effects, both time- and space-related. These trade-offs are particularly challenging to resolve since there are no single criteria or universal scales of comparison. Nevertheless, it is essential to quantify the rates of different exchanges.
Levels of technical refinement and component efficiency have been increasing over time and are currently approaching ultimate physical limits. Beyond the primary gains being sought, each evolution brings with it a number of undesirable side effects. Arbitration thus becomes more and more tricky, for instance between engine specific fuel consumption (hence CO_2) and NO_x emissions, or between noise and fuel consumption (hence CO_2). Choices of types of engines and their configuration will be even more crucial in the future (between open rotors and advanced turbofans for instance) and will need to take into account the overall impact on fuel consumption (CO_2), noise and other key factors.
The further complex analysis and additional testing activities associated with environmental interdependencies and trade-offs are underway to-day, but they will need to be pursued and developed as required in future.

7 FURTHER DEVELOPMENTS IN THE ENVIRONMENTAL CONTEXT

Should innovative products emerge from studies for new aircraft concepts, they could bring additional environmental benefits.
This could also be the case for the possible discovery of new n^{th} generation biofuels, although the likelihood of decisive progress in this area remains slim.
Developments in the area of operations and air traffic management could involve the widespread adoption of “green” practices in terms of energy and fuel consumption by operators and airports (e.g. electric taxiing, already under study). Potential reductions in CO_2 emissions in this domain are however limited by the low impact of ground and low altitude operations.
Additional gains might come from more sophisticated modelling of environmental interdependencies, optimal combinations of standards or a broader carbon compensation scheme.

19/11/2008 amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community). It has led the European Commission to postpone implementation of the corresponding European Directive regarding flights outside Europe for one year (November 2012).

A slackening of environmental constraints cannot be ruled out in the event of growing economic or energy pressures. Neither can the granting of special emission permits or exemptions if CO_2 reduction objectives are recognised as over-ambitious for aviation, in view of the major socio-economic role played by air transport and the irreplaceable services it provides (should an accompanying communication campaign emphasise its low past and present contribution).
The situation could also develop in the opposite direction, through a CO_2 standard (in preparation to-day within ICAO/CAEP), and/or more stringent measures/penalties for instance, or should a significant worsening effect come to light linked to contrail-induced clouds. Very ambitious research goals might also impact the regulatory framework[13].

Further study of the regional analysis of CO_2 aviation emissions and their implications (2013-2015)

Another aspect coming out of the initial study made by the Air and Space Academy was further investigated recently, consisting in a more detailed regional analysis of the CO_2 emissions (current and projected).
It starts from a three-legged observation:

i) difficulty to meet over-challenging industry / ICAO objectives in terms of limiting CO_2 emissions from aviation worldwide
ii) likely drifting of these emissions in future, notably coming from the air traffic growth within and between developing/emerging countries (much higher traffic growth rate anticipated compared to industrialised countries)
iii) in international negotiations related to climate, which reflect on the aviation sector, ICAO acting under the delegation of UNFCCC relative to aviation emissions from the international traffic, the developing/emerging countries shelter behind the principle of « common but differentiated responsibilities », pointing out the historical major portion of emissions cumulated by industrialised countries, and their own right to develop, in turn.

This triple observation entails the risk for airlines of industrialised countries, by definition not protected by the principle of differentiated responsibilities, to be faced with growth restrictions resulting from international emissions limitations, with competition distortion (versus airlines from other countries) and loss of a crucial portion of their own growth.

In this sensitive context, it is in the interest of the industrialised countries to know/anticipate the break-down of emissions related to the air traffic within and in between them, in order to be in a position to better assess the risks involved, face up to them and suitably adjust their position in relevant bodies.

Updated information on GHG, global warming aspects of aviation and other environmental aspects (Mid-2015)

The air traffic, energy and environmental forecast and the effect on the environmental comparisons are currently undergoing an updating exercise performed within the Civil Aviation Commission of the Air & Space Academy.

As part of the coordinated work carried out by the Air & Space Academy (FC) during the 2009-2013 period, a study had been done covering extensively the energy aspects: this permitted to estimate the quantity of jet fuel needed every year by aviation, over the period from 2010 to 2050: this, taking into account the oil production and the refinery capabilities, allowed to identify a potential aviation fuel availability shortage, starting sometimes during the second half of the period. This led to the recommendation to entrust a proper entity (at European or worldwide level, including all players involved), with the task of ensuring adequate continuous energy supply to cover aviation needs (for instance using alternative drop-in fuel with characteristics equivalent to jet fuel). This, which requires timely anticipation, was one of the significant outcomes of the entire exercise,

[13] Certain developments could go one way or the other, depending on circumstances, politico-economic factors and issues at stake.

and it also incited the FC to keep updated the relevant projections. The recent update, currently undergoing its final stages, revisits the forecasts related to aircraft production/deliveries, the number of aircraft in the fleet and its composition, the fuel efficiency of the fleet, and it derives from there new air traffic projections, which might significantly increase. As a preliminary indication, the update shows that whilst the projections of fuel efficiency at fleet level do not seem to be very strongly affected, the new air traffic projection is significantly increasing (in line with the actual observed trend since 2010), in particular in the first half of the period. As a consequence, the quantities of jet fuel required per annum, the potential fuel shortage and the CO_2 emissions will increase significantly. This of course means that the discrepancy noted between the FC projections and the industry/ICAO objectives in terms of CO_2 emissions will also increase, thus making all problematics more severe.

As a result of this update, the technical progress is even less likely to fill the gap. Nevertheless, strong efforts will be even more needed on that side, and stronger mitigation efforts will be needed in general. In particular, more efforts would be needed on the carbon compensation / carbon offset efforts, also on new generations of biofuels, but realistic prospects remain limited in those areas by multiple technical, operational, industrial and practical factors.

In this situation even more challenging than it was, the further developments discussed in paragraph 7 above will become even more crucial, and so will the environmental interdependencies aspects discussed in paragraph 6, with heavier weighting to be expected on the fuel consumption and CO_2 emissions criteria.

It can be noted that, based on the preliminary updated data, the overall situation relative to noise should not be very strongly affected, except for the initial period where an increase of total acoustic energy may temporarily occur. However, the situation on noise-critical platforms will need to be tightly monitored anyway, as it has been mentioned above.

Concerning the NO_x emissions, it is likely that the new data will lead to a moderate increase instead of the relative stability noted. This also entails that the contribution of aviation to local air quality impacts may increase around air quality-critical platforms, but this again needed to be monitored in any case.

Acronyms & Abbreviations

CAEP Committee on Aviation Environmental Protection (Environmental Committee of ICAO)
CO_2 Carbon Dioxide
EPNdB Effective Perceived Noise level in decibels
EU European Union (or Europe)
FC Foresight Commission (Air & Space Academy)
GHG Greenhouse gases
ICAO International Civil Aviation Organization
NO_x Nitrogen oxides
PKT Passenger kilometers