Introduction

AVIATION OUTLOOK

ICAO
ENVIRONMENTAL
REPORT 2010

Aviation Outlook Overview

By ***ICAO Secretariat***

This chapter presents ICAO's outlook on global demand for air transport services, as well as projections of future aircraft noise and emissions. The trends presented in this chapter were developed by ICAO's Committee on Aviation Environmental Protection (CAEP) and the ICAO Secretariat.

Air Traffic Outlook

Economic growth, fuel price volatility, airline productivity gains, the evolution of low cost carriers and the liquidity position of the air carriers are reviewed in the context of the past history and projected future trends for air traffic demand.

Noise Outlook

Although aircraft being produced today are 75% quieter than those manufactured 50 years ago, aircraft noise remains the most significant cause of adverse community reaction related to the operation and expansion of airports worldwide. This outlook reviews the tremendous progress being made in aircraft noise technology and the projected trends of aircraft noise through the year 2036.

Local Air Quality Outlook

The health and well-being of all people is affected by the quality of the air that they breathe. While aircraft emissions typically contribute a small percentage to the overall emissions loading within a region, particularly in urban areas, ICAO has set strict emissions certification requirements for nearly 30 years. This outlook reviews projected trends of aircraft emissions that affect local air quality through the year 2036.

Climate Change Outlook

As the world has become increasingly concerned with global climate change, ICAO has taken the lead in addressing international aviation's contribution, which is estimated by the IPCC to be less than 2% of global human-made CO_2 emissions. As this outlook discusses, projections of global aviation fuel consumption and efficiency through the year 2050 reveal that on a per flight basis, fuel efficiency is expected to improve over the period. However in absolute terms an emissions "gap" could exist relative to 2006 or earlier in order to achieve sustainability. For this reason, ICAO has established the first and only globally-harmonized agreement from a sector on a goal to address its CO_2 emissions and continues to pursue even more ambitious goals.

Key Points

The key points from the articles in this part of the report can be summarized as follows:

- The world's airlines carry around 2.3 billion passengers and 38 million tonnes of freight on scheduled services, representing more than 531 billion tonne kilometres combined.
- Passenger traffic is expected to grow at an average rate of 4.8% per year through the year 2036.
- Overall, global trends of aviation noise, emissions that affect local air quality, and fuel consumption predict an increase through the year 2036 at less than the 4.8% growth rate in traffic.
  - In 2006, the global population exposed to 55 DNL aircraft noise was approximately 21 million people. This is expected to increase at a rate of 0.7% to 1.6% per year through the year 2036.
  - In 2006, 0.25 Mt of NO_x were emitted by aircraft within the LTO cycle globally. These emissions are expected to increase at a rate of between 2.4% and 3.5% per year.
  - In 2006, aircraft consumed approximately 187 Mt of fuel globally.
  - International flights are responsible for approximately 62% of global aviation fuel consumption.
  - Global aircraft fuel consumption is expected to increase at a rate of between 3.0% and 3.5% per year.
- Environmental standards set by ICAO and the investments in technology and improved operational procedures are allowing aviation's noise, local air quality, and CO_2 footprints to grow at a rate slower than the demand for air travel.
- The ICAO Programme of Action on International Aviation and Climate Change, agreed in 2009, set a goal of 2% annual fuel efficiency improvement through the year 2050. It is the first and only globally-harmonized agreement from a sector on a goal and on measures to address its CO_2 emissions. ICAO continues to pursue even more ambitious goals for aviation's contribution to climate change.

Air Traffic Outlook

By **ICAO Secretariat**

Historical Growth of Air Travel

Over the period 1989-2009, total scheduled traffic, measured in tonne kilometres performed, grew at an average annual rate of 4.4%. In 2009, the world's airlines carried about 2.3 billion passengers and 38 million tonnes of freight on scheduled services.

	Average annual growth (%)		
	1979-1989	1989-1999	1999-2009
Passenger-kilometres performed (PKPs)	5.3	4.7	4.3
Freight tonne-kilometres performed	7.4	6.6	2.6
Mail tonne-kilometres performed	4.0	1.2	-2.7
Total tonne-kilometres performed	5.8	5.2	3.7

Table 1 *– Trends in Total Scheduled Air Traffic (1979-2009[1])*
2009 ICAO Provisional Data

The financial crisis of 2008 followed by the 2009 recession caused a severe decline in all air transport areas and significantly impacted the average air traffic growth rates for 1999-2009 which fell compared to previous decades, as highlighted in Table 1.

However, in the last ten years, the airline industry has grown in absolute size, showing an increased diversity in the categorization of airlines operating in the different markets. Thanks to liberalization in many countries, completely new types of airlines have been entering the air transport market. These new entrants, mainly Low Cost Carriers (LCCs), which refers to their low cost operating basis, have had a dramatic impact on air traffic growth in all parts of the world.

Factors that Promote or Constrain Air Traffic Growth

Economic growth and falling ticket prices expressed in real terms are the main drivers of air traffic growth. While economic growth is largely determined outside the industry, airfares reflect many factors that are determined mostly by the industry environment.

Over the previous five decades, better aerospace technology has allowed airlines to increase their management efficiencies, thereby enabling them to lower their costs. The end result is that the passengers have been the greatest beneficiaries of these technical improvements. In parallel, liberalization of aviation markets, resulting in increased airline competition, has ensured that customers benefit from lower airline costs through lower ticket prices. A decrease in fares has encouraged people of all incomes to travel more, causing a growth in air travel demand significantly larger than what economic growth alone would have created.

Consequently, airlines have adapted their business models. LCCs started operating flights to airports that were underserved by the incumbents, building on their competitive advantage, and attractive air fares. The regional airlines continued to operate short haul routes, mainly as a feeder for the hub and spoke network of a large airline, and the legacy carriers reacted to LCCs by lowering their fares and by adopting many of the LCC's attributes. This shift has blurred the distinction between the business models of LCCs and legacy airlines.

A more liberalized regulatory environment provides stimulus to the growth of commercial aviation, but may also put pressure on aviation infrastructure, States capabilities for safety oversight and other technical regulations, operating yields of airlines (due to heightened competition) and environmental protection. The profit margin has been very small for commercial airlines. Despite some consistently profitable exceptions, most airlines have performed very poorly for investors. Average operating margins between 1999 and 2009 ranged from 3.8% to 4%; showing insufficient levels to cover overheads, generate a profit, or attract new capital. Intense price competition under liberalized regimes, including those from LCCs, coupled with increasing and widespread use by consumers of low fares rendered by internet search engines, have contributed to the reduced earnings.

On the cost side, the inherent volatility of fuel prices will continue to cause short term changes in operating costs. In early 2008 crude oil price was on average US$ 80 per barrel, before reaching in July 2008 US$ 134 and ending the year at around US$ 40. In 2008, fuel accounted for 30% of total airline operating expenses. The fuel price hedging practice was highly profitable for some carriers, enabling them to offset severe losses in their core business, while leading to large losses for other airlines.

	1979	1989	1999	2009[2]
Passenger load factor (%)	66	68	69	76
Aircraft utilization (hours per aircraft per year)	2,068	2,193	2,770	3,502
Average aircraft capacity (seats)	149	181	171	166

Table 2: *Developments in Selected Elements of Airline Productivity (1979-2009) 2009 ICAO Provisional Data,* Source – ICAO Statistics Programs

Liberalization and the severe 2009 economic downturn have encouraged airlines to optimize the use of their assets, as shown in Table 2. Higher load factors, resulting from better capacity supply management, helped airlines to maintain revenues while average ticket prices have fallen. The higher aircraft utilization resulted from greater aircraft reliability and versatility, and the decline in average aircraft capacity after 1989 could notably be attributed to the introduction of regional jets and the extended ranges of traditionally short haul aircraft.

Despite the current industry's profitability issues, ICAO's traffic forecasts are assuming that growing demand for air travel will ensure that the airline industry has continued access to capital markets, in order to enable the renewal of the different assets needed to operate an airline.

Air Traffic Forecasts

The new ICAO forecast methodology uses a sophisticated set of econometric models, combined with industry knowledge at a global and regional level. The forecasts consider both quantitative relationships, such as the impact of economic growth on traffic, and insights about the factors driving growth in each geographical market. The latter, due to their qualitative nature, could not be factored into the models. The world has been divided into 9 forecasting regions defining 53 route groups (36 international markets, 8 intra-region market and 9 domestic markets), with an additional non-scheduled segment. ICAO produces forecasts of revenue passenger-kilometres through to 2030 extended to the 2040 horizon which could be required for some environmental analysis.

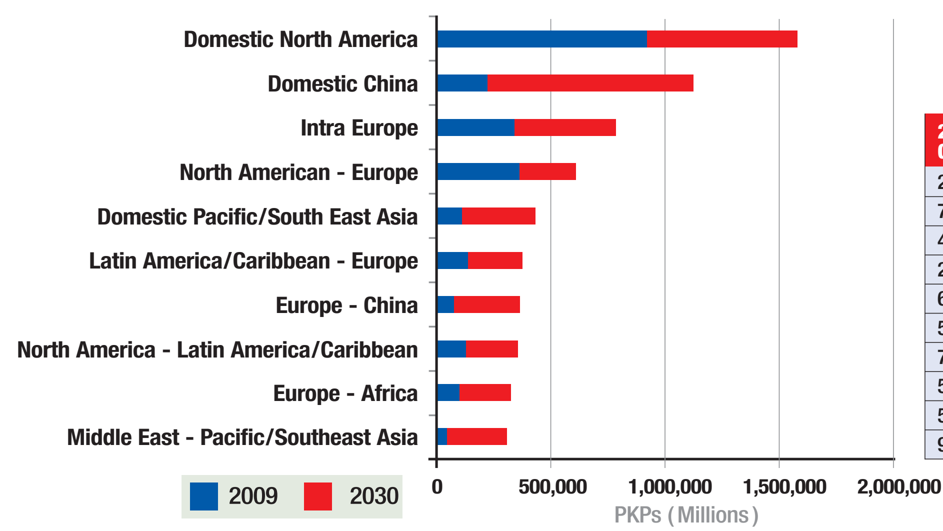
The future growth of air traffic will depend on the economic growth and on the technological advances that allow decreasing the cost of air travel. Besides, market liberalization has greatly stimulated air traffic growth in the past and will continue to do so. It has been observed that during the first steps of the liberalization process, the growth rates are the fastest and they stabilize to a standard level, after the market has absorbed the changes.

According to economic forecasters, annual economic growth between 2010 and 2030, expressed in terms of percent change in Gross Domestic Product (GDP), will range from 2% in North Asia to 6.9% in China. The developed economies of North America, Japan and Western Europe will experience slow growth because of the economic maturity of their aging labour forces. The developing areas of Asia, Latin America, Eastern Europe and Africa will see strong and sustained growth. As a result, at the world level, GDP, expressed in real terms and calculated on the basis of Purchasing Power Parity (PPP), is expected to grow on average at 4% per year.

Accordingly, the forecasts of the current top ten markets are featured in Figure 1.

Domestic services in North America will grow at the lowest rate of any of the top ten routes. However, their large magnitude – the product of a large and prosperous economy and the longest post-liberalization period (which has allowed the effects of liberalization to be felt), will preserve their leadership through to 2030. Domestic services in China will benefit from the very high growth rates that will result from economic development. The large scale of Western European traffic and the growth of Eastern Europe will together make the Intra-European market, the third largest in 2030.

Based on these route groups forecasts, ICAO is deriving both regional passenger forecasts for its statistical regions (as shown in Figure 2) and aircraft movement forecasts.



20-Year Growth %	% World PKPs
2.6%	15.0%
7.9%	10.7%
4.3%	7.4%
2.6%	5.7%
6.7%	4.1%
5.3%	3.6%
7.8%	3.5%
5.0%	3.3%
5.9	3.1%
9.0	2.9%

Figure 1: *Top 10 Traffic flows in 2030.*

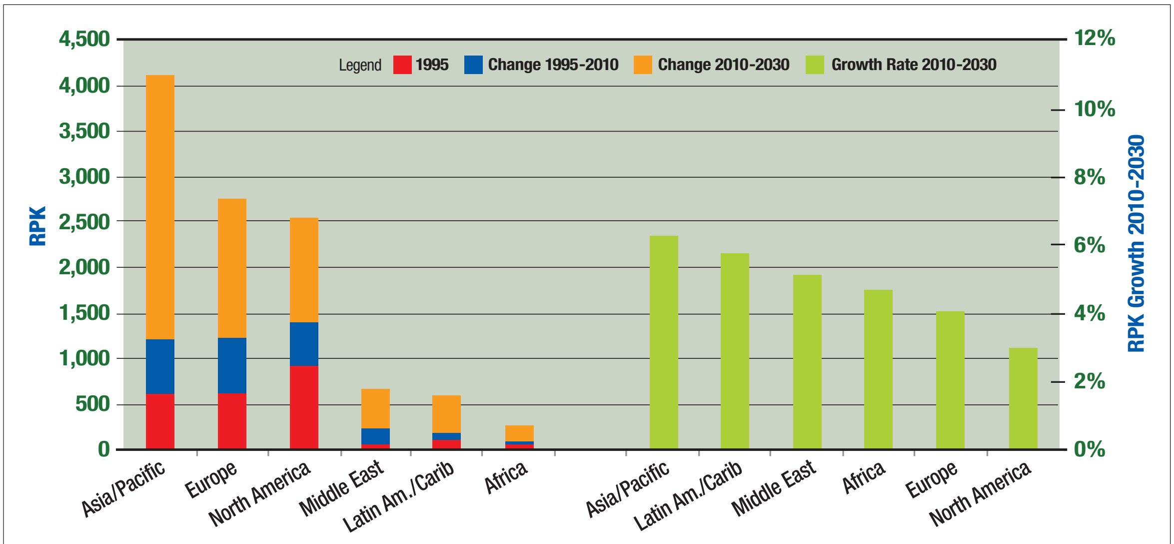


Figure 2: *ICAO Passenger Traffic Forecasts by ICAO Statistical Region.*

Air traffic will grow at rates set by, but larger than, the GDP growth in all world regions. The growth that will be registered by Asia/Pacific airlines will reflect the expansion of civil aviation in China, India and Southeast Asia. The airlines domiciled in Middle East, Latin America and Africa will experience very strong growth, although their small absolute sizes in 2010 will limit the resulting traffic increases.

The detailed regional analyses, forecasting methodologies and results for ICAO traffic forecasts are available in a forthcoming publication which will be available in November 2010. ■

Noise Outlook

By ***ICAO Secretariat***

Since the introduction of modern jet aircraft in the 1960s, aircraft noise has remained the most significant cause of adverse community reaction related to the operation and expansion of airports worldwide. Limiting or reducing the number of people affected by significant aircraft noise remains a key environmental goal for ICAO. The ICAO Environmental Report of 2007 provided detailed background information on the issue of aircraft noise and the Standards and Recommended Practices (SARPs) put in place by ICAO to mitigate these noise impacts. More information is also available in the report of the eighth meeting of ICAO's Committee on Aviation Environmental Protection (ICAO Doc. 9938) which contains a status update of CAEP's work on this issue. This article provides a high-level overview as well as an update on some of the issues related to aircraft noise first described in the 2007 Environmental Report.

Background

Because of improved aircraft noise SARPs developed by ICAO, the number of people exposed to significant aircraft noise has decreased by as much as 90% in parts of the world over the last half century. Tremendous technological advancements have made aircraft more than 75% quieter than they were 50 years ago. Figure 1 illustrates this point by plotting the cumulative aircraft noise relative to the Chapter 4 Noise Standard (see inset box on certification points and Chapter 4 requirements) in effective perceived noise level expressed in decibels (EPNdB[1]) by year. The aircraft are grouped by engine bypass ratio (BPR[2]), a key driver of overall aircraft noise.

On the other hand, the projected growth in air traffic means that the number of people exposed to significant aircraft noise is expected to increase in the future rather than decrease. In addition, because of the increased awareness of environmental issues, the public has become more sensitized to aviation noise. For these reasons, aircraft noise is expected to remain an environmental concern for the foreseeable future.

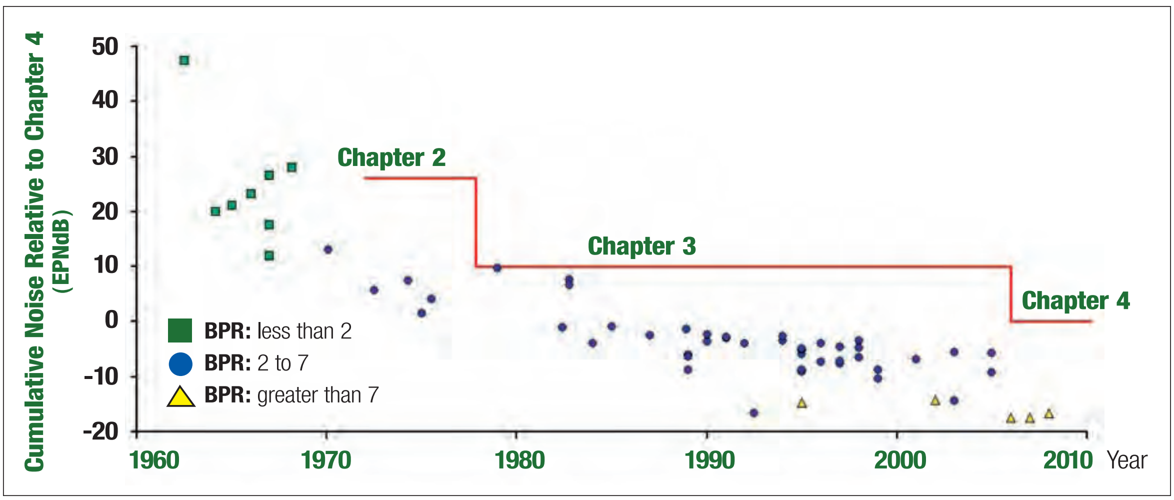


Figure 1: *Progress made in noise reduction at source since implementation of aircraft noise Standards - by engine bypass ratio (ICCAIA 2008).*

Quantifying Aircraft Noise

The level of noise that emanates from aircraft operations in and around an airport depends upon a number of factors including: types of aircraft using the airport, overall number of daily take-offs and landings, general operating conditions, time of day that the aircraft operations occur, runways that are used, weather conditions, topography, and airport-specific flight procedures. The noise effect caused by aircraft operations is somewhat subjective and can depend on a number of factors related to the individual listener's cultural and socio-economic background as well as their psychological and physical situation. Reactions may vary from no effect, to severe annoyance, to potential health concerns.

The number of people exposed to aircraft noise is the metric normally used to estimate aircraft noise impact. In other words, the population within certain noise contours (e.g. 55dB DNL) is defined as being exposed to "significant levels" of aircraft noise. The Day-Night Average Sound Level (DNL), expressed in decibels (dB), is a 24-hour average noise level, with a 10dB penalty applied to night time noise, which is used to define the level of noise exposure on a community. Figure 2 shows an example of noise contours for an airport.

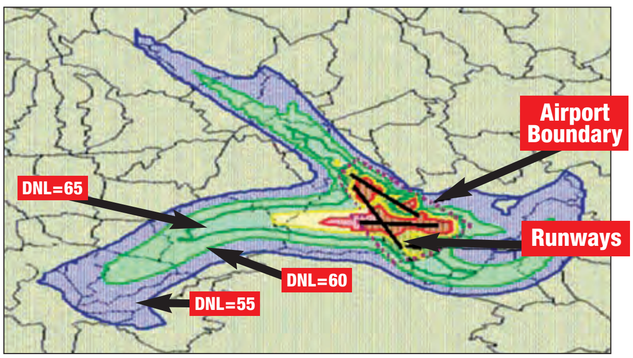


Figure 2: *Noise contours around an airport.*

Global Aircraft Noise Trends

ICAO's Committee on Aviation Environmental Protection recently completed a comprehensive global projection of future exposure to aircraft noise using several computer models developed by States or regions. To ensure the success of this assessment, an essential prerequisite was the evaluation of candidate models and databases. The complete list of models evaluated is provided in Chapter 1 of this report. Using the approved models, scenarios that included possible technology and operational improvements for the future years 2016, 2026 and 2036 were evaluated compared to a baseline year of 2006.

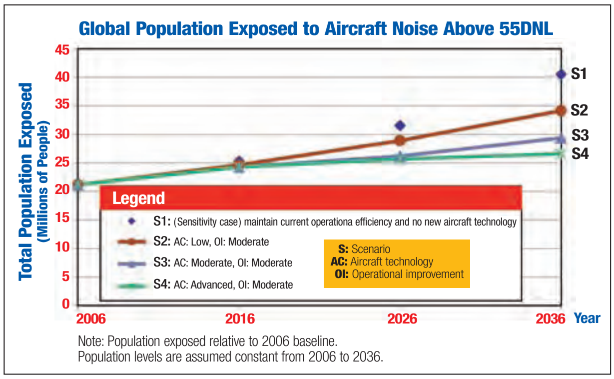


Figure 3: *Total global population exposed to aircraft noise above 55 DNL.*

Figure 3 shows that within the 55DNL significant level noise contour, the 2006 baseline value is approximately 21.2 million people worldwide exposed to that level of aircraft noise. In 2036, total population exposed to that level ranges from about 26.6 million people to about 34.1million people, depending on the scenario.

The results shown for Scenario 1 (i.e. operational improvements necessary to maintain 2006 operational efficiency levels but not including any technology improvements beyond those available in 2006) are not considered realistic, and are therefore shown without a line connecting the data for each of the computed years. Scenarios 2 and higher are assumed to be the most likely outcomes; they include the planned operational initiatives (e.g. NextGen and SESAR) and additional fleet-wide moderate operational improvements of 2% for population within the noise contours evaluated.

As is expected, as the scenario becomes more optimistic in terms of improvements, the trend line is lower in terms of population affected. Due to a lack of data on future population levels in the vicinity of airports, the population was assumed to be constant throughout the 30-year assessment period.

As noted previously, the CAEP central forecast predicted an annual growth in passenger traffic of 4.8 % per year through 2036. Environmental Standards set by ICAO and the investments in technology and improved operational procedures are allowing aviation noise to grow at a rate far slower than the demand for air travel. The population exposed to aircraft noise is expected to grow at an average annual growth rate of 0.7% to 1.6% under the central forecast, and for the low demand forecast case it is possible that, following a peak in 2026, the global population exposed to significant aircraft noise may actually decline.

ICAO Work on Aircraft Noise Reduction

ICAO has been addressing the issue of aircraft noise since the 1960s.[3] The first Standards and Recommended Practices (SARPs) for aircraft noise certification were published in 1971 and have been updated since then to reflect improvements in technology. They are contained in Volume I of Annex 16 to the Convention on International Civil Aviation. Aircraft noise certification involves measuring the noise level of an aircraft in EPNdB at three points: two during take-off (flyover and sideline), and the third during the approach (see inset box on certification points and Figure 4).

Noise Certification Reference Points - Defined

For noise certification, aircraft noise levels are measured at three certification points:

1- ***Fly-over:*** *6.5 km from the brake release point, under the take-off flight path.*

2- ***Sideline:*** *the highest noise measurement recorded at any point 450 m from the runway axis during take-off.*

3- ***Approach:*** *2 km from the runway threshold, under the approach flight path.*
Cumulative levels are defined as the arithmetic sum of the certification levels at each of the three levels.

The initial standards for jet-powered aircraft designed before 1977 were included in Chapter 2 of Annex 16. Subsequently, newer aircraft were required to meet the stricter standards contained in Chapter 3 of the Annex. Starting 1 January 2006, the new Chapter 4 standard became applicable to newly certificated aeroplanes.

In September 2001, ICAO established a global policy to address aircraft noise, referred to as the "balanced approach" to noise management (ICAO Doc 9829, *Guidance on the Balanced Approach to Aircraft Noise Management*). This policy has provided ICAO Contracting States with an internationally agreed approach for addressing aircraft noise problems in a comprehensive and economically responsible way. It is ultimately the responsibility of individual States to implement the various elements of the balanced approach by developing appropriate solutions to the noise problems at airports. This must be done with due regard to ICAO provisions and policies, while recognizing that States may have existing constraints such as: relevant legal obligations, existing agreements, current laws and established policies on noise management. Any of these may influence the way in which States implement the Balanced Approach.

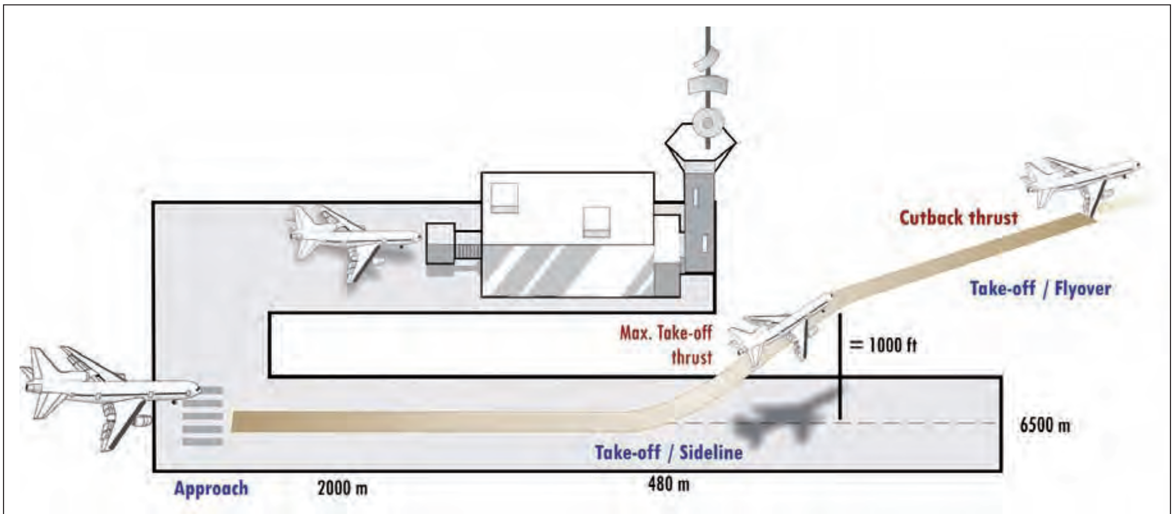


Figure 4: *Aircraft noise certification reference points.*

ICAO/CAEP - Balanced Approach to Aircraft Noise Management

ICAO's Balanced Approach consists of identifying the noise problem at an airport and then analyzing the various measures available to reduce the noise, using four principal elements, namely:

*1- **reduction of noise at source;***

*2- **land-use planning and management;***

*3- **noise abatement operational procedures;** and*

*4- **operating restrictions.***

The goal is to address the local noise problems on an individual airport basis and to identify the noise-related measures that achieve maximum environmental benefit most cost-effectively using objective and measurable criteria.

An emerging issue over the last few years has been the impact of night-time curfews related to noise at some airports on airports in other regions of the world. ICAO undertook a study to estimate the environmental impact of curfews in one region on other regions of the world. Based on case-studies, it was concluded that, while the curfews may be a contributing factor to the transfer of night-time aircraft movements from one airport to other airports, there are probably a number of other influencing factors such as time zones, airline economics and passenger demand.

Aircraft Noise Reduction Technology

Reduction of aircraft noise at source is one of four principal elements of ICAO's Balanced Approach to noise management and it remains a cornerstone of the Organization's efforts to reduce the adverse effects of aircraft noise on the public.

Over the last three years, CAEP carried out a study to review and analyze certification levels of subsonic jets and heavy propeller driven aeroplanes to understand the current state-of-the-art of aeroplane noise technology. A database of today's best practice aircraft was analyzed according to five classes each representing different market segments for airlines and manufacturers: business jets, regional jets, short-medium range jets with 2 engines, long range jets with 2 engines, and long range jets with 4 engines. A summary of these results is presented in Figure 5.

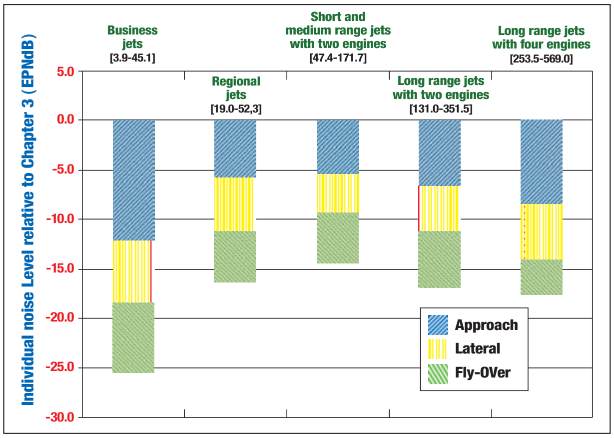


***Figure 5:** Average noise margins relative to Chapter 3 limits by class of aeroplane.*

It should be noted that the wider margins that are shown for larger aeroplanes are not because of their size, but because a number of aeroplanes in this category incorporate the most recent noise reduction design concepts and technologies since the market has required the development of new models. Only incremental changes for short and medium range aeroplanes have occurred in recent years because no brand new aeroplane programme has been launched yet in this category that would enable the incorporation of the new technologies that have already been implemented in the larger aeroplanes.

As demonstrated by this comprehensive study, the aircraft industry has achieved significant noise reduction through advances in technology. One important factor that will ensure continued success is sustained research and technology funding from industry and governments. In order to complement the efforts of industry and governments and to establish targets, ICAO has introduced a process to establish medium term (10 years) and long term (20 years) goals for environmental improvements from technology and operations. These goals are based on technologies that are currently at a technology readiness level (TRL) of less than 8, but are expected to reach TRL8 at a specified time. TRL is a measure, ranging from 1 to 9, which is used to assess the maturity of evolving technologies (e.g. materials, components, devices, etc.) prior to incorporating that technology into a system.

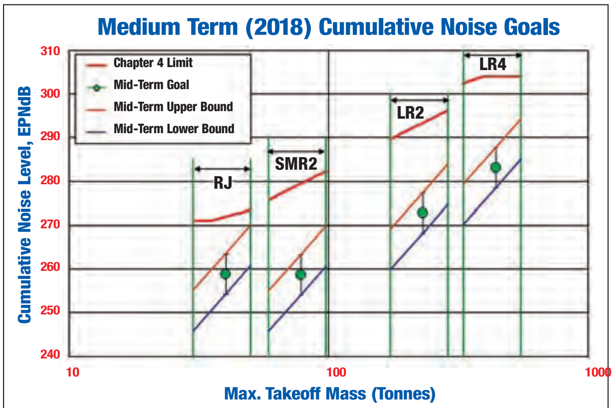
An Independent Expert (IE) Panel formed in 2008 spent a considerable amount of time analyzing various data sources and information provided by various stakeholders to recommend a set of goals for four categories of aircraft. The IE Panel identified two contributors to aircraft system source noise reduction: cycle improvements related to BPR increase and component noise reduction technologies. A modelling exercise was then undertaken to consolidate the results and to ascertain the uncertainty associated with the noise level goals. The goals are given in terms of cumulative margins relative to the ICAO Annex 16, Chapter 4 limits. These Goals are summarized in Table 1.

Independent Expert Panel aircraft noise reduction technology goals

Aircraft Category	Margin to Chapter 4 (EPNdB)	
	Medium Term (2018)	Long Term (2028)
Regional Jet	13.0±4.6	20.0±5.5
Small-Medium-Range Twin	21.0±4.6	23.5±5.5
Long-Range Twin	20.5±4.6	23.0±5.5
Long-Range Quad	21.0±4.6	23.5±5.5

Table 1: *Independent Expert Panel aircraft noise reduction technology goals.*

These goals are shown in graphical format in Figure 6.



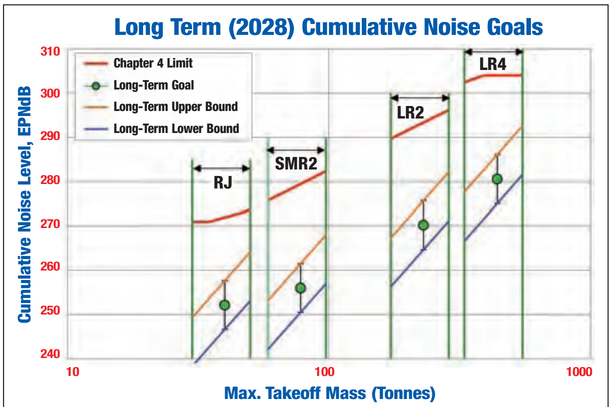


Figure 6: *Medium and long term technology goals for noise reduction technology.*

The reduction of noise at source through technology improvements has always been one of the cornerstones of ICAO's noise mitigation efforts. ICAO will continue to closely monitor the latest developments in technology which might lead to quieter aircraft and will translate this new technology into even more effective noise standards.

Next Steps

The eighth meeting of ICAO's Committee on Aviation Environmental Protection (CAEP) in February 2010, identified the need for further analyses to assess several stringency scenarios in order to potentially improve the aircraft noise Standards. The assessment results will be reviewed by CAEP/9 in 2013.

ICAO's goal of sustainable growth is directly related to noise where a major constraint on growth at the airport level is believed to be noise in the vicinity of airports. Other emerging issues in this regard include the increasing noise farther away from airports and introduction of new air traffic procedures leading to concentration of noise in certain corridors. These additional issues need to be explored and solutions provided to ICAO member States in the form of SARPs. ■

REFERENCES

1 ***EPNdB is a measure of human annoyance to aircraft noise which has special spectral characteristics and persistence of sounds. It accounts for human response to spectral shape, intensity, tonal content and duration of noise from an aircraft.***

2 ***Bypass ratio refers to how much air goes through a jet engine's propulsor versus how much air goes through its core.***

3 ***For more information on ICAO work on aircraft noise,***
please see ICAO Environmental Report 2007, Chapter 2 – Aircraft Noise,
www.icao.int/env/pubs/env_report_07.pdf.

Local Air Quality Outlook

By ***ICAO Secretariat***

The ICAO Environmental Report for 2007 provided detailed background information on the issue of aircraft emissions and the Standards and Recommended Practices (SARPs) put in place by ICAO to mitigate local air quality concerns. More information is also available in the report of the eighth meeting of ICAO's Committee on Aviation Environmental Protection (CAEP/8, ICAO Doc 9938) which contains a status update of the CAEP's work on this issue. This article provides a brief summary as well as an update on some of the issues related to aircraft emissions that affect local air quality that were first described in Chapter 3 of the 2007 ICAO Environmental Report[1].

Overview

The potential adverse effects of air pollutants released within an aircraft's landing and takeoff cycle (LTO, nominally up to 3,000 feet or 915 meters above ground level) primarily pertain to human health and welfare. The current ICAO Standards for emissions certification of aircraft engines contained in Volume II of Annex 16 to the Convention on International Civil Aviation were originally designed to respond to concerns regarding air quality in the vicinity of airports. To achieve certification, any engine must demonstrate that its characteristic emissions of HC (unburned hydrocarbons), CO (carbon monoxide), NO_x (oxides of nitrogen) and smoke, are below the limits defined by ICAO. The contribution of aircraft emissions during the LTO cycle to the overall emissions in a typical urban area is small and the Standards set by ICAO are designed to ensure that they remain that way. The certification process is performed on a test bed, where the engine is run at four different thrust settings (see Figure 1), to simulate the

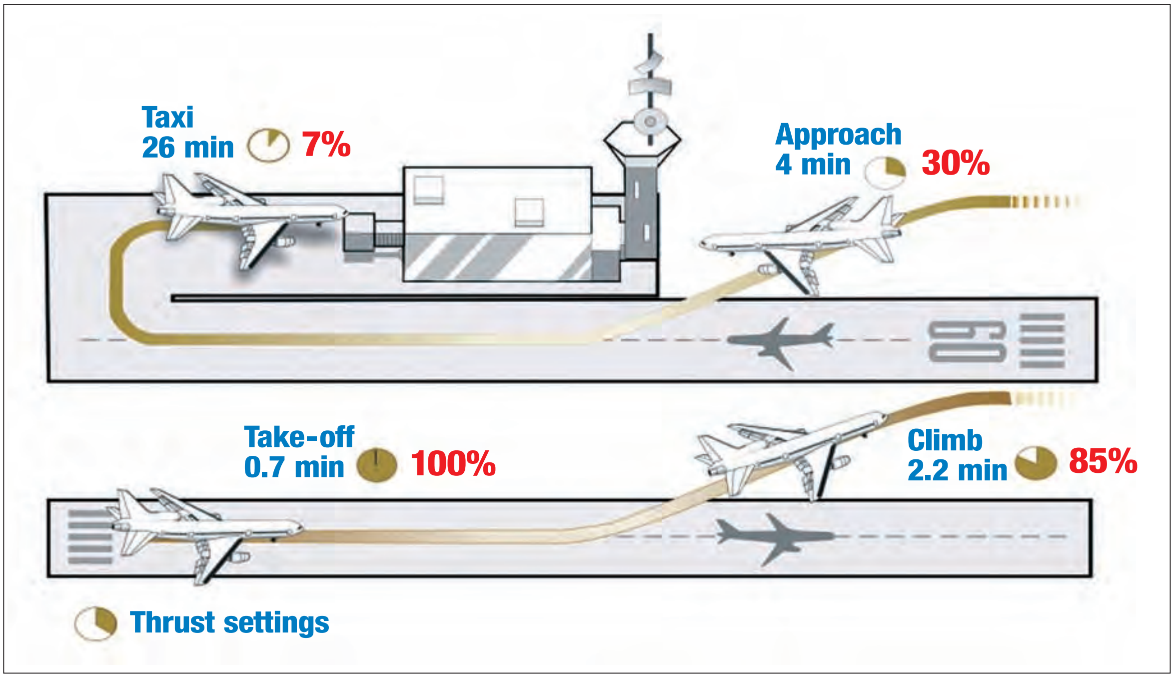


Figure 1: *Illustration of ICAO emissions certification procedure in the LTO cycle.*

various phases of flight, as follows:

- **Takeoff** (100% available thrust) for 0.7 min;
- **Climb** (85% available thrust) for 2.2 min;
- **Approach** (30% available thrust) for 4.0 min; and
- **Taxi** (7% available thrust) for 26 min.

Dramatic progress in reducing the emissions from aircraft engines has been made since the first Standards were set. Unburned hydrocarbons have been virtually eliminated from the exhaust stream due to improved engine technologies and visible smoke is also almost completely gone. However, ICAO's focus is now shifting to improved understanding of the formation of aircraft particulate matter (PM), which is sometimes referred to by the more general term, soot. Potential effects on human health due to various species of emissions are described in Table 1.

Since the original NO_x Standard was adopted in 1981, it has been made 50% more stringent. CAEP/8 in February 2010 reviewed the analyses of various scenarios of increased NO_x stringency options, and agreed on a new NO_x Standard (CAEP/8 NO_x Standard). It improves on the current CAEP/6 NO_x Standard by between -5% and -15% for small engines, and by -15% for large engines; and will be in effect on 31 December 2013. In addition, engines not meeting the current CAEP/6 Standard will no longer be produced as of 31 December 2012.

CAEP has also set mid and long-term technology goals for aircraft engine NO_x emissions through a panel of independent experts (see *Setting Technology Goals*, Chapter 3 of the 2007 Environmental Report). Although NO_x Standards were initially intended to address local air quality, they also contribute to reducing the impact of aviation on climate.

Impact of Aircraft Emissions On Local Air Quality – Trends

In 2010, CAEP completed a comprehensive global projection of future emissions trends that affect local air quality. For this analysis, the aircraft engine emissions were projected for NO_x and PM from aircraft operating at up to 3,000 feet (915 metres) above ground level. As with the noise analysis (see *Noise Outlook*, Aviation Outlook of this report), aircraft emissions were modelled for a baseline year of 2006 and then for the future years 2016, 2026, and 2036, across a range of scenarios that considered different technological and operational options, as per Table 2. For context, aircraft NO_x emissions contribute between 70% and 80% of total airport NOx emissions.

Aircraft NOx emissions emitted at less than 3,000 feet above ground level for those scenarios is projected to increase from 0.25 million metric tonnes (Mt) in 2006 to between 0.52 Mt and 0.72 Mt in 2036 (see Figure 2). These results are presented for the central demand forecast case. The analysis shows that the results are particularly sensitive to the level of projected air traffic demand. This corresponds to growth in NO_x emissions of between 2.4% and 3.5% per year, which is less than the projected growth rate in traffic of 4.8% annually (see *Air Traffic Outlook*, Aviation Outlook of this report).

Pollutant	Health Effect
CO – Carbon Monoxide	• Cardiovascular effects, especially in those persons with heart conditions
HC – Unburned Hydrocarbons (a primary component of Volatile Organic Compounds, or VOC)	• Eye and respiratory tract infection • Headaches • Dizziness • Visual disorders • Memory impairment
NO_x – Nitrogen Oxides	• Lung irritation • Lower resistance to respiratory infections
O_3 – Ozone (HC is a precursor for ground-level O_3 formation)	• Lung function impairment • Effects on exercise performance • Increased airway responsiveness • Increased susceptibility to respiratory infection • Increased hospital admissions and emergency room visits • Pulmonary inflammation, lung structure damage
PM – Particulate Matter (smoke is a primary component of PM.)	• Premature mortality • Aggravation of respiratory and cardiovascular disease • Changes in lung function • Increased respiratory symptoms • Changes to lung tissues and structure • Altered respiratory defence mechanisms

Table 1: *Representative health effects from local air quality pollutants.*[2]

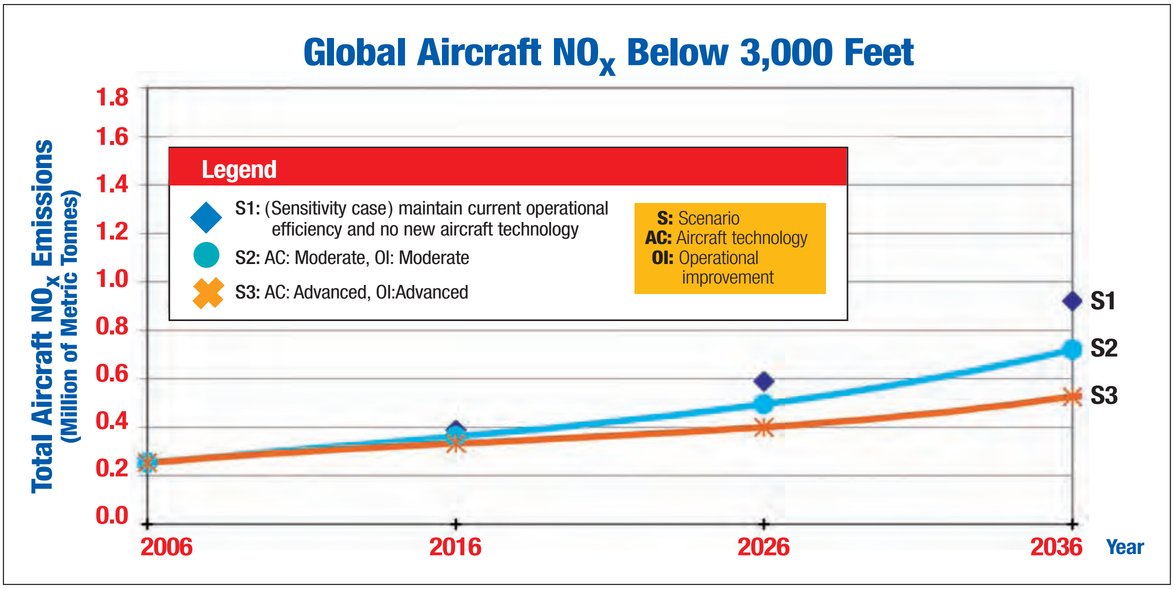


Figure 2: *Total global aircraft NO_x below 3,000 feet (915 Metres) AGL.*

Scenario 1 *is the sensitivity case that assumes the operational improvements necessary to maintain current operational efficiency levels, including the planned introduction of NextGen and SESAR, but does not include any aircraft technology improvements beyond those available in current (2006) production aircraft. Since Scenario 1 is not considered a likely outcome, it is purposely depicted with no line connecting the modelled results in 2006, 2016, 2026 and 2036.*

Scenario 2 *is the moderate aircraft technology and operational improvement case that assumes aircraft NO_x improvements based upon achieving 50% of the reduction from the current NO_x emission levels to the NO_x emissions levels set by CAEP/7 NO_x Independent Expert goals review (60% +/-5% of current CAEP/6 NO_x Standard) for 2026, with no further improvement thereafter. This scenario also includes fleet-wide moderate operational improvements by region.*

Scenario 3 *is the advanced aircraft technology and operational improvement case that assumes aircraft NO_x improvements based upon achieving 100% of the reduction from the current NO_x emission levels to the NO_x emissions levels set by CAEP/7 NO_x Independent Expert goals review for 2026, with no further improvement thereafter. This scenario also includes fleet-wide advanced operational improvements by region that are considered to be an upper bound of those improvements.*

Table 2: *Scenarios used for the NO_x analysis.*

In recent years, there has been considerable research into the formation of particulate matter (PM) and its effect on human health. ICAO sets standards for smoke from aircraft engines, but has not yet set specific requirements for PM. Since PM emissions are not currently measured directly as part of the ICAO engine certification process, they were estimated for the CAEP trends assessment using a technique called First Order Approximation. The results for PM emissions at less than 3,000 feet follow the same trends as those for NO_x, although at significantly lower levels. The 2006 baseline value is 2,200 metric tonnes and the total global aircraft PM is projected to increase at a rate of 3.3% per year to a total of about 5,800 metric tonnes in 2036.

Aircraft Airport Emissions Put Into Context

The contribution of airport emissions to the overall emissions loading in the vicinity of airports is dependent upon the emission sources surrounding the airport. For a typical urban environment, airport emissions represent approximately 10% of total regional emissions in the vicinity of airports, whereas in more rural environments airport emissions would tend to be a higher percentage. In this case, the term "region" refers to the local communities surrounding the airport (i.e. within 50 km).

Mass emissions, measured in units such as total tonnes of NO_x or total tonnes of PM, from airport sources are only a metric for comparison purposes. To understand the influence on ambient air quality, airport mass emissions must be converted to ambient concentrations, measured in units such as micrograms per cubic meter ($\mu g/m^3$) or parts per million (PPM). The incremental contribution in ambient pollutant concentrations from airport emissions decreases the further one travels away from the airport. Each airport's contribution is unique, subject to the surrounding urbanization/industrialization and meteorological conditions within the vicinity of the airport. ICAO's Airport Air Quality Guidance Manual (ICAO Doc 9889), provides detailed information on this subject.

Conclusions and Next Steps

Standards set by ICAO, coupled with investments in technology and improved operational procedures have resulted in the near elimination of some pollutants from aircraft engine exhaust and are allowing aviation's local air quality emissions footprint to grow at a rate slower than the demand for air travel. The emissions Standards and measurement methods incorporated in the original and still applicable certification scheme in Annex 16, Volume II, have stood the test of time quite well and remain relevant to its purpose.

Looking forward, some changes may be necessary to account for new findings. In particular, CAEP is focused on better understanding the formation of non-volatile PM and has targeted the development of a certification requirement by CAEP/9, and a certification Standard by CAEP/10. ■

REFERENCES

1 ***More information about aviation's effects on local air quality is available***
in Chapter 3 of the 2007 ICAO Environmental Report.

2 *Adapted from United States EPA,*
Evaluation of Air Pollutant Emissions from Subsonic Commercial Jet Aircraft.

Climate Change Outlook

*By **ICAO Secretariat***

Around the world, people, nations, and industries have become increasingly concerned with their contribution to global climate change. Aircraft are powered by the combustion of jet fuel and aviation gasoline, the result of which are emissions that are comprised of approximately 70% carbon dioxide (CO_2), slightly less than 30% water vapour, and less than 1% of a number of other emissions. CO_2 and water vapour are greenhouse gases (GHG). The effects of these emissions last for vastly different lengths of time with CO_2 being a very long lived gas in the atmosphere, and water vapour having a relatively short term effect. This brief outlook provides you an initial introduction to the discussion on aviation and climate change, to which this 2010 environmental report is entirely dedicated.

- Total aviation CO_2 emissions (domestic and international) are approximately 2% of the world's anthropogenic (human-made) CO_2 emissions (Figure 1);
- International flights are responsible for approximately 62% of these emissions;
- The amount of CO_2 emissions from aviation is projected to grow around 3% to 4% per year; and
- Medium-term mitigation for CO_2 emissions from the aviation sector can potentially come from improved fuel efficiency. However, such improvements are expected to only partially offset the growth of aviation CO_2 emissions.

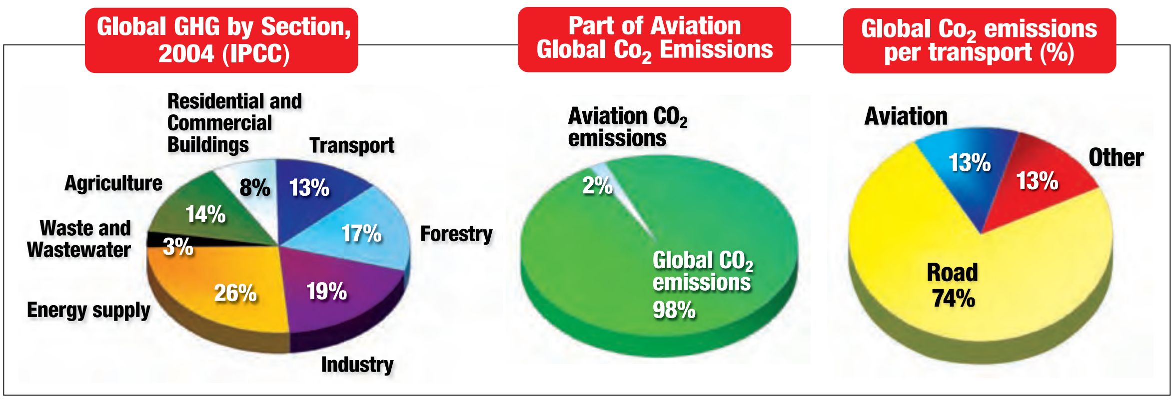


***Figure 1**: Aviation's contribution to global CO_2 emissions.*
Source: IPCC, 4th Assessment Report, 2007, WGIII, Technical Summary and IPCC Special Report on Aviation and the Global Atmosphere (1999).

Scientific Understanding

ICAO's cooperation with other United Nations bodies, in particular the Intergovernmental Panel on Climate Change (IPCC), is essential in obtaining a better scientific understanding of aviation's impact on the global climate. Main finding related to aviation emissions in IPCC Fourth Assessment Report (AR4) published in 2007 are shown in the inset box as follows.

The IPCC has initiated the preparation of its Fifth Assessment Report (AR5), which is scheduled to be completed in 2014. ICAO is participating in the IPCC process to ensure that issues related to aviation and climate change are covered in the AR5. ICAO requested that the AR5 further explore the effects of non-CO_2 aviation emissions, update the trends of aviation CO_2 emissions, include the latest ICAO work on mitigation measures, and address the life-cycle analysis of the environmental benefits on the use of alternative fuels for aviation taking into account cross-sectoral issues.

Fuel Burn / Fuel Efficiency Trends

CAEP has conducted a detailed assessment of environmental trends. Based on the unconstrained CAEP central forecast and without accounting for the lifecycle emissions reduction potential of sustainable alternative fuels (see Chapter 5 of this report), CO_2 emissions from aircraft will continue to increase even under the assumption of optimistic technological and operational advances. However, technological and operational advances will allow aviation system efficiency to continue to improve.

Figure 2 provides results for global full-flight fuel burn for 2006, 2016, 2026, 2036 and 2050. These results are for both domestic and international traffic combined. As shown in Figure 3, the 2006 baseline value is 187 Mt of fuel, with domestic traffic representing approximately 38% of this total and international traffic representing 62%.

The baseline value of 187 Mt in 2006 only includes fuel burn from the main aircraft engines of Instrument Flight Rules (IFR). It does not include fuel burn from auxiliary power units, from

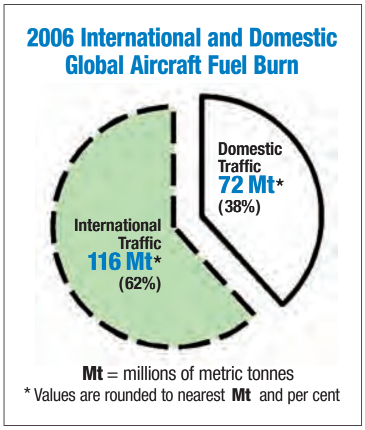


Figure 3: *International aviation represented approximately 62% of global aviation fuel consumption in 2006.*

aviation-related operations (e.g., ground support equipment) or from visual flight rules (VFR) flights. Non-scheduled flights in regions for which radar data are not available were also not accounted for. Fuel burn from aviation-related operations, VFR flights, and non-scheduled flights may together amount to approximately 10% to 12% additional fuel burn.

The global fuel consumption is expected to grow from a baseline of 187 Mt in 2006 to between 461Mt and 541 Mt in 2036. Without considering the effects of alternative fuels,

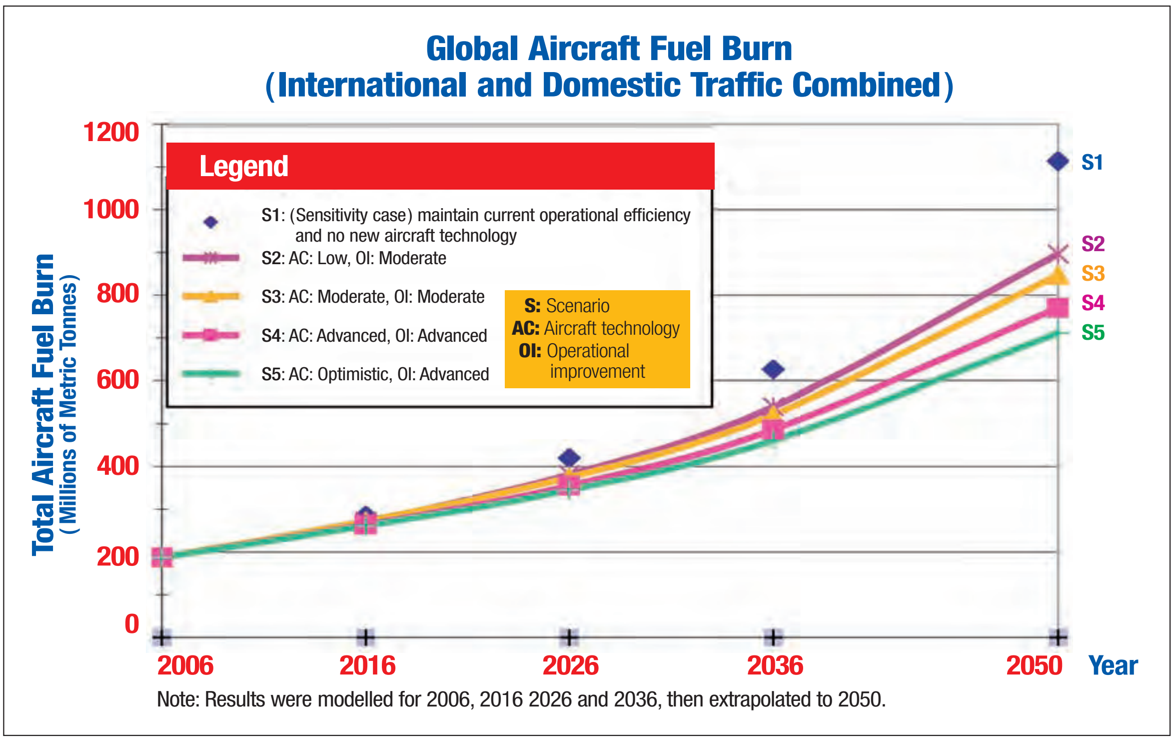


Figure 2: *Total Global Aircraft Fuel Burn 2006 to 2050.*

Fuel Burn / Fuel Efficiency Scenarios

- ***Scenario 1*** *is the sensitivity case that assumes the operational improvements necessary to maintain current operational efficiency levels, including the planned introduction of NextGen and SESAR, but does not include any aircraft technology improvements beyond those available in current (2006) production aircraft. Since Scenario 1 is not considered a likely outcome, it is purposely depicted with no line connecting the modelled results in 2006, 2016, 2026, 2036 and 2050.*

- ***Scenario 2*** *is the low aircraft technology and moderate operational improvement case that, in addition to including the improvements associated with the migration to the latest operational initiatives, e.g. those planned in NextGen and SESAR (Scenario 1), includes fuel burn improvements of 0.96% per annum for all aircraft entering the fleet after 2006 and prior to 2015, and 0.57 percent per annum for all aircraft entering the fleet beginning in 2015 out to 2036. It also includes additional fleet-wide moderate operational improvements by region.*

- ***Scenario 3*** *is the moderate aircraft technology and operational improvement case that, in addition to including the improvements associated with the migration to the latest operational initiatives, e.g. those planned in NextGen and SESAR (Scenario 1), includes fuel burn improvements of 0.96% per annum for all aircraft entering the fleet after 2006 out to 2036, and additional fleet-wide moderate operational improvements by region.*

- ***Scenario 4*** *is the advanced aircraft technology and operational improvement case that, in addition to including the improvements associated with the migration to the latest operational initiatives, e.g. those planned in NextGen and SESAR (Scenario 1), includes fuel burn improvements of 1.16% per annum for all aircraft entering the fleet after 2006 out to 2036, and additional fleet-wide advanced operational improvements by region.*

- ***Scenario 5*** *is the optimistic aircraft technology and advanced operational improvement case that, in addition to including the improvements associated with the migration to the latest operational initiatives, e.g. those planned in NextGen and SESAR (Scenario 1), includes an optimistic fuel burn improvement of 1.5% per annum for all aircraft entering the fleet after 2006 out to 2036, and additional fleet-wide advanced operational improvements by region. This scenario goes beyond industry-based recommendations for potential improvements.*

assuming that 3.16 kg CO_2 is produced for every kg of fuel burnt gives a baseline value of 591 Mt CO_2 in 2006 to between 1,450 and 1,710 Mt CO_2 in 2036. This represents an absolute growth of between 2.5 and 2.9 times over the period or an annual average growth rate of between 3 and 3.5 per cent, which is far less than the assumed growth in air traffic demand. For the 2050 results, a 2.9 per cent to 3.4 per cent annual average growth rate is predicted.

Figure 4 presents the global fuel efficiency trends for the years 2006, 2016, 2026 and 2036, using the CAEP-approved Commercial Aircraft System Fuel Efficiency (CASFE) metric. The 2006 baseline value is 0.32 kg/tonne-km. In 2036, global CASFE ranges from about 0.25 kg/tonne-km (with Scenario 2) to about 0.21 kg/tonne-km (with Scenario 5). Lower CASFE values represent more efficient operations. Also depicted in Figure 4, by a dashed line, is an approximation of the effects of the global goal of 2% annual fuel efficiency improvement agreed by the Group on International Aviation and Climate Change (GIACC) and the High-level Meeting on International Aviation and Climate Change in October 2009.

On a per flight basis, fuel efficiency is expected to improve over the period. However in absolute terms an emissions "gap" could exist relative to 2006 or earlier that would require a form of intervention in order to achieve sustainability.

CO_2 Emissions Reduction Target for Aviation

The ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent an irreversible change in the global climate system. In this regard all activities, independent of their share of the contribution, must pursue the means necessary to address their part of responsibility in the global picture.

Within the share of the global CO_2 emissions attributed to the aviation sector (approximately 2%), a substantial part represents domestic aviation emissions, which follow the same treatment agreed under the UNFCCC and Kyoto Protocol as other emissions of a domestic nature. Approximately 62% of aviation emissions are attributed to international aviation operations. However, as mentioned above, this amount is projected to grow at around 3% to 3.5% per year, and ICAO has been actively developing a comprehensive mitigation strategy to limit or reduce GHG emissions from international aviation.

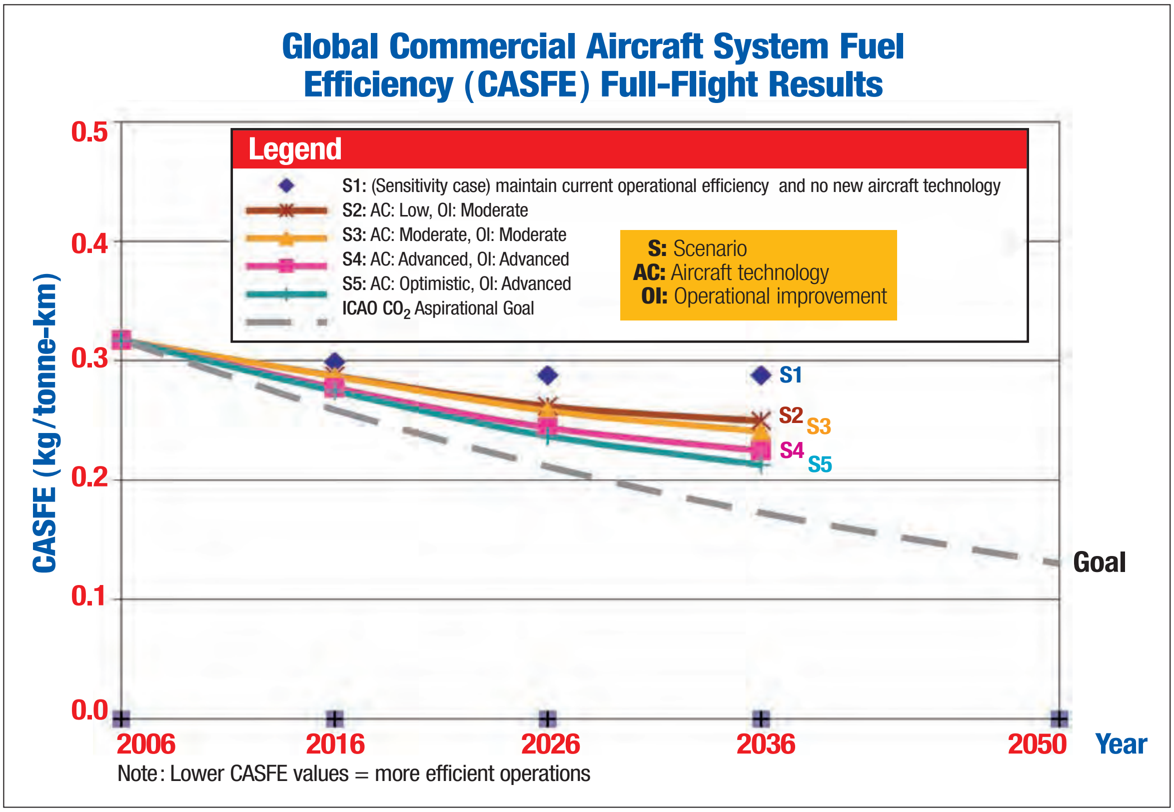


Figure 4: *Commercial Aircraft System Fuel Efficiency (CASFE) Full-Flight Results.*

A milestone in this strategy was achieved by the High-level Meeting on International Aviation and Climate Change in October 2009. The meeting agreed on a set of comprehensive measures known as the ICAO Programme of Action on International Aviation and Climate Change. It includes the agreement on a global goal of 2% annual improvement in fuel efficiency until the year 2050. It is the first and only globally-harmonized agreement from a sector on a goal to address its CO_2 emissions.

At the same time, the High-level Meeting "*noted the scientific view that the increase in global average temperature above pre-industrial levels ought not to exceed 2°C*" (9th preambular clause of the Declaration), and "*recognized that the aspirational goal of 2% annual fuel efficiency improvement is unlikely to deliver the level of reduction necessary to stabilize and then reduce aviation's absolute emissions, and that goals of more ambition will need to be considered to deliver a sustainable path for aviation*". ICAO and its member States consequently declared to undertake further work to explore the feasibility of more ambitious goals, including carbon-neutral growth of the sector and long-term emissions reduction (see inset box from excerpt from the Declaration).

Despite ICAO's success no binding agreement on global emissions reduction targets was reached in COP15. The Copenhagen Accord that was "noted" by the UNFCCC Climate Change Conference in Copenhagen (COP15) in December 2009 recognized that deep cuts in global emissions are required, as documented by the IPCC AR4, with a view to reducing global emissions so as to limit the increase in global temperature below 2°C.

As illustrated in Table 1, according to the IPCC AR4, in order for the global average temperature to not exceed 2°C, global CO_2 emissions must peak between 2000 and 2015, and be reduced in 2050 by between 50 and 85 percent compared to the 2000 level.

Excerpt from High-level Meeting Declaration
(October 2009)

__2.__ In pursuing the implementation of the ICAO Programme of Action on International Aviation and Climate Change, States and relevant organizations will work through ICAO to achieve a global annual average fuel efficiency improvement of 2 per cent over the medium term until 2020 and an aspirational global fuel efficiency improvement rate of 2 per cent per annum in the long term from 2021 to 2050, calculated on the basis of volume of fuel used per revenue tonne kilometre performed;

__3.__ Taking into account the relevant outcomes of the 15th Conference of the Parties to the United Nations Framework Convention on Climate Change, and recognizing that this declaration shall not prejudge the outcome of those negotiations, ICAO and its Member States, with relevant organizations will also keep working together in undertaking further work on medium and long-term goals, including exploring the feasibility of goals of more ambition including carbon-neutral growth and emissions reductions, taking into account the collective commitments announced by ACI, CANSO, IATA and ICCAIA on behalf of the international air transport industry, the special circumstances and respective capabilities of developing countries and the sustainable growth of the international aviation industry, for consideration by the 37th Session of the ICAO Assembly;

Category	Additional radiative forcing (W/m^2)	CO_2 concentration (ppm)	CO_2-eq concentration (ppm)	Global mean temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity (°C)	Peaking year for CO_2 emissions	Change in global CO_2 emissions in 2050 (% of 2000 emissions)
I	2.5-3.0	350-400	445-490	2.0-2.4	2000-2015	-85 to -50
II	3.0-3.5	400-440	490-535	2.4-2.8	2000-2020	-60 to -30
III	3.5-4.0	440-485	535-590	2.8-3.2	2010-2030	-30 to +5
IV	4.0-5.0	485-570	590-710	3.2-4.0	2020-2060	+10 to +60
V	5.0-6.0	570-660	710-855	4.0-4.9	2050-2080	+25 to +85
VI	6.0-7.5	660-790	855-1130	4.6-6.1	2060-2090	+90 to +140

Table 1: *Classification of IPCC AR4 stabilization scenarios according to different stabilization targets and alternative stabilization metrics.*
Source: IPCC, 4th Assessment Report, 2007, WGIII.

Conclusions

With the solid basis of the Programme of Action on International Aviation and Climate Change, ICAO continues to pursue even more ambitious goals to address aviation's contribution to climate change. The Organization and the industry are working aggressively toward a sustainable future for international aviation. More information on ICAO efforts to unite aviation on climate change is available from **www.icao.int/Act_Global**.