ICAO

Aviation and the Environment

STRATEGIC OBJECTIVE:

ENVIRONMENTAL PROTECTION

A specialized agency of the United Nations, the **International Civil Aviation Organization (ICAO)** was created in 1944 to promote the safe and orderly development of international civil aviation throughout the world. It sets standards and regulations necessary for aviation safety, security, efficiency and regularity, as well as for aviation environmental protection.

The Organization serves as the forum for cooperation in all fields of civil aviation among its 191 Member States.

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List of Acronyms

ACI: Airports Council International

ASK: Available Seat-Kilometres

AVSEC: Aviation Security

CAGR: Compound Annual Growth Rate

FAL: Facilitation

FTK: Freight Tonnes-Kilometres

ICAO: International Civil Aviation Organization

ITF: International Transport Forum, Organisation for Economic Co-operation and Development

LCC: Low cost carrier

LF: Load factor

MDWG: Multi-disciplinary working group

RPK: Revenue Passenger-Kilometres

UNWTO: World Tourism Organization

VFR: Visiting friends and relatives

YoY: Year on Year

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Aviation and the Environment

Environmental Protection is one of ICAO's five strategic objectives. When ICAO first began working on Environmental Protection in the late 1960s, the focus was on the establishment of international policies and Standards and Recommended Practices related to aircraft noise.

This focus gradually expanded and led to the adoption ICAO's three main environmental goals in 2004. Those are to limit or reduce the number of people affected by significant aircraft noise, to limit or reduce the impact of aviation emissions on local air quality, and to limit or reduce the impact of aviation greenhouse gas emissions on the global climate.

Many aspects of ICAO's environmental work are conducted in cooperation with the ICAO Committee on Aviation Environmental Protection (CAEP), which consists of Members and Observers from States, intergovernmental and non-governmental organizations representing aviation industry and environmental interests.

In October 2010, at the 37th Session of the ICAO Assembly, ICAO's Member States agreed to the global aspirational goal to stabilize international civil aviation GHG emissions at 2020 levels.

The Assembly also defined a basket of measures designed to help achieve ICAO's global aspirational goal. This basket includes aircraft technologies such as lighter airframes, higher engine performance and new certification standards, operational improvements (e.g. improved ground operations and air traffic management), sustainable alternative fuels, and market-based measures (MBMs). These resolutions were reaffirmed in October 2016 by the ICAO 39th Assembly.

Elements of this basket of measures, in combination with environmental trends, are presented in this chapter. Further details on the agreement by the 39th Session of the ICAO Assembly on a global market-based measure (MBM) scheme for international aviation, referred to as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), as one part of the basket of measures can be found on pages 14 onwards.

Environmental Trends in Aviation to 2050

ICAO

WASA Web Database Tool

The Most Complete Database of Air Service Agreements in the World

ICAO's WASA is a unique analytical tool for air services negotiations and consultations. It empowers regulators and aviation experts to evaluate developments in the air transport field, to run comparative analyses of air services agreements, and to assess the degree of liberalization.

Environmental Trends in Aviation to 2050

Background

Each three-year work cycle, the International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP) develops an analysis of environmental trends in aviation to include:

- Aircraft Emissions that affect the Global Climate;
- Aircraft Noise; and
- Aircraft Emissions that affect Local Air Quality (LAQ).

CAEP aims to use the latest input data and related assumptions to assess the present and future impact and trends of aircraft noise and aircraft engine emissions.

Trends in Aviation Emissions that affect the Global Climate

The assessment of GHG trends is based on the latest CAEP central demand forecast using a base year of 2010; the validity of which was assessed in the CAEP/10 (2016) cycle. Forecasted years included 2020 and 2030 with an extension to 2040 and results extrapolated to 2050. Data presented for 2005 and 2006 are reproduced from prior trends assessments.

Three models contributed results to the GHG trends assessment: US Federal Aviation Administration's (FAA) Aviation Environmental Design Tool (AEDT), EUROCONTROL's IMPACT, and Manchester Metropolitan University's Future Civil Aviation Scenario Software Tool (FAST). Key databases utilized in this assessment included the AEDT Airports Database, Campbell-Hill, the Growth and Replacement Fleet Database, and the Common Operations Database (COD), which are all proprietary databases, including Campbell-Hill which is owned and maintained by Airlines for America (A4A).

Table 1 below summarizes the nine full-flight fuel burn and CO_2 emissions scenarios developed for the assessment of trends for aircraft emissions that affect the global climate.

The trends presented were developed in the context of a longer-term view. Short term changes in global fuel efficiency can be affected substantially by a wide range of factors such as fluctuations in fuel prices, and global economic conditions. Figure 1 provides results for global full-flight fuel burn for international aviation from 2005 to

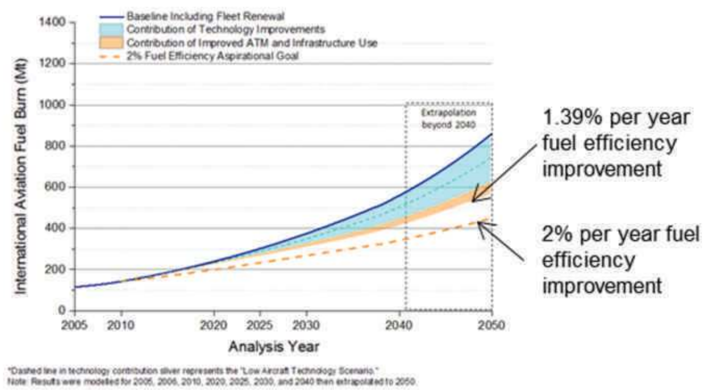


Figure 1. Fuel Burn Trends from International Aviation, 2005 to 2050

Table 1. Full-Flight Fuel Burn and CO_2 Scenarios.

Scenario	Name	Technology Improvement	Operational Improvement
1	Baseline Including Fleet Renewal	None	None
2	Low Aircraft Technology and Moderate Operational Improvement	0.96%/annum, 2010-2015 0.57%/annum, 2015-2050	CAEP/8 IE Lower Bound
3	Moderate Aircraft Technology and Operational Improvement	0.96%/annum, 2010-2050	CAEP/8 IE Lower Bound
4	Advanced Aircraft Technology and Operational Improvement	1.16%/annum, 2010-2050	CAEP/8 IE Upper Bound
5	Optimistic Aircraft Technology and Advanced Operational Improvement	1.50%/annum, 2010-2050	CAEP/8 IE Upper Bound
6	Low Aircraft Technology and CAEP/9 Independent Expert (IE) Operational Improvement	0.96%/annum, 2010-2015 0.57%/annum, 2015-2050	CAEP/9 IE
7	Moderate Aircraft Technology and CAEP/9 IE Operational Improvement	0.96%/annum, 2010-2050	CAEP/9 IE
8	Advanced Aircraft Technology and CAEP/9 IE Operational Improvement	1.16%/annum, 2010-2050	CAEP/9 IE
9	Optimistic Aircraft Technology and CAEP/9 IE Operational Improvement	1.50%/annum, 2010-2050	CAEP/9 IE

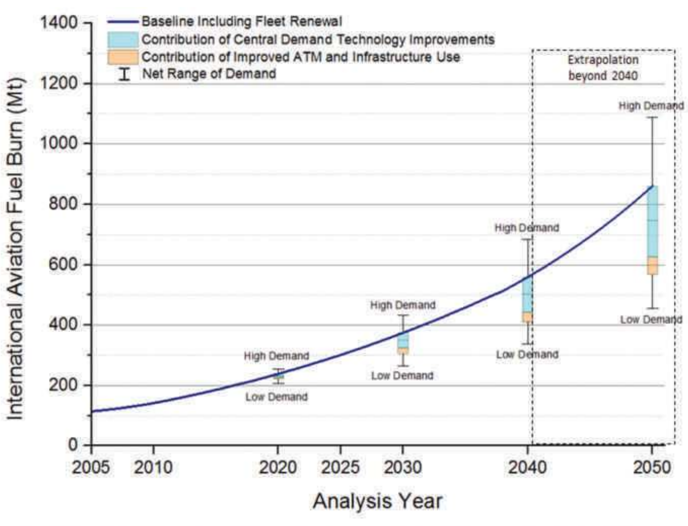
Note: Independent Expert is represented as IE. In CAEP/8 (2010), IEs provided a range of operational improvements in the form of a lower bound and upper bound.

2040, and then extrapolated to 2050. The fuel burn analysis considers the contribution of aircraft technology, improved air traffic management, and infrastructure use (i.e., operational improvements) to reduce fuel consumption. The figure also illustrates the fuel burn that would be expected if ICAO's 2 per cent annual fuel efficiency aspirational goal were achieved.

Figure 2 puts these contributions in context with the uncertainty associated with the forecasted demand, which is notably larger than the range of potential contributions from technological and operational improvements. Despite this uncertainty, the baseline trends forecast is broadly consistent with other published aviation forecasts. The trends forecast, which is for revenue tonne kilometres (RTK) and international aviation, shows a 20 year (2010-2030) compound average annual growth rate (CAGR) of 5.3 per cent. By way of comparison, using revenue passenger kilometres (RPK) for all traffic as the forecast measurement, Boeing's, Airbus' and Embraer's most recent 2015 forecasts have 20 year (2014-2034) CAGRs of 4.9 per cent, 4.6 per cent and 4.9 per cent respectively.[1] The CAEP's RPK 20 year forecast (2010-2030) has a baseline forecast of 4.9 per cent, with a low outlook at 4.2 per cent and high at 5.7 per cent. While acknowledging the different forecast units and coverage, the trends baseline outlook shows reasonable alignment with the aviation industry and the most recent CAEP view of future aviation growth in the early 2010s.

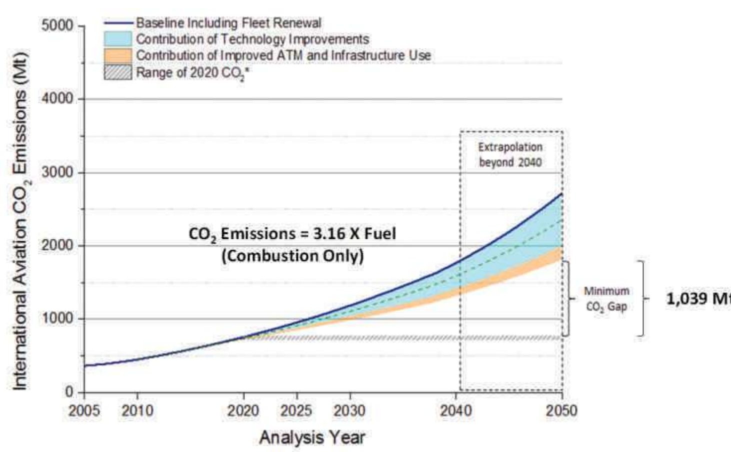
The results presented in Figures 1 and 2 are for international aviation only. In 2010, approximately 65 per cent of global aviation fuel consumption was from international aviation. Based on CAEP/MDG's analysis, this proportion is expected to grow to nearly 70 per cent by 2050.

Figure 3 presents full-flight CO_2 emissions for international aviation from 2005 to 2040, and then extrapolated to 2050. This figure only considers the CO_2 emissions associated with the combustion of jet fuel, assuming that 1 kg of jet fuel burned generates 3.16 kg of CO_2. As with the fuel burn analysis, this analysis considers the contribution of aircraft technology, improved air traffic management and infrastructure use (i.e., operational improvements). In addition, the range of possible CO_2 emissions in 2020 are displayed for reference to the global aspirational goal of keeping the net CO_2 emissions at this level. Although not displayed in a separate figure, the demand uncertainty effect on the fuel burn calculations shown in Figure 2 has an identical effect on the CO_2 results. Based on the maximum anticipated fuel consumption in 2020 (Scenario 1) and the anticipated Scenario 9 fuel consumption in 2040, a minimum CO_2 emission gap of 523 Mt is projected in 2040. Extrapolating Scenario 9 to 2050 results in a 1,039 Mt gap.



Note: Fuel burn was only modelled for the central demand forecast. The effects of the high and low demand sensitivities shown are based on the ratio of forecasted revenue passenger kilometres for high/low demand relative to central demand.

Figure 2. Range of Uncertainties Associated with Demand Forecast, 2005 to 2050



*Actual carbon neutral line is within this range
Dashed line in technology contribution sliver represents the "Low Aircraft Technology Scenario."
Note: Results were modelled for 2005, 2006, 2010, 2020, 2025, 2030, and 2040 then extrapolated to 2050.

Figure 3. CO_2 Emissions Trends from International Aviation, 2005 to 2050

[1] http://www.boeing.com/resources/boeingdotcom/commercial/about-our-market/assets/downloads/Boeing_Current_Market_Outlook_2015.pdf; http://www.airbus.com/company/market/forecast/; http://www.embraermarketoutlook.com/RPK-GPD.html

Contribution of Alternative Fuels to GHG Trends Assessment

CAEP was charged with calculating estimates of alternative jet fuel (AJF) contributions to fuel replacement and life cycle GHG emissions reductions in the Trends Assessment out to 2050. Analyses were performed for 2020 and 2050. The short-term scenarios for AJF availability were established from fuel producers' announcements regarding their production plans from State-sponsored production plans, if associated with ICAO Member State target. For the long-term scenarios, CAEP assessed future jet fuel availability by first estimating the primary bioenergy potential constrained by selected environmental and socio-economic factors; by second estimating the proportion of bioenergy potential that could actually be achieved or produced; and finally by exploring the quantity of AJF that could be produced from the available bioenergy. AJF availability was calculated including 9 different groups of feasible feedstocks (starchy crops; sugary crops; lignocellulosic crops; oily crops; agricultural residues; forestry residues; waste fats, oils and greases; microalgae; municipal solid waste (MSW)). The final values provided by CAEP to MDG include potential total global production and an average Life Cycle Assessment (LCA) value based on the share of different fuel types that contribute to each scenario. The LCA values are not intended to be applied separately to regional forecasts.

For 2020, there were six production estimates and two GHG LCA estimates (low and high), resulting in 12 possible GHG emissions scenarios. The 2020 scenarios provide up to 2 per cent petroleum-based fuel replacement and up to 1.2 per cent GHG emissions reductions.

For 2050, CAEP calculated 60 production achievement scenarios and two GHG emissions scenarios resulting in 120 scenarios. Certain global conditions, economic investments, and policy decisions are assumed as part of each scenario definition and would be necessary to reach the associated outcome of alternative fuel production and GHG reductions.

The trends assessment figures for international aviation shown below include the range of CAEP results and an "illustrative" scenario that achieves 19 per cent net CO_2 emissions reduction assuming significant policy incentives and high biomass availability. Fuel replacement results for international aviation can be found in Figure 4. See Figure 5 for net CO_2 emissions results. The amount of AJF and the associated CO_2 emissions reductions were allocated proportionally between international and domestic use based on projected fuel demand (65 per cent and 35 per cent in 2010, respectively).

For 2020 and 2050, total petroleum-based fuel amounts for the different fuel demand scenarios were multiplied by the specific CO_2 combustion emissions factor of 3.16 to get baseline GHG emissions shown in Figure 5. Calculations of GHG emissions reduction were performed according to the following formula provided by the CAEP Market Based Measure Task Group:

Total Emissions = 3.16 x (CJF + AJF*(LCA_AJF/LCA_CJF))

Where CJF = conventional jet fuel, AJF = alternative jet fuel, and LCA_X = life cycle CO_2 equivalent emissions of fuel X.[2]

The GHG reduction "wedge" was created by connecting the least contribution scenario values to each other and the greatest contribution values to each other. The 2020 "medium scenario without green diesel" was connected to the 2050 value for the illustrative scenario. CAEP elected to show linear growth for intermediate and high GHG reduction scenarios.[3]

[2] This calculation provides an "in-flight" equivalent of CO emissions reduction based on the life cycle values of the alternative fuels, which are used because reductions in atmospheric carbon from aviation biofuel use occur from feedstock production and fuel conversion and not from fuel combustion.

[3] CAEP did not specify a function for connecting the 2020 results to the 2050 results in their outputs. However, CAEP did provide information on the range of options for connecting these results. CAEP anticipates that growth of a new industry such as that for AJF will follow an "S-shaped" trajectory, but it is not clear when investment, and therefore, growth of production capacity of the industry, will ramp up. Ramp up to alternative fuel production in 2050 is anticipated to be somewhere between linear and exponential growth (i.e., the lower end of the S-curve). Linear growth for intermediate and high net CO_2 emissions reduction scenarios is shown. No meaningful data exist in order to calibrate the curve. Therefore, values for intervening years between 2020 and 2050 for the AJF scenarios should be considered illustrative only.

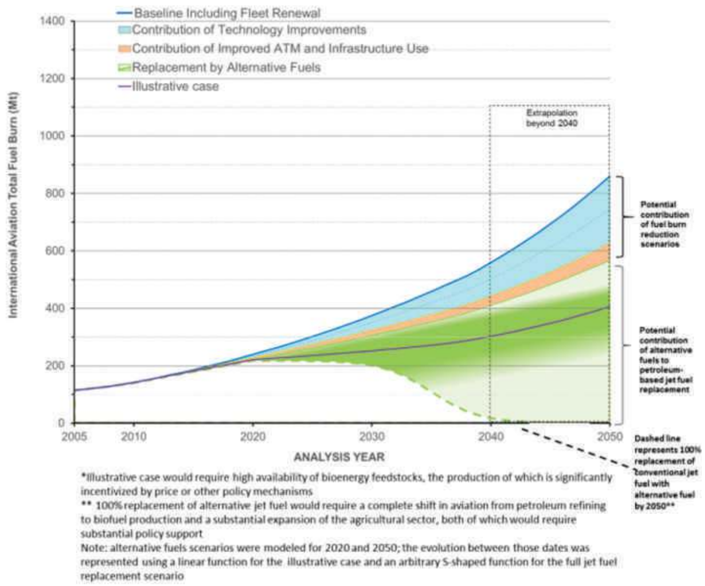


Figure 4. Aircraft Fuel Burn from International Aviation, 2005 to 2050 Updated to Include Potential Replacement of Jet Fuel with Alternative Fuels

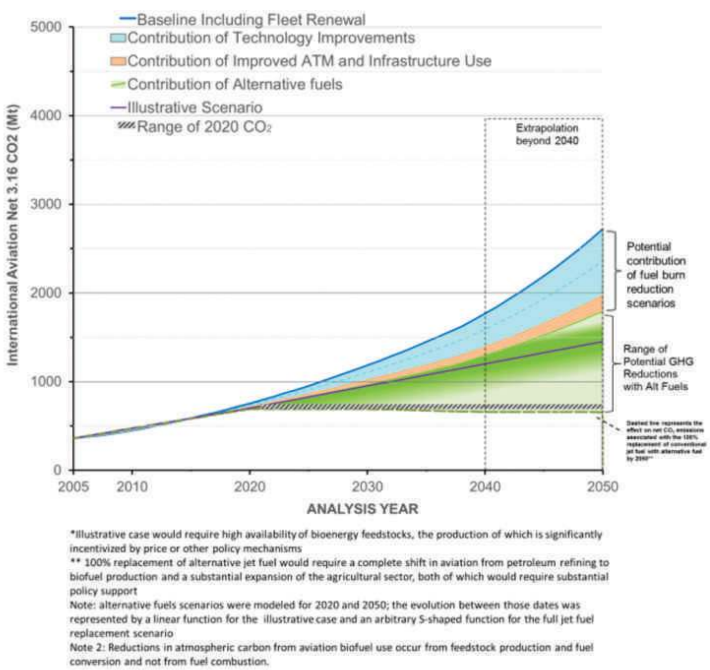


Figure 5. Aircraft CO_2 Emissions from International Aviation, 2005 to 2050, Updated to Include Alternative Fuels Life Cycle Emissions Reductions

Several of the 2050 scenarios that CAEP evaluated resulted in zero alternative jet fuel production and therefore no contribution to GHG emissions reduction. [4]

The zero AJF results are equivalent to the line associated with Scenario 9 for technology and operational improvements as described above. The scenario with the greatest contribution to GHG emissions reduction could supply more alternative jet fuel than is anticipated to be used in 2050. For the purposes of this analysis, production for the highest contribution scenario is ramped up to full replacement in 2050 based on Scenario 9.

If industry growth were to follow an s-shaped curve, the highest growth rates would occur around 2035, in which 328 new large biorefineries would need to be built each year at an approximate capital cost of US$ 29 Billion to US$ 115 Billion per year. Lower growth rates would be required in years closer to 2020 and 2050.. Achieving this level of emissions reduction would also require the realization of the highest assumed increases in agricultural productivity, highest availability of land for feedstock cultivation, highest residue removal rates, highest conversion efficiency improvements, largest reductions in the GHG emissions of utilities, as well as a strong market or policy emphasis on bioenergy in general, and alternative aviation fuel in particular. This implies that a large share of the globally available bioenergy resource would be devoted to producing aviation fuel, as opposed to other uses.

Achievement of carbon neutral growth at 2020 emissions levels out to 2050 would require nearly complete replacement of petroleum-based jet fuel with sustainable alternative jet fuel besides the implementation of aggressive technological and operational scenarios. The future development and use of alternative fuels will highly depend on the policies and incentives in place for such fuels. Based on the analysis assumptions, if enough alternative jet fuel were produced in 2050 to completely replace petroleum-derived jet fuel, it would reduce net CO2 emissions by 63 per cent

Trends in Aircraft Full Flight NOX Emissions

The following scenarios were assessed for Full Flight NOx:

Scenario 2 is the moderate aircraft technology and CAEP/9 (2013) Independent Expert (IE) Operational Improvement case

[4] These scenarios reflect a lack of bioenergy availability in general or a prioritization of other bioenergy usages over aviation..

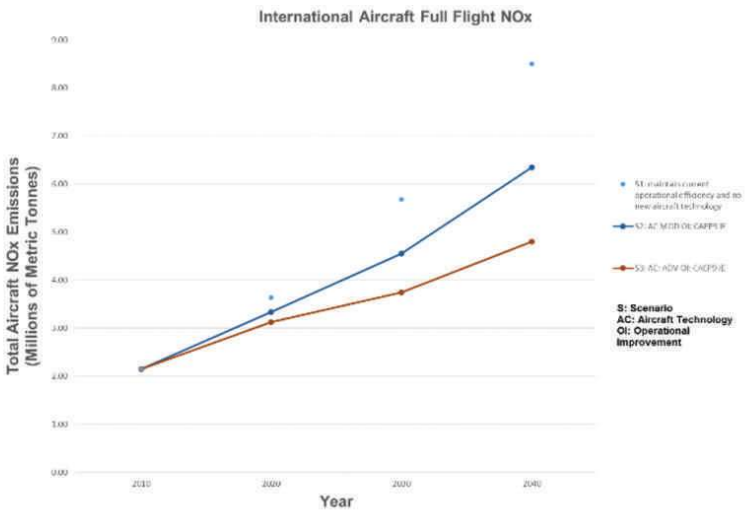


Figure 6. International Aircraft Full Flight NOx

that assumes aircraft NOx improvement based upon achieving 50 per cent of the reduction from current NOx emission levels to the NOx emissions levels by CAEP/7 (2007) NOx IE goals review (-60 per cent +/- 5 per cent of current CAEP/6 (2004) NOx Standard) for 2030, with no further improvement thereafter.

Scenario 3 is the advanced aircraft technology and CAEP/9 (2013) IE Operational Improvement case that assumes aircraft NOx improvement based upon achieving 100 per cent of the reduction from current NOx emission levels to the NOx emissions levels by CAEP/7 (2007) NOx IE goals review (-60 per cent +/- 5 per cent of current CAEP/6 (2004) NOx Standard) for 2030, with no further improvement thereafter.

Two models contributed results to the full flight NOx trends assessment: (1) FAA's AEDT; and (2) EUROCONTROL's IMPACT. MDG results for international operations are shown in Figure 6. The 2010 baseline NOx value is 2.15 MT. In 2040, the NOx value ranges from about 4.81 MT with Scenario 3 to 6.35 MT with Scenario 2.

Interpretation

In 2010, international aviation consumed approximately 142 million metric tonnes of fuel, resulting in 448 million metric tonnes (Mt, 1kg x 109) of CO_2 emissions. By 2040, fuel consumption is projected to have increased 2.8 to 3.9 times the 2010 value, while revenue tonne kilometres are expected to increase 4.2 times under the central demand forecast. By extrapolating to 2050, fuel consumption is projected to have increased 4 to 6 times the 2010 value, while revenue tonne kilometres are expected to increase 7 times under the central demand forecast.

Under Scenario 9 as defined in Table 1, aviation fuel efficiency, expressed in terms of volume of fuel per RTK, is expected to improve at an average rate of 1.4 per cent per annum to 2040, and at 1.39 per cent per annum, if extrapolated to 2050. While in the near term (2010 to 2020), efficiency improvements from technology and improved ATM and infrastructure use are expected to be moderate, they are projected to accelerate in the mid-term (2020 to 2030). During the 2020 to 2030 period, fuel efficiency is expected to improve at an average rate of 1.76 per cent per annum under Scenario 9. The magnitude of the modelled fuel efficiency improvements is as expected given the 1.5 per cent per annum technology improvement associated with Scenario 9, and the variability of the forecasted RTK. This analysis shows that additional technological and operational improvements beyond even those described in Scenario 9 will be required to achieve the global aspirational goal of 2 per cent per annum fuel efficiency.

In 2020, it is expected that international aviation will consume between 216 and 239 Mt of fuel, resulting in 682 to 755 Mt of CO_2 emissions. Under the range of 2020 scenarios, it is estimated that up to 2 per cent of this fuel consumption could consist of sustainable alternative fuels in 2020. Significant uncertainties exist in predicting the contribution of sustainable alternative fuels in 2050. Based on scenarios considered by CAEP, it is possible that up to 100 per cent of the CO_2 emissions gap could be closed with sustainable alternative fuels in 2050, but this would require nearly complete replacement of petroleum-based fuels with sustainable alternative jet f u e l . C omp le t e re p l a ceme n t w o u l d re q u i re approximately 170 new large biorefineries to be built every year from 2020 to 2050, at an approximate capital cost of US$15 Billion to US$60 Billion per year if growth occurred linearly.

Achieving this level of emissions reduction would also require the realization of the highest assumed increases in agricultural productivity, highest availability of land for feedstock cultivation, highest residue removal rates, highest conversion efficiency improvements, largest reductions in the GHG emissions of utilities, as well as a strong market or policy emphasis on bioenergy in general, and alternative aviation fuel in particular. This implies that a large share of

Table 2. Scenarios Developed for the Assessment of Aircraft Noise Trends

Scenario	Name	Technology Improvement	Operational Improvement
1	Sensitivity Case	None	None
2	Low Aircraft Technology and Moderate Operational Improvement	0.3 EPNdB/annum, 2011 -2013 0.1 EPNdB/annum, 2014 -2040	2 per cent reduction in contour area shape applied to population exposed.
3	Moderate Aircraft Technology and Operational Improvement	0.3 EPNdB/annum, 2011 -2030 0.1 EPNdB/annum, 2031 -2040	2 per cent reduction in contour area shape applied to population exposed.
4	Advanced Aircraft Technology and Moderate Operational Improvement	0.3 EPNdB/annum, 2011 -2040	2 per cent reduction in contour area shape applied to population exposed.

Note: EPNdB means Effective Perceived Noise Level in Decibels.

the globally available bioenergy resource would be devoted to producing aviation fuel, as opposed to other uses.

Even under this scenario, achieving carbon neutral growth exclusively from the use of sustainable alternative fuels is unlikely to happen in 2021 or shortly thereafter as for the production of alternative fuels an initial ramp-up phase is required before production can reach the levels mentioned above.

Trends in Aircraft Noise

A range of scenarios were developed for the assessment of aircraft noise trends, as shown in Table 2.

Scenario 1 is the sensitivity case that assumes the operational improvements necessary to maintain current operational efficiency, but does not include any aircraft technology improvements beyond those available in 2010 production aircraft. Since Scenario 1 is not considered a likely outcome by the CAEP, it is purposely depicted in all graphics with no line connecting the modelled results in 2010, 2020, 2030, and 2040. The other scenarios assume increased implementation of both operational and technological improvements. Scenarios 2, 3, and 4 are assumed to represent the range of most likely outcomes.

For airports outside the United States (US) and Europe two different population sources were used to count people inside of contours (legacy GRUMP and the newer LANDSCAN).[5] Comparisons between GRUMP/ LANDSCAN and census sources from the US, United Kingdom, and Mainland Europe yielded mixed results, with some airports having higher and some lower population counts. Consequently, population results were presented as an uncertainty range, showing both low and high values.

Figure 7 provides results for the total global population exposed to aircraft noise above 55 DNL for 2010, 2020, 2030, and 2040. The 2010 baseline value ranges from a low of 21.4 to a high of 34.9. The population results assume 2010 levels throughout the analysis period (2010 to 2040). Of note is that under an advanced aircraft technology and moderate operational improvement scenario, from 2030, aircraft noise exposure may no longer increase with an increase in traffic.

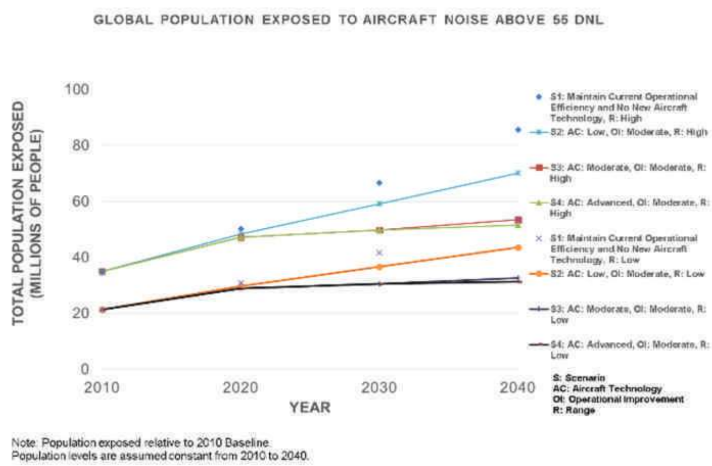


Figure 7. Total Global Population Exposed to Aircraft Noise Above 55 DNL

Trends in Aircraft Emissions that affect Local Air Quality

A range of scenarios have also been developed for the assessment of aircraft emissions trends below 3,000 feet above ground level (AGL) that affect LAQ, particularly NOx, as shown in Table 3.

[5] http://beta.sedac.ciesin.columbia.edu/data/set/grump-v1-population-count; http://web.ornl.gov/sci/landscan/

Table 3. Scenarios Developed for the Assessment of Aircraft LAQ Trends

Scenario	Name	Technology Improvement	Operational Improvement
1	Sensitivity Case	None	None
2	Moderate Aircraft Technology and Operational Improvement	50 % CAEP/7 NOx Independent Expert goals for 2030, nothing thereafter	CAEP/9 IE
3	Advanced Aircraft Technology and Operational Improvement	100 % CAEP/7 NOx Independent Expert goals for 2030, nothing thereafter	CAEP/9 IE

Again, Scenario 1 is the sensitivity case that assumes the operational improvements necessary to maintain current operational efficiency levels, but does not include any aircraft technology improvements beyond those available in 2010 production aircraft. Scenarios 2 and 3 assume aircraft NOx improvements based upon achieving some per cent (50 per cent and 100 per cent, respectively) of the reduction from the current NOx emission levels to the NOx emissions levels by CAEP/7 (2007) NOx Independent Expert goals review (about 60 per cent of the current CAEP/6 (2004) NOx Standard) for 2030, as well as fleet-wide operational improvements by region.

Figure 8 provides results for NOx emissions below 3,000 feet AGL from international operations for 2010, 2020, 2030, and 2040. The 2010 baseline value is about 0.15 million metric tonnes (Mt, 1kg x 109). In 2040, total NOx ranges from 0.32 Mt, with Scenario 3, to 0.42 Mt with Scenario 2.

The results for PM emissions from international operations below 3,000 feet AGL follow the same trends as those for NOx. The 2010 baseline PM value is 914 metric tonnes. In 2040, total global PM is projected to be about 3,003 metric tonnes with Scenario 2.

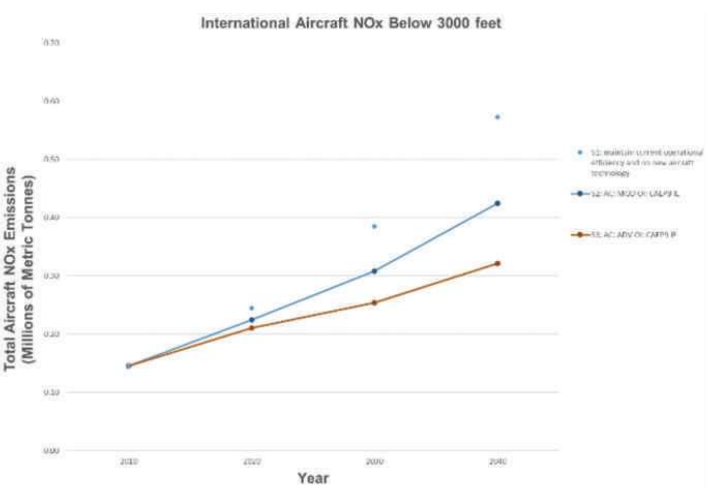


Figure 8. Total International Aircraft NOx Below 3,000 Feet

Conclusion

The CO_2 emissions that affect the global climate, and emissions that affect local air quality are expected to increase through 2050, but at a rate slower than aviation demand. Under an advanced aircraft technology and moderate operational improvement scenario, from 2030, aircraft noise exposure may no longer increase with an increase in traffic. However, it has to be kept in mind that the uncertainty associated with future aviation demand is notably larger than the range of contributions from technology and operational improvements.

International aviation fuel efficiency is expected to improve through 2050, but measures in addition to those considered in this analysis will be required to achieve ICAO's 2 per cent annual fuel efficiency aspirational goal. Sustainable alternative fuels have the potential to make a significant contribution, but sufficient data are not available to confidently predict their availability over the long term. Also, considering only aircraft technology and operational improvements, additional measures will be needed to achieve carbon neutral growth relative to 2020.

References

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2. http://www.airbus.com/company/market/forecast/;
3. http://www.embraermarketoutlook.com/RPK-GPD.html
4. These scenarios reflect a lack of bioenergy availability in general or a prioritization of other bioenergy usages over aviation.
5. http://beta.sedac.ciesin.columbia.edu/data/set/grump-v1-population-count
http://web.ornl.gov/sci/landscan/

Sustainable Alternative Fuels for Aviation

Sustainable Alternative Fuels for Aviation

Over the past several years, there have been significant advances related to the development and deployment of sustainable alternative fuels from clean, renewable sources of energy. Deploying alternative fuels as a means to limit carbon emissions is of particular relevance for aviation, because unlike other industries, aviation has no alternatives to liquid fuels for the foreseeable future. Fortunately, the numerous advancements and achievements to date have demonstrated that drop-in alternative fuels are a technically sound solution for aviation that will not require changes to aircraft or fuel delivery infrastructure.

In 2007, the 36th ICAO Assembly requested the ICAO Council to "promote understanding of the potential use, and the related emissions impacts, of alternative aviation fuels". Since that time, the importance of alternative fuels has become increasingly evident in ICAO Assembly Resolutions.

In October 2010, the 37th Session of the ICAO Assembly adopted Resolution A37-19 which requested Member States to develop policy actions to accelerate the appropriate development, deployment and use of sustainable alternative fuels for aviation, as part of a basket of measures to limit carbon emissions from international aviation. This agreement was re-affirmed in October 2013 as a part of ICAO Assembly Resolution A38-18 and in October 2016 as a part of ICAO Assembly Resolution A39-2.

CURRENT STATUS OF SUSTAINABLE ALTERNATIVE FUEL DEVELOPMENT AND DEPLOYMENT

Current Alternative Jet Fuel Pathways

Today, alternative jet fuel can be produced through the following pathways:

- Fischer-Tropsch Synthetic Kerosene with Aromatics (FT-SKA);
- Fischer-Tropsch Synthetic Paraffinic Kerosene (FT-SPK);
- Hydroprocessed Esters and Fatty Acids (HEFA-SPK);
- Hydroprocessed Fermented Sugar-Synthetic Isoparaffins (SIP); and
- Alcohol to Jet Synthetic Paraffinic Kerosene (ATJ-SPK).

These methods, approved by the American Society for Testing Materials (ASTM) International, a standards-setting organization, enable the conversion of a broad range of renewable sources of biomass into sustainable jet fuel. Research into additional techniques for producing alternative jet fuels is evolving rapidly. The addition of the SIP and ATJ-SPK pathways are new since the 38th Session of the ICAO Assembly and there are many additional pathways at different levels of the approval process. As with the already-approved HEFA-SPK, some of the forthcoming pathways will not require the use of land for feedstock production.

Importantly, the aviation industry has a focus on not competing with food production.

Development and Deployment

The ICAO Conference on Aviation and Alternative Fuels which launched the Global Framework on Aviation Alternative Fuels (GFAAF), both in 2009, there have been many accomplishments. Of the more than 500 announcements and initiatives recorded in the GFAAF, some of the highlights include:

2010: The ICAO 37th Triennial Assembly adopted A37-19, which encourages the use of alternative fuels for the aviation industry;

2011: First commercial flights operated using biofuel;

2012: Flightpath to a Sustainable Future, an ICAO special Rio+20 global initiative, the first-ever series of connecting flights powered by sustainable alternative fuels, on which the ICAO Secretary General, travelled from Montréal, Canada to Rio de Janeiro, Brazil;

2013: First regular flight operations using alternative fuel began between New York, United States and Amsterdam, Netherlands;

2014: SIP fuel gained approval for use in aviation, which was followed by numerous flights by various airlines;

2015: There were 21 initiatives on-going worldwide, the highest number of initiatives seen to date, and 9 new fuel purchasing agreements signed between key stakeholders and fuel producers;

2016: Oslo Gardermoen airport in Norway became the world's first "bio-port", offering aviation biofuel to its users, followed by a similar initiative in Los Angeles airport in the United States, and recently by Stockholm Arlanda airport in Sweden.

2017: Stockholm Arlanda Airport, Stockholm Bromma Airport, and Åre Östersund Airport in Sweden all began mixing biofuel into their fuel tanks.

More than 2 500 commercial flights have flown using alternative fuels since 2011, with the prediction that by the end of 2016, the number of such flights exceeded 5 500, according to IATA. There have been more than 140 new announcements since the 38th Session of the ICAO Assembly alone. The significant growth in announcements of alternative fuel projects and initiatives underscores the forthcoming growth in deployment.

Based on the Action Plans on Emissions Reduction submitted by States as of 1 October 2016, 64 States representing 80.78 per cent of global Revenue Tonne Kilometres (RTK) indicated that they will pursue investments in sustainable alternative fuels for aviation. Additional information is presented in A39-WP/54 States' Voluntary Action Plans on CO_2 Emissions Reduction Activities and A39-WP/51 Civil Aviation and the Environment.

CHALLENGES

In updating the environmental trends assessment to further account for the potential contribution of sustainable alternative fuels on international aviation CO_2 emissions, ICAO developed, with the technical support provided by CAEP, a range of scenarios to reflect the primary factors that will influence the development of alternative jet fuel globally.

Substantial progress has been made during the past three years in the development of alternative jet fuels from a technical perspective, although significant challenges remain before alternative jet fuels will be available in significant quantities worldwide. These include the need for investment in biorefineries, as well as dedicated policy decisions that will ensure that biofuels are available for aviation.

In addition, the price gap with conventional jet fuel remains a key barrier for commercial-scale adoption and deployment. Table 1 illustrates the magnitude of the investments required to achieve a range of emissions reduction scenarios from international aviation. Many States are focusing on removing these barriers to commercialization through the development of regional or industry roadmaps.

Aviation GHG emissions reduction (percentage)	Required AJF production volume in 2050 (Mt/year)	Requirements under linear growth		Requirements under exponential growth	
		Number of new biorefineries/year	Capital investment/ year	Number of new biorefineries/year	Capital investment/ year
2	30	10	$1B - $3B	<5 (2025) to 30 (2050)	<$1B - $2B (2025) to $3B - $10B (2050)
10	130	40	$3B - $14B	<5 (2025) to 200 (2050)	<$1B - $2B (2025) to $15B - $60B (2050)
17	220	70	$6B - $25B	<5 (2025) to 300 (2050)	<$1B - $2B (2025) to $30B - $110B (2050)
40	570	170	$15B - $60B	<10 (2025) to 1000 (2050)	$1B - $3B (2025) to $80B - $330B (2050)
63	870	260	$20B - $90B	<10 (2025) to 1600 (2050)	$1B - $3B (2025) to $130B - $550B (2050)
Average historical global ethanol and biodiesel production		Total annual volumes (Mt/year)		10 (years 1975 - 2000) to 45 (2001 - 2011)	
		Number of new biorefineries/year		5 (years 1975 - 2000) to 60 (2001 - 2011)	
Projection for average annual investment in petroleum refining in 2035				$55B	

Table 1. Required fuel production volume in 2050 (based on CAEP/10 Scenario 7 total fuel demand projections), number of new 5000 barrels per day (bpd) facilities required annually (assuming 50 per cent jet fuel share in product slate) and range of annual capital investment required (jet-fuel portion only) for different GHG emission reduction percentages under the simplifying assumption of linear or exponential growth and low GHG intensity of AJF. CAEP expects the long-term development of AJF deployment to resemble an s-curve. Average historical growth for transportation biofuels in terms of annual production volumes and the number of new facilities per year (assuming a 5000 bpd scale for illustrative purposes) and projected petroleum refinery investment in 2035 shown for comparison purposes[1]. All monetary values are shown in US Dollars ($).

CONCLUSIONS

Despite the challenges remaining for the deployment of aviation alternative fuels on a global scale, the progress to date has been significant. This is an area of the aviation industry that is expected to grow as technologies develop. To date, 25 airlines have powered commercial flights on alternative fuel, with a growing number of airlines and States expressing interest in these developments. Stakeholders in the aviation industry should be encouraged by the significant growth evident in the field of alternative fuels and encouraged by the developments to come.

A New ICAO Aeroplane CO_2 Emissions Standard

A New ICAO Aeroplane CO_2 Emissions Standard

Introduction

Following six years of development, ICAO's Committee on Aviation Environmental Protection (CAEP) at its tenth meeting (CAEP/10) recommended an aeroplane Carbon Dioxide (CO_2) emissions certification Standard. This new standard is part of the ICAO "basket of measures" to reduce greenhouse gas emissions from the air transport system, and it is the first global technology Standard for CO_2 emissions for any sector with the aim of encouraging more fuel efficient technologies into aeroplane designs.

This technology-based approach is similar to the current ICAO Annex 16 Standards on engine emissions for local air quality (Volume II) and aircraft noise (Volume I). The recommended CO_2 Standard has been developed at the aeroplane level, and therefore has considered all technologies associated with the aeroplane design (e.g. propulsion, aerodynamics and structures). Once adopted by the ICAO Council, the aeroplane CO_2 emissions certification Standard will be published as a new Annex 16, Volume III.

The framework for the CO_2 Standard consists of a certification requirement and regulatory limit, as shown in Figure 1, and the work to develop the CO_2 Standard was divided into two phases. Phase 1, which was completed at the ninth meeting of the CAEP (CAEP/9) in February 2013, resulted in the approval of some of the details regarding the applicability of the Standard, the CO_2 Metric System and the development of a CO_2 Standard certification requirement. Phase 2 involved the development of the regulatory limit lines and the applicability requirements such as scope and date.

In the ICAO Environmental Report 2013, a summary was provided of the work that had been completed during Phase 1. This new article provides an overview of both phases over the past six years, the lead up to the CAEP/10 meeting and the recommendation from the CAEP/10 meeting on the first ICAO aeroplane CO_2 emissions certification Standard.

Phase 1 work- The Development of a certification requirement

1.1 An important Phase 1 milestone in the development of the CO_2 Standard was the agreement on a CO_2 metric system to measure the aeroplane fuel burn, and therefore CO_2 emissions, performance. The intent of this CO_2 metric system is to equitably reward advances in aeroplane technologies (e.g. propulsion, aerodynamics and structures) that contribute to reductions in aeroplane CO_2 emissions, and differentiate between aeroplanes with different generations of these technologies. As well as accommodating the full range of technologies and designs which manufacturers can employ to reduce CO_2 emissions, the CO_2 metric system has been designed to be common across different aeroplane categories, regardless of aeroplane purpose or capability. An overview of the CO_2 Metric System can be found in Figure 2.

GENERAL CO_2 STANDARD APPLICABILITY SCOPE FOR AEROPLANE CATEGORIES

- Subsonic Jet Aeroplanes Over 5700 kg
- Propeller-Driven Aeroplanes Over 8618 kg

1.2 To establish the fuel efficiency of the aeroplane, the CO_2 metric system uses multiple test points to represent the fuel burn performance of an aeroplane type during the cruise phase of flight. Specifically, there are three averaged (i.e. equally weighted) points representing aeroplane high, middle

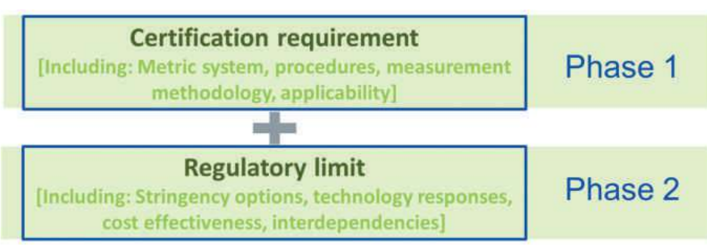


Figure 1. The framework and development phases of the CO_2 Standard.

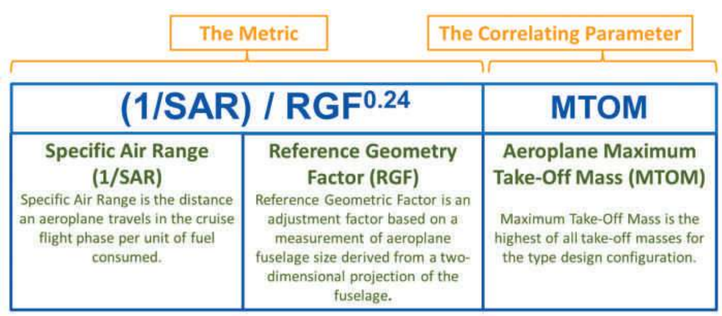


Figure 2. An overview of the CO_2 Metric System

and low gross masses, which are calculated as a function of Maximum Take-Off Mass (MTOM). Each of these represents an aeroplane cruise gross mass seen regularly in service. The objective of using three gross mass cruise points is to make the evaluation of fuel burn performance more relevant to day-to-day aeroplane operations.

1.3 The metric system is based on the inverse of Specific Air Range (i.e. 1/SAR), where SAR represents the distance an aeroplane travels in the cruise flight phase per unit of fuel consumed. In some aeroplane designs, there are instances where changes in aeroplane size may not reflect changes in aeroplane weight, for example when an aeroplane is a stretched version of an existing aeroplane design. To better account for such instances, not to mention the wide variety of aeroplane types and the technologies they employ, an adjustment factor was used to represent aeroplane size. This is defined as the Reference Geometric Factor (RGF), and it is a measure of aeroplane cabin size based on a two-dimensional projection of the cabin. This improved the performance of the CO_2 metric system, making it fairer and better able to account for different aeroplane type designs.

1.4 The overall capabilities of the aeroplane design is represented in the CO_2 metric system by the certified MTOM. This accounts for the majority of aeroplane design features which allow it to meet market demand.

1.5 Based on the CO_2 metric system, CAEP developed procedures for the certification requirement including, inter alia, the flight test and measurement conditions; the measurement of SAR; corrections to reference conditions; and the definition of the RGF used in the CO_2 emissions metric. CAEP utilised manufacturers' existing practices in measuring aeroplane fuel burn in order to understand how current practices could be used and built upon for the new Standard. Based on this information, the ICAO Annex 16 Volume III CO_2 Standard certification requirement was developed; and, pending some future work, this was initially approved by the CAEP/9 meeting in February 2013. This was a crucial component in the CO_2 Standard development and allowed CAEP to move onto Phase 2 of the work.

Phase 2 work – Setting the regulatory limit

ICAO environmental Standards are designed to be environmentally effective, technically feasible, economically reasonable, while considering environmental interdependencies. These four tenets of CAEP guided Phase 2 work, which involved carrying out a comprehensive assessment of the costs and benefits of all the options which could be selected to form the CO_2 Standard. This involved defining an analytical space within which CAEP would work to investigate the options available. This included the development of options for the regulatory limit line, applicability options and dates, and all the associated assumptions which allowed the CAEP working groups to perform the cost-effectiveness analysis required to make an informed decision on the Standard at the CAEP/10 meeting. The foundation of the CAEP/10 recommendation on the CO_2 emissions Standard was supported by this significant data informed process, involving input from ICAO member states and stakeholders. The modelling exercise involved several analytical tools, including fleet evolution modelling, environmental benefits, recurring costs, non-recurring costs, costs per metric tonne of CO_2 avoided, certification costs, applicability scenarios and various sensitivity studies to inform the decision-making process. This work allowed CAEP to conduct an analysis, with the aim of providing a reasonable assessment of the economic costs and environmental benefits for a potential CO_2 standard in comparison with a "no action" baseline.

CHOICES CONSIDERED DURING THE CO_2 STANDARD WORK

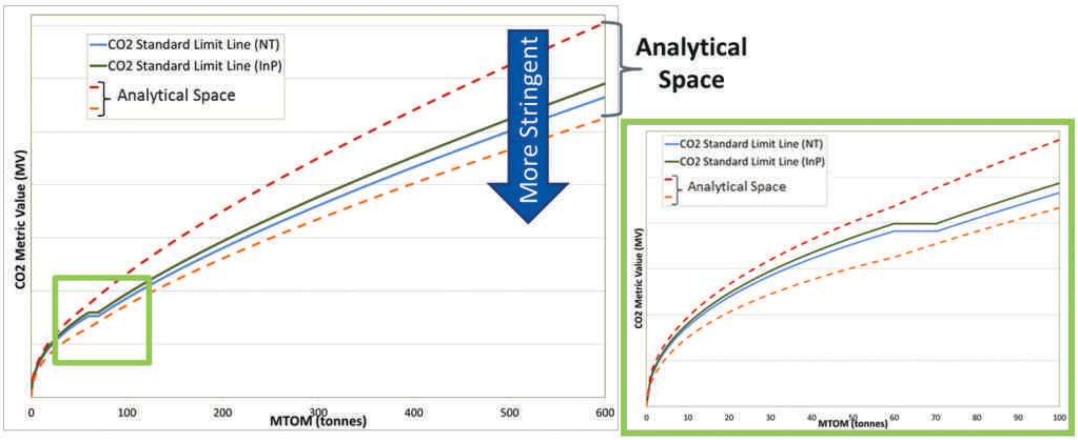
- Ten Regulatory Limit Lines;
- Treatment of aeroplanes above and below 60 tonnes;
- New Type and InProduction applicability;
- Production cut-off; and
- Applicability dates of 2020, 2023, 2025 and 2028.

A full overview of the work and input into the CAEP/10 meeting can be found in the Report of CAEP/10, ICAO Doc 10069.

The decision on the CO_2 Standard

Taking into account all the analysis and data, the CAEP/10 meeting was able to make a recommendation on the first ICAO aeroplane CO_2 Standard.

The Standard will apply to subsonic jet and turboprop aeroplanes that are new type (NT) designs from 2020. It will also apply to in-production (InP) aeroplanes from 2023 that are modified and meet a specific change criteria. This is subsequently followed up by a production cut-off in 2028 which means that InP aeroplanes that do not meet the standard can no longer be produced beyond 2028 unless the designs are modified to comply with the Standard. Figure 3 shows an overview of the CO_2 Standard regulatory limit lines for both NT and InP CO_2 Standards.



The CO_2 Standard covers a broad range of aeroplane masses and types and is especially stringent where it will have the greatest impact: for larger aeroplane types with an MTOM of greater than 60 tonnes. CAEP considers technical feasibility very carefully during the development of environmental standards, and as such, the decision at CAEP10 recognised the fact that the larger aeroplane designs have access to the broadest range of CO_2 emissions reduction technologies. This is less so for aeroplanes below 60 tonnes where the standard provides additional margin for a sector. This is particularly recognised for aeroplanes of MTOMs less than 60 tonnes and with fewer than 19 seats maximum passenger seating capacity, where for new aeroplane type designs the applicability date of the standard is 2023.

A WIDE COVERAGE OF AEROPLANES

The standard is most stringent for larger aeroplanes with an MTOM of greater than 60 tonnes. This accounts for more than 90% of international aviation emissions.

The contribution of the CO_2 Standard to reducing CO2 emissions from international aviation

It is complex to fully understand the impact of the CO_2 Standard due to potential unknown market driven responses to the regulation, and the fact that the CO_2 Standard cost-effectiveness analysis was a comparative investigation of regulatory limit lines. However, it is clear that the new standard will have direct effects by increasing the importance of fuel efficiency in the design process such that an aeroplane type not just meets the regulatory limit but also has good relative product positioning in terms of a margin to the limit.

The Aeroplane CO_2 emissions certification Standard is currently going through the adoption process within ICAO. This has involved a review for the Air Navigation Commission (ANC), a consultation process with all the 191 ICAO Member States, and on 3 March 2017, the Standard was adopted by the ICAO Council. Following this, the First Edition of Annex 16, Volume III should become applicable during the latter part of 2017.

References

ICAO Circular 337 - CAEP/9 agreed certification requirement for the aeroplane CO_2 emissions standard

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Land Use and Environmental Management

Land Use and Environmental Management

INTRODUCTION

In recent years, there has been increased public concern regarding the protection of the natural environment from the impact of transportation, and consequently, a growing emphasis on the need to employ effective measures to minimize such impacts. Since pollution may be generated within an airport as well as within the area surrounding it, environmental management practices should be applied at the airport and its environs.

The need for land-use planning in the vicinity of an airport was recognized in the early history of civil aviation and focused on use and control of land. The objectives of these measures were to ensure the safety of people in the air and on the ground and to maintain efficient airport operations. In recent years, there has been increased public concern regarding the protection of the natural environment from the impacts of transportation.

To lessen local and global impacts, it is important that the civil aviation industry endeavors to manage environmental impacts. This includes operational impacts such as emissions, noise, and the management of solid and hazardous wastes.

BACKGROUND

ICAO Doc 9184 Airport Planning Manual is focused on master planning at an airport. The Airport Planning Manual Part 1 (APM Part 1) is primarily focused on operational safety and efficiency. The ICAO Doc 9184 Airport Planning Manual Part 2 – Land Use and Environmental Management (APM, Part 2) is focused on land use and environmental management on and around an airport. The purpose of APM, Part 2 is to provide effective practices at an airport to reduce the potential environmental effects caused by the airport and its operations.

The scope of APM, Part 2 does include information on impacts from ground sources, but does not focus on reducing the impacts of aircraft in-flight. The recommendations and considerations for airport planning from APM, Part 1 should always be considered in cooperation with the information provided in APM, Part 2 to manage environmental impacts.

The APM Part 2 was released in the early 1980s as a guidance document for new airports. Over time, it was recognized as a valuable tool for existing and expanding airports. Since 1996, it has been continually updated by the ICAO Committee on Aviation Environmental Protection (CAEP) Working Group 2 "Airports and Operations" to reflect new and emerging knowledge in the area of environmental management and land-use planning. An update in 2016 expanded the information related to recommended infrastructure decisions to facilitate environmentally-friendly airport design and management.

The following sections outline the essential areas of the APM, Part 2:

- Environmental Impacts Associated with Aviation Activities
- Environmental Management Measures and Considerations
- Infrastructure for Environmental Management
- Land Use
- Land-Use Planning
- Land-Use Administration
- Heritage Considerations
- Climate Change Resilience and Adaptation

GENERAL

The compatibility of an airport with its environs can be achieved by proper planning of the airport, management of pollution-generating sources, and land-use planning of the area surrounding the airport. The aim is to provide the best possible conditions for the needs of the airport, the community in the surrounding area, and the ecology of the environment. The location, size and configuration of the airport needs to be coordinated with patterns of residential, industrial, commercial, agricultural and other land uses of the area, taking into account the effects of the airport on people, flora, fauna, the atmosphere, water courses, air quality, soil pollution, rural areas and other facets of the environment.

To the extent that safety and operational considerations permit a choice, decisions on runway alignment and other airport development should take into account their potential effects on the environment in order to prevent or minimize environmental conflicts. In effect, "land-use management" is a term which describes only a portion of the total planning process, and even highly innovative management practices can have little impact unless they are imposed within the context of sound policies and careful planning. "Land-use planning" or "planning for compatible land uses which takes into account the needs of airport development" more adequately describes the process of achieving an optimum relationship between an airport and its environs.

Pollution occurring in and around the airport can have an effect on human health and the ecology of a broad area surrounding an airport. Efforts should be made towards pollution prevention in the first instance and impact management in the second instance. Environmental management thus provides a means of either decreasing pollution at the source or reducing the potential for negative environmental impacts. Environmental management includes items such as air and water quality guidelines, aircraft engine or ground-sourced noise limits, waste management plans, environmental emergency plans, and environmental management plans. By planning for intended growth and development, estimations can be made about the type and extent of potential future environmental impacts to allow for a more integrated approach to environmental management.

ENVIRONMENTAL IMPACTS ASSOCIATED WITH AVIATION ACTIVITES

APM Part 2 identifies most of the major environmental issues that may be directly associated with air transport and civil aviation in particular. The environmental issues described focus on land use, soil erosion, impacts on surface and subsurface water drainage, and the impact on flora and fauna. For each environmental issue presented, a brief description is provided, including a summary of past and present ICAO activities aimed at mitigating the issue, as well as comments on the relevant activities of other organizations, whenever pertinent.

ENVIRONMENTAL MANAGEMENT MEASURES AND CONSIDERATIONS

Implementation of environmental management measures at airports and surrounding areas is in the best interest of the airport operators, the community and the natural environment. These measures may include compliance with international standards and national and/or local regulations. They are implemented by airports, often in collaboration with airport stakeholders. When planning infrastructure development, an airport operator should consider how environmental management will be integrated to reduce the impacts on operations and the environment.

Some measures limit pollution at its source, while others reduce its effect on communities and ecosystems. An Environmental Management System (EMS) is seen as the best method to incorporate environmental management into all levels of corporate operations and decision making processes. A well, planned EMS at an airport can help to manage environmental impacts.

Airport operators can reduce the environmental impacts of their operations by incorporating environmental management plans and procedures with land-use planning. Several important components of environmental management at an airport are noise mitigation, emissions reduction and pollution prevention. Pollution prevention includes the use of materials, processes and practices that reduce or eliminate the creation of pollutants and wastes at the source. Adequate pollution prevention pre-empts the need for remedial actions later.

INFRASTRUCTURE FOR ENVIRONMENTAL MANAGEMENT

APM Part 2 provides high-level guidance material on the infrastructure that can be included in an airport design that can enable and facilitate environmental management by the airport operator.

LAND USE

Land use around airports can impact community exposure to the environmental effects of airport operations. As guidance on proper airport and land-use compatibility planning, APM Part 2 presents a variety of possible land uses with a broad appreciation of their relative sensitivity to the operational safety of aircraft and airport operations, local third party risk and aircraft noise exposure, and describes their compatibility with aircraft noise and airport operations.

LAND-USE PLANNING

Land-use planning is an effective means to ensure that the activities nearby airports are compatible with aviation activities. Its main goal is to minimize the population affected by aircraft noise by introducing land-use planning measures, such as land-use zoning around airports. Compatible land-use planning and management based on appropriate "planning" noise contours, rather than "current" noise contours, can prevent encroachment of residential development at airports where future aircraft noise levels are projected to increase.

ICAO Doc 9829 Guidance on the Balanced Approach to Aircraft Noise Management provides guidance on alleviating the problem of noise in the vicinity of airports. This Balanced Approach recommends consideration of four noise management pillars, one of which is land-use planning.

There are substantial benefits to be gained from the correct application of land-use planning techniques in the development of airports. While these benefits should not be overstated, more attention should be given to proper land-use planning as a tool with the main objective being to minimize the population affected by aircraft noise.

Land-use planning benefits may take time to be fully realized and should be implemented as soon as noise problems are foreseen.

LAND-USE ADMINISTRATION

Noise exposure is not the only factor to be taken into account for the purpose of land-use management in the vicinity of airports. It is recognized that economic factors are involved in land-use choices. Ideally, land-use decisions around airports would try to find a compatible balance between the interests in the land and the aeronautical use of the airport. For this reason, the authorities, local or central, have an important part to play in ensuring that aircraft noise exposure is taken into account when planning land-use in the vicinity of airports and that the ensuing plans are implemented.

There are many techniques for regulating development or bringing about conversion or modification of existing land-uses to achieve greater compatibility between the airport and its environs. Some of these may be controls, such as zoning or building and housing codes; other methods influence development through acquisition or taxation. The desired goal is for effective land-use planning based on objective criteria to minimize the amount of noise-sensitive development close to airports, while allowing for other productive uses of the land.

HERITAGE CONSIDERATIONS

Airports may be located within or close to natural or cultural environments that have aesthetic, historic, scientific, social or national significance which States may wish to protect for future generations. Airports may also include buildings and artefacts on site which are deemed to have heritage values. It is important, therefore, to consider in the planning of airport infrastructure whether any development proposal may impact upon heritage elements at the airport and how such impacts may be mitigated.

CLIMATE CHANGE RESILIENCE AND ADAPTATION

The level of greenhouse gas emissions in the atmosphere is understood to be having an effect on climate and will continue to do so into the future. According to the Intergovernmental Panel on Climate Change, "Climate change is projected to amplify existing climate-related risks and create new risks for natural and human systems".

Going forward, despite States' agreement to limit global warming through the United Nations Framework Convention on Climate Change, the effects of a changing climate on human activities are expected to intensify; this presents risks and challenges for all sectors of society including the transportation sector.

APM Part 2 identifies possible impacts, risks and vulnerabilities and provides examples of effective adaptation and resilience practices to reduce projected climate change impacts on airports. Airports are often classified as critical infrastructure by their States and regions as they facilitate mobility, economic growth, and provide essential services during disaster and emergency recovery situations. Moreover, any disruption that results in a loss of capacity at one airport can have a ripple effect throughout the wider network. In this context, it is important to develop resiliency against the projected effects of climate change, as they may negatively impact service continuity for aircraft and airport operations.

The APM Part 2 provides guidance on how to address potential climate impacts in order to build more climate resilient infrastructure.

This article has been extracted from the ICAO Environmental Report - 2016.