International Civil Aviation Organization
WORKING PAPER

GROUP ON INTERNATIONAL AVIATION AND CLIMATE CHANGE (GIACC)

FOURTH MEETING

Montréal, 25 to 27 May 2009

Agenda Item 3: Report actions and policy elements developed by the Working Groups

PROGRESS REPORT OF GOALS DEVELOPMENT WORKING GROUP

(Presented by the Chairman of the Working Group)

1. Background

1.1 Between GIACC/2 and /3, Working Group (WG) 1 identified fundamental matters for GIACC's consideration at its third meeting. Of central importance, it recommended two short-term fuel-efficiency goals: (1) a global fuel-efficiency target by 2012 (e.g., XX liters of fuel/100 RTK) and (2) a rate of annual fuel-efficiency improvement from 1990 to 2012 of X%/year. Considering ICAO, OAG, and industry-submitted data, WG 1 noted a range of annual fuel-efficiency improvement by 2012 from 1.7%/year to 2.1%/year. GIACC/3 noted an indicative agreement on a short-term fuel-efficiency goal of 2.0%/year improvement with a view to revising this based on further information.

1.2 WG 1 acknowledged some difficulty in establishing medium- and long-term goals. Timeframes, it indicated, should generally be along those of the UNFCCC (i.e., 2020 MT and 2050 LT), although it did note one State suggesting 2025 for the medium term. Discussion about identifying fuel efficiency goals in the medium and long terms centered on the difficulty of identifying credible data on which to base such goals. In addition, some expressed the view that more stretching goals should be set, while others were of the opinion that aspirational goals should be expressed in the form of fuel efficiency only

1.3 The Goals Development Working Group (WG 4) was created to continue and advance the efforts of WG 1. WG 4 was also to consider industry's input from GIACC/3 in its efforts to develop possible medium- and long-term goals for the GIACC's review. It should be recalled then that industry suggested that it could achieve fuel-efficiency improvements, compared to 2005 levels, of 15% in 2012 (about 2.1% annually), 29% in 2020 (about 1.9% annually), and 50% by 2050 (about 1.1% annually). Industry was invited to provide further input to WG 4 but did not.

2. Metrics

2.1 The group's discussion on the definitions of fuel efficiency and fuel efficiency metrics adjusted for carbon content (to take into account fuels made from renewable sources and market-based measures) evolved into a discussion of metrics.

2.2 For **<u>fuel efficiency</u>**, there was general consensus that Volume/RTK, as developed by WG 1, is a good initial metric. However, some countries considered the need for a metric to take into account carbon intensity, to enable determination of efficiency improvements achieved through sustainable alternative fuels for aviation or market-based measures. The fuel efficiency metric would be a component of this broader metric, which was named a "**<u>Net CO_2 Intensity Metric</u>**" for the purposes of our discussion. European representatives proposed a formula that would take into account such developments.

2.3 The group discussed offsets and the degree to which a carbon-intensity formula could accurately reflect reductions in other sectors. Similarly, there was concern about the degree to which the carbon intensity formula would take into account mass vs. volume of fuel. The group noted that WG 1 had proposed two possible fuel-efficiency formulas, each using mass or volume. The group suggested that the fuel-efficiency formula, Volume/RTK, could be expanded into a larger formula which would include kg/Volume (fuel density), and CO_2/kg (carbon factor), and MBM Reductions/RTK (carbon reductions from market-based measures):

$$\text{"Net } CO_2 \text{ Intensity Metric"} = \overbrace{\left(\frac{Vol_{\text{fuel}}}{RTK}\right)}^{\substack{\text{Fuel Efficiency}\\ \text{Metric}}} \cdot \overbrace{\left(\frac{Mass_{\text{fuel}}}{Vol_{\text{fuel}}}\right)}^{\substack{\text{Fuel}\\ \text{Density}}} \cdot \overbrace{\left(\frac{Mass_{CO_2}}{Mass_{\text{fuel}}}\right)}^{\substack{CO_2\\ \text{Factor}}} - \overbrace{\left(\frac{\text{MBM Reductions}}{RTK}\right)}^{\substack{\text{Market-Based}\\ \text{Measures}}}$$

2.4 Japan noted that the goals should be established based on Volume/RTK, while as to sustainable alternative fuels, appropriate conversion factors should be developed (refer to Para. 29 of WG1 report) and that complex terms such as fuel density should be avoided.

2.5 There was also discussion regarding the notion of establishing each efficiency goal in terms of a fixed fuel volume per 100 revenue-tonne kilometers (*vol/100RTK*) at each of the various goal end dates (i.e., 2020/2025 and 2050), as was suggested by WG 1 (see para. 38, GIACC/3 – WP/2). This global goal would be established based upon the percent reductions that were discussed, as applied to the international aviation system. An absolute value global aspirational goal has an advantage in that when it is considered in the context of individual aviation systems, various systems could undertake different actions to achieve the global goal. An absolute value may also help in communicating a more concrete and transparent goal. Japan noted that if an absolute fuel efficiency goal were adopted, it should be based on actual data rather than calculated inputs based on certain assumptions.

3. Definitions

3.1 The group considered how to define carbon neutral growth and carbon neutrality, based on a paper submitted by Australia (copy attached). The group reflected on the degree to which the aviation sector could globally achieve carbon neutral growth using technology and operational improvements alone. In the event that this would not be possible, as several suggested, the group discussed the paper's intent of defining achievement of carbon neutral growth and carbon neutrality through the additional use of offsets. In particular, the paper states:

> "<u>Carbon neutral growth</u> occurs when the net carbon footprint of the aviation industry does not exceed a chosen baseline value in any given year."

> "<u>Carbon neutrality</u> is achieved when the net carbon footprint of the aviation industry equals zero – that is, when the gross carbon footprint is fully offset. The most likely route to this goal would be through the purchase of CO_2 offsets at least for the foreseeable future. An industry ambition is

that carbon neutrality be achieved in the long term through the use of biofuels."

3.2 While acknowledging that it is better to use "CO_2 emissions" rather than "carbon footprint" to avoid misunderstanding and while needing further discussion, these constructs were useful in the group's later conversations.

4. Choosing a Baseline Year

4.1 The basis of conversation for the in-person meeting held by Working Group 4 was comprised of responses to a set of guiding questions submitted to each of the participants (copy attached). The questions sought to understand each State's thinking regarding a possible baseline year, possible aspirational goals in terms of fuel efficiency in the short, medium, and long terms, and possibilities for aspirational goals that would indicate stronger ambition.

4.2 Regarding selection of a baseline year for medium and long terms, there were two specific suggestions 2000 and 2005. Some countries suggested baselines set in the future, which raised concerns for others, sending signals that could potentially encourage more emissions. There was also a request for information to better understand the emissions circumstances of 2000 vs. 2005 globally and regionally (table attached, supplied by the ICAO Secretariat). The group also noted that timeframes for goals should be generally consistent with UNFCCC timelines.

5. Fuel Efficiency Goals

5.1 The group agreed that all goals, including the fuel efficiency goals, would be at a global level, non-binding and applicable only to international aviation with no responsibility or obligation for action attributable to any individual ICAO Contracting State. States may choose to pursue these goals at certain rates which allow them adequate space for development of their aviation industries, taking into account their various national circumstances and capacities. China emphasized that it is crucial for developed nations to take a leading role in pursuing these goals. In addition, China and Brazil stressed the importance of developed states helping developing states in their capacity building to improve fuel efficiency to contribute to these global goals.

5.2 **Short Term -** Following the discussion at GIACC/3 and absent new information, the group agreed on a 2% annual fuel-efficiency improvement until 2012, based on historic trends.

5.3 **Medium Term -**The group's discussion coalesced around a range of options from 2% to 2.5% annual improvement from 2013 to 2020 or 2025. While most suggested 2020 as the target date for the medium term, the United States proposed 2025 as it allows for more time for greater ambition, particularly for ATM procedures and technology to make an impact. Discussions revolved around whether 2.5% was too ambitious. Several states emphasized the need to make the medium term goal as achievable as possible. The United States noted the aspirational nature of the framework to be proposed by GIACC, which by definition must reach beyond what is possible today, be more ambitious, and set a bar that will encourage innovation and investment.

5.4 **Long Term -** The range of options runs from 2% to 3% annual improvement from 2021 or 2026 to 2050. There was concern expressed here about the certainty of predicting possible fuel-efficiency improvements so far into the future. One State suggested that a political statement with possible scenarios may be a more appropriate approach. Discussions revolved around whether 3% was too ambitious. The United States offered to provide a paper to explain its support for 2.5 to 3% aspirational goal of annual improvement to 2050 (attached).

6. Goals Indicating Stronger Ambition

6.1 There was recognition that fuel efficiency improvement alone will not get the sector to carbon neutral growth globally and that there could be need for additional measures beyond fuel efficiency for those States that so choose. The group considered additional goals that could indicate stronger ambition. For the medium term, the discussions focused on a goal of carbon neutral growth. It was generally acknowledged that the carbon-intensity formula would be a useful tool to show progress toward this goal.

6.2 With regard to the long term, discussion focused on carbon reductions. The European proposal that, in 2050, aviation should maintain the same percentage share of global emissions as it had in 1990 was shared. As serious concerns were raised, and no other proposals were put forward yet, further discussion is needed for a possible long term goal.

6.3 The notion of a “bouquet” or range of goals was discussed. This could be particularly useful in that a general goal would be set for all, and some countries may go further to show leadership, if they can. However, some expressed concern that the lower level of the range would be seen by critics as allowing a lower level of ambition.

6.4 China introduced the notion of per-capita emissions in the context of the metric, but after discussion, some countries indicated it could have more potential as a threshold for indicating when a country should seek to achieve more ambitious goals. However, some concerns were raised, and further discussion would advance understanding of this idea.

6.5 Both Brazil and China stated that medium and long term goals beyond fuel efficiency should take into account on-going UNFCCC climate negotiations. However, other countries stated that this could complicate GIACC fulfilling its mandate. Further discussion is needed regarding goals indicating stronger ambition.

7. Assistance to Developing Countries

7.1 GIACC has considered extensively the idea that developed States should assist developing States with measures to allow them to contribute to global aspirational goals. Working Group 2 provided a list of measures and principles in this spirit. While not within the direct purview of Working Group 4, there was continued acknowledgement among the participants that assistance initiatives between States and drawing on the development banking community will be central to the overall successful implementation of GIACC’s recommendations.

8. Summary of Possible Goals and Timeframes

Baseline: 2000 or 2005

Options for Fuel Efficiency Goals:

	Goal: Efficiency Improvement	**Target Date(s)**	**Comment**
Short Term	2% annual improvement in efficiency	2012	Extension of current trends.
Medium Term	2.0%-2.5% annually starting 2012 (further discussion needed)	2020 or 2025	Ambitious. A range approach will better reflect the risk of achieving the goal and the level of ambition set by States for aviation system. Some concern over achievability.
Long Term	2.0%-3% annually starting 2020 or 2025 (further discussion needed)	2050	Highly ambitious. The upper end of the range would be nearly 50% more than industry target. Significant uncertainty regarding technology and States' level of ambition. Some concern over achievability.

Options for Goals to Indicate Stronger Ambition: Further Discussion Needed

	Goal	**Timeline**	**Comment**
Medium Term	Carbon Neutral Growth	2020 or 2025	Ambitious. For some, possible only with market-based measures. Must be calculated with net carbon intensity formula. As with other goals, aspirational and global. Triggers, such as per capita, could indicate when a State should use best efforts to contribute to goal. Further discussion is needed.
Long Term	Reduction: Global sector represents same percentage of emissions as in 1990	2050	European proposal. Several concerns expressed. Discussion recognized additional options need development/consideration.

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APPENDIX A
English only

GIACC Goals Development Group – WG4

Defining 'Carbon Neutrality'

Summary

In order to assist the Group in its deliberations on carbon neutrality, the paper puts forward draft definitions of the key terms such as 'carbon neutral growth'.

Estimations of the costs associated with applying the suggested definitions to international aviation indicate that:

i) carbon neutral growth, using 1990 as the base year, could be achieved at a cost of about \$5/passenger at a CO_2 cost of \$20/tonne

ii) carbon neutrality could be achieved at a cost of approximately \$10/passenger at a CO_2 cost of \$20/tonne.

(Submitted by the Adviser Australia)

1 Introduction

1.1 The terms of reference for the GIACC Goals Development Group require the Group to '*Assess the scope for additional goals and statements to indicate a strong ambition for addressing emissions, including **in the form of carbon neutrality**.*'

1.2 At the present time there appears to be no common understanding on the meaning of the terms *'carbon neutral growth'* and *'carbon neutrality'*. Agreement on the definition of these two terms is clearly a prerequisite for assessing the scope for using these concepts within ICAO.

1.3 In the absence of an agreement on the definition of the terms it has not yet been possible to inject into the GIACC process estimations of the magnitude of the costs of adopting carbon neutrality concepts.

1.4 This paper proposes, for discussion purposes, draft definitions of the terms *'gross carbon footprint'*, *'net carbon footprint'*, *'carbon neutral growth'* and *'carbon neutrality'* and provides estimates of the magnitude of the average costs if carbon neutral concepts, based on these definitions, were adopted as goals for international aviation.

2 Draft Definitions

2.1 Gross Carbon Footprint

2.1.1 In this context **Gross** carbon footprint means the actual CO_2 emissions generated by international aviation in one year.

2.1.2 The magnitude of growth in international aviation's **Gross** carbon footprint is determined essentially by the difference between two factors

- *Growth* – the rate of growth in demand for international aviation
- *Technology* – the rate at which fuel efficiency measures can be adopted by the aviation industry.

2.1.3 Since 1990, Growth has outstripped Technology at a rate of about 3% per year – that is, the **Gross** carbon footprint of international aviation is growing at about 3% per year.

2.2 Net Carbon Footprint

2.2.1 In circumstances where Technology cannot keep pace with Growth, the magnitude of aviation's **Net** carbon footprint can be managed through the purchase of offsets using some form of economic instrument.

2.2.2 The relationship between **Net** and **Gross** carbon footprint can be expressed in the following expression:

Net CO_2 emissions = (**Gross** CO_2 emissions) – (CO_2 emissions purchased through offsets).

2.3 Carbon Neutral Growth

2.3.1 Carbon neutral growth occurs when the **Net** carbon footprint of the aviation industry does not exceed a chosen baseline value in any given year.

2.3.2 In circumstances where Technology is able to match or outstrip Growth, carbon neutral growth is achieved without the purchase of offsets. When growth in demand exceeds gains in efficiency there is a 'CO_2 gap'; in these circumstances carbon neutrality can be achieved by purchasing CO_2 offsets equal in magnitude to the 'CO_2 gap'.

2.3.3 A carbon neutral growth strategy is usually implemented by selecting a baseline year and then ensuring that the net annual emissions do not exceed the baseline during any future year. Based on experience over the past two decades, the industry will generally, but not always, need to purchase CO_2 offsets in order to achieve carbon neutral growth.

2.4 Carbon Neutrality

2.4.1 Carbon neutrality is achieved when the **Net** carbon footprint of the aviation industry equals zero – that is, when the **Gross** carbon footprint is fully offset. The most likely route to this goal would be through the purchase of CO_2 offsets at least for the foreseeable future. An industry ambition is that carbon neutrality be achieved in the long term through the use of biofuels.

2.5 Explanatory Diagram

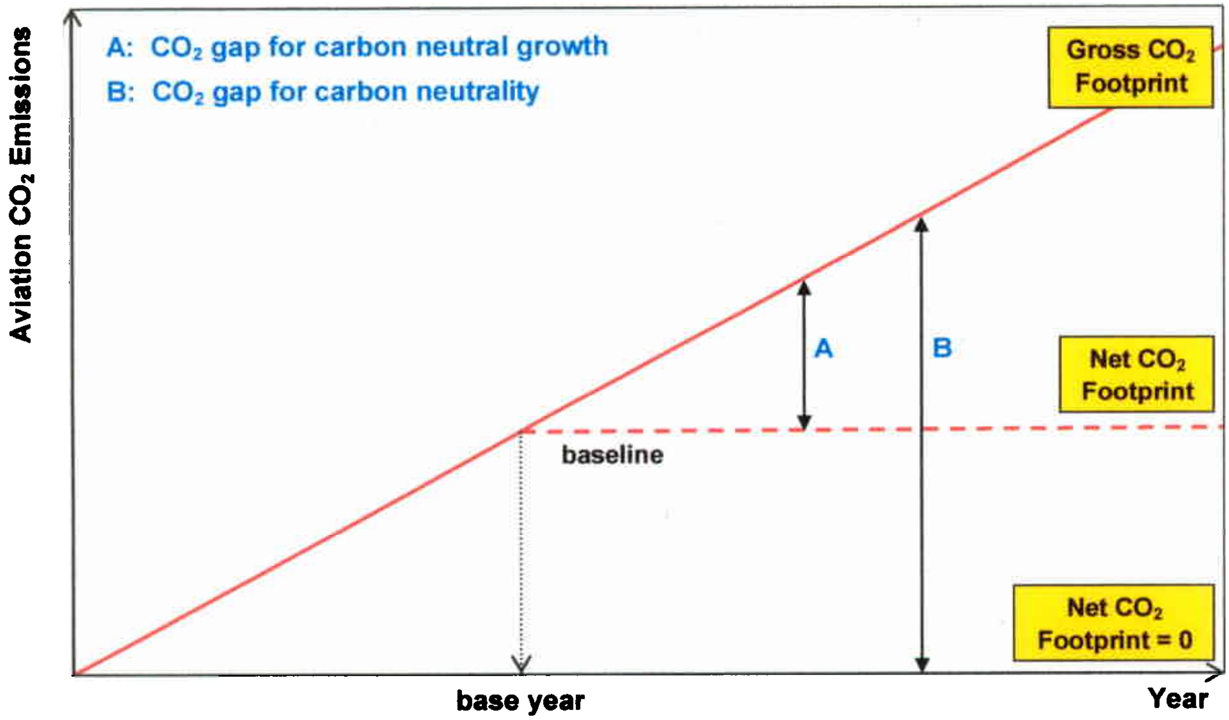
2.5.1 The concepts described in sections 2.1 to 2.4 are illustrated in Figure 1.

3 Implementation Hierarchy

3.1 If a goal incorporating carbon neutral concepts is to be adopted it is fundamental that the following implementation hierarchy underpin the goal:

i) priority be given to minimising the **Gross** carbon footprint of aviation through technology
ii) CO_2 offsets be purchased to bridge any 'CO_2' gap when technology gains fail to keep pace with growth in demand.

Figure 1: Illustration of carbon neutral growth and carbon neutrality



4 Estimation of Costs

4.1 This section provides indicative estimations of system wide costs for *'carbon neutral growth'* and *'carbon neutrality'* for international aviation based on fuel use and passenger data sourced from ICAO.[1] Three scenario costs for carbon ($20, $40 & $100 per tonne of CO_2) are used to show illustrative costs. The costs shown in the graphs are global averages based on $/passenger – on short routes the costs will be less than the average while on long haul routes the costs will be significantly higher. In a similar manner, there may be significant variations in the costs between different global regions.

4.2 Carbon Neutral Growth – 1990 baseline

4.2.1 Figure 2 indicates that if a carbon neutral growth policy were adopted using 1990 as the base year costs would currently be of the order of $5/passenger at a CO_2 cost of $20/tonne. This cost per passenger has remained relatively stable throughout this decade.

4.3 Carbon Neutral Growth – 2000 baseline

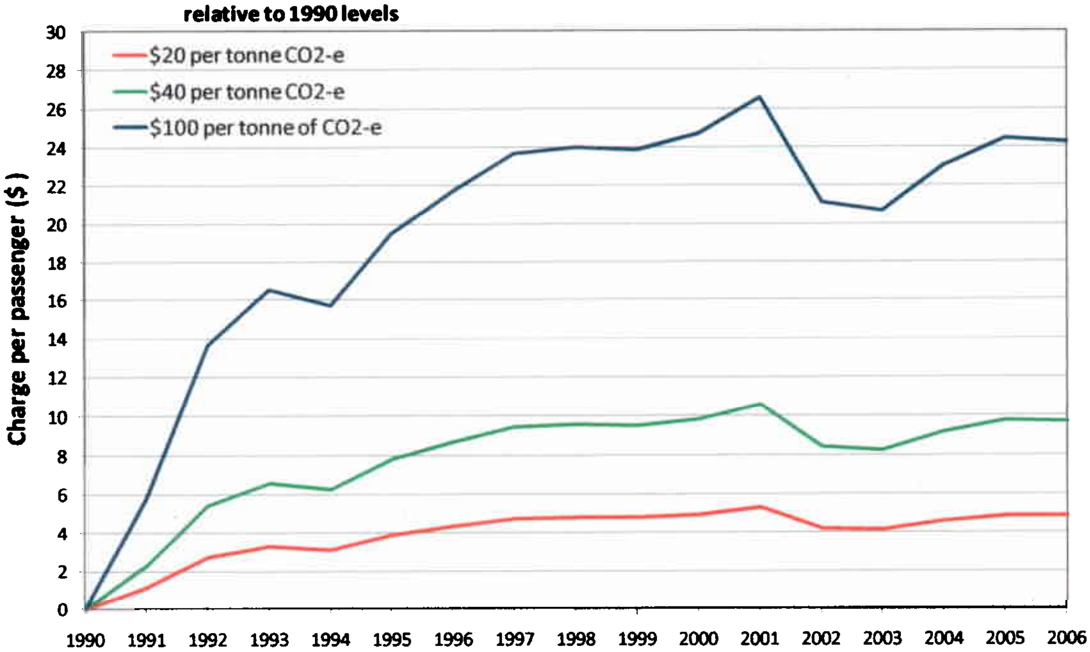
4.3.1 Figure 3 indicates that if a carbon neutral growth policy were adopted using 2000 as the base year, costs would currently be of the order of $1/passenger at a CO_2 cost of $20/tonne. It can be seen that for the years 2002 and 2003 carbon neutral growth would have been achieved without the need to purchase any CO_2 offsets.

[1] The annual weight of CO_2 emissions has been calculated by multiplying the annual tonnage of aviation fuel used in international aviation by a factor of 3.16. This has been reduced to a per passenger basis using annual global international aviation passenger numbers. The fuel consumption data was provided by ICAO's *Economic Analyses and Databases Section*, Air Transport Bureau, while passenger data is from ICAO's *Annual Report of the Council*, various years (http://www.icao.int/annualreports).

4.4 Carbon Neutrality

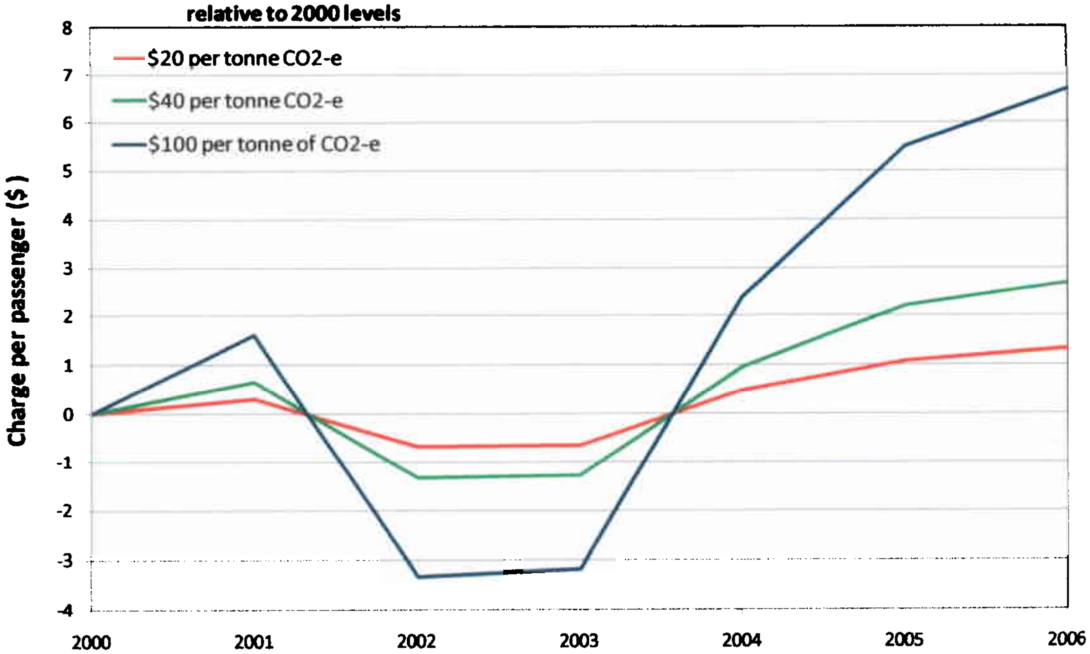
i) 4.4.1 Figure 4 shows the annual costs of achieving carbon neutrality for international aviation since 1990. It can be seen that the magnitude of this cost has been steadily declining as efficiency gains have been achieved. Carbon neutrality could be achieved at a cost of approximately $10/passenger at a CO_2 cost of $20/tonne.

Figure 2: Carbon neutral growth cost per passenger for global international airline scheduled services relative to 1990 levels



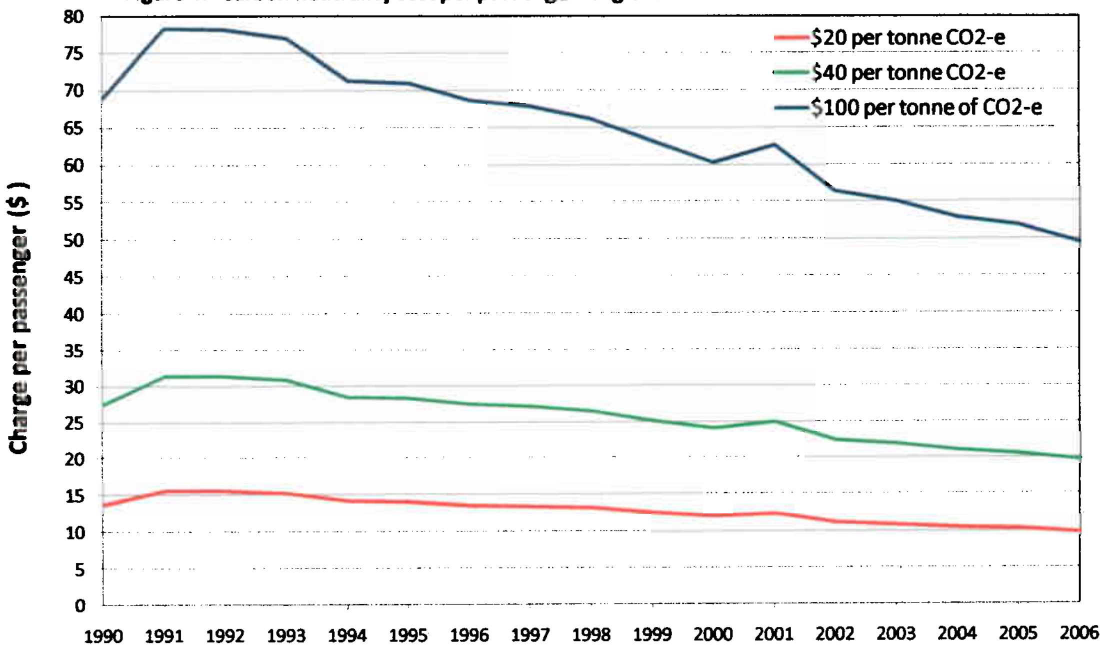
Source: Emissions were calculated using ICAO fuel consumption estimates of global international scheduled services based on OAG data, Economic Analyses and Databases Section, Air Transport Bureau, ICAO. Passenger data is from ICAO, *Annual Report of the Council*, various years (http://www.icao.int/annualreports).

Figure 3: Carbon neutral growth cost per passenger for global international airline scheduled services relative to 2000 levels



Source: Emissions were calculated using ICAO fuel consumption estimates of global international scheduled services based on OAG data, Economic Analyses and Databases Section, Air Transport Bureau, ICAO. Passenger data is from ICAO, *Annual Report of the Council*, various years (http://www.icao.int/annualreports).

Figure 4: Carbon neutrality cost per passenger for global international airline scheduled services



Source: Emissions were calculated using ICAO fuel consumption estimates of global international scheduled services based on OAG data, Economic Analyses and Databases Section, Air Transport Bureau, ICAO. Passenger data is from ICAO, *Annual Report of the Council*, various years (http://www.icao.int/annualreports).

5 Recommendation

5.1 For discussion.

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APPENDIX B
English only

"Guiding Questions" for Working Group 4 – Goals Development
March 25, 2009

Terms of Reference

1. For the short term global aspirational goal for fuel efficiency, review available data to determine whether the 2% per year indicative figure supported at GIACC/3 is the most appropriate.

2. Progress the development of possible medium and long-term global aspirational goals based upon fuel efficiency in consultation with CAEP and on consideration of available data on industry trends and relevant forecasts.

3. Assess the scope to develop a global aspirational goal for carbon neutrality having regard to fuel efficiency trends and time frames. **[Alternative language to be clarified by the Secretariat: Assess the scope for additional goals and statements to indicate a strong ambition for addressing emissions, including in the form of carbon neutrality.]**

4. Review other goals provided by industry and others with respect to level of ambition for addressing emissions from international aviation.

5. Deliver a report to GIACC/4 with options and supporting information.

Definitions

Global aspirational goal: A non-binding goal, applicable only to international aviation, with no responsibility or obligation for action attributable to any individual ICAO Contracting State.[*]

Fuel efficiency metric: Liters (gallons) of fuel consumed / Revenue Ton Kilometers (miles) with provision made to modify in future based on carbon content of fuel. *

Timelines:* Short-term: 2012
Medium-term: No agreement
Long-term: 2050

Carbon neutral: Carbon neutral means that the growth of carbon dioxide from aviation fuel burn will not exceed a base year level regardless of the increase in level of operations.

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[*] Terms generally accepted at the GIACC 3 meeting.

Carbon reduction: Carbon reduction means that the growth of carbon dioxide from aviation fuel burn will be less than the base year level regardless of the increase in level of operations.

Guiding Questions

Given the terms of reference, there are a number of key issues on which our group should try to reach agreement. Please bear in mind the progress we made in discussions of a way forward from GIACC/3 on concerns raised by developing nations as you address concerns and rationales. The questions include:

1. Based on information available, is a 2% annual improvement in fuel efficiency an appropriate short-term goal through 2012?

2. Based on your review of CAEP, industry and other information on medium and long-term fuel efficiency gains, would you recommend more ambitious global aspirational goals in the medium and long term than those provided by industry?

3. For a fuel efficiency target for the medium term global aspirational goal, what date and what target rate would you suggest?

4. For a fuel efficiency target for the long-term global aspirational goal, what date and what target rate would you suggest?

5. What scope do you see for achieving carbon neutral growth as a medium term goal? What base year and what target year would you suggest?

6. What scope do you see for achieving carbon neutral growth as a long-term goal? What base year and what target year would you suggest?

7. What scope do you see for achieving carbon reduction growth as a medium term goal? What base year and what target year would you suggest?

8. What scope do you see for achieving carbon reduction growth as a long-term goal? What base year and what target year would you suggest?

9. Under what conditions would you agree to a global aspirational goal other than fuel efficiency?

10. Would you prefer a single point target for medium and long-term aspirational goals or a range?

11. Would you prefer a single baseline year and target year for medium and long-term aspirational goals or a range?

Goals	Efficiency Target	Timeline	Other Target	Timeline	Comment
Short Term					
Medium Term					
Long Term					

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APPENDIX C
English only

Potential Aircraft Fuel Consumption Reduction Aspirational Goals and their Implications to Fuel Consumption Trends

Introduction

Total aviation fuel consumption is a function of the number of aircraft operating in the airspace system, how those aircraft operate, and the fuel consumption technology characteristics of those aircraft and the engines that power them. This paper focuses on understanding potential fuel consumption technology characteristics of future aircraft. Predictions of the numbers of aircraft in the airspace system and how those aircraft will operate are outside the scope of this paper.

To understand the implication of fuel consumption technology characteristics, the paper briefly discusses ICAO and U.S. Government estimates for aviation fuel consumption trends. Fuel consumption can be considered a direct surrogate for CO_2, a primary Greenhouse Gas (GHG) emission for aviation. Any alternative aviation fuels which can act as a 'drop-in' aviation fuel will not significantly impact fuel consumption, though they may lead to GHG reductions when the full life-cycle (including production) is considered.

ICAO goals

The Modelling and Databases Task Force (MODTF) of ICAO's Committee on Aviation Environmental Protection (CAEP) is the group responsible for modeling of various scenarios to capture future trends in aviation noise, air quality emissions, and GHG emissions.

MODTF recently completed an initial analysis of the trends in global aviation fuel consumption. The analysis assumes a growth in the numbers of operations from the baseline year of 2006 out to 2036 based on the consensus forecast of the CAEP's Forecasting and Economics Support Group (FESG). The fuel consumption growth is mitigated to varying degrees by the implementation of various technology improvement scenarios, which are discussed in more detail in Appendix A.

From a starting point of about 191 Megatons of total aviation fuel consumed in 2006, MODTF predicts a range of annual fuel consumption in 2036 from a "non-interference" scenario fuel consumption of about 800 Megatons, to an optimistic technology and operational improvement scenario fuel consumption of about 500 Megatons. Alternative fuels were not considered in the MODTF analysis. The most optimistic scenarios required MODTF to assume technology improvement more ambitious than those recommended by the manufacturing industry. The more aggressive scenarios were recommended by government and research entities as a way of bounding the potential improvements and to provide a sensitivity analysis for policy-makers.

U.S. National fuel consumption reduction technology goals

The U.S. Government, in the National Plan for Aeronautics Research and Development and Related Infrastructure (National Science and Technology Council, December 2007), has adopted fuel consumption reduction goals for new aircraft. This National Plan has articulated these goals as N+1, N+2, and N+3 technology generations. The "N" refers to the baseline generation level of the aircraft. The associated numbers refer to subsequent technology generations. The U.S. National goals are discussed in more detail below. The National Goals also include ambitious targets for reducing aircraft noise and air quality emissions (primarily Oxides of Nitrogen emissions, NOx). There are tradeoffs among the goals, and it may not be possible to achieve all goals simultaneously.

Technology generation N+1

The N+1 technology generation represents the next generation of traditional tube-and-wing civil transport airplanes. The expected entry-into-service (EIS) date for this aircraft is the latter part of the next decade. An example of this aircraft would be a Boeing 737 or Airbus A-320 replacement with a significantly improved propulsion system such as an open rotor (currently under study by General Electric) or a Geared Turbofan (GTF) (currently under development by Pratt & Whitney). These propulsion systems have the potential to significantly improve fuel consumption, but, particularly for the open rotor engine, have challenges with regard to the aircraft's community noise levels. In addition, significant drag reduction on the wing, tail surfaces, and engine nacelles would be required using techniques such as laminar flow control. The goal for aircraft of this generation is to be 33% more fuel efficient than an aircraft with an EIS date of 1998.

Technology generation N+2

The N+2 technology generation envisions a step-change from the traditional tube-and-wing aircraft configuration to a more integrate wing and body architecture, such as to a blended-wing-body (BWB). The expected EIS date for this technology generation is 2025. The airframe layout of such an aircraft is not determined, nor is the propulsion system. To achieve the N+2 goals, an integrated airframe and engine would likely be required, as well as advanced propulsion system concepts, extensive drag reduction techniques (such as laminar flow control), and weight reduction through advanced material and structural systems. Such an aircraft might first be used as a cargo carrier if airlines foresee passenger acceptance as an issue. The goal for aircraft of this generation is to be 40% more fuel efficient than the baseline aircraft with an EIS date of 1998.

Technology generation N+3

The N+3 aircraft are defined as the next generation after N+2. Any airframe layout or propulsion system architecture is conjectural. The EIS date for this aircraft is 2035. The goal for aircraft of this generation is to be 70% more fuel efficient than the baseline 1998 aircraft.

A comparison between the different MODTF scenarios and the National Plan goals is shown in Figure 1 below. The figure does not include MODTF scenarios 1 and 2 since these involve no change in the baseline aircraft technology. Note that the MODTF scenarios are defined out to the year 2036 and last National Plan technology introduction date is 2035; Figure 1 assumes the MODTF trends continue until the year 2050.

In the figure, the U.S. National goals have been shifted from the 1998 baseline to the 2006 baseline of the MODTF goals for consistency. The U.S. National goals are adjusted by a 15% improvement in fuel consumption from 1998 to 2006. With this shift in the goals baseline to 2006, the N+1, N+2, and N+3 fuel efficiency improvements are 24%, 32% and 66%, respectively. In addition to the MODTF and the U.S. National goals in Figure 1, a 2% per annum improvement curve is also shown as a very aggressive goal for improvement in per aircraft fuel consumption, and a 3.5% per annum curve in shown to demonstrate the improvement necessary to meet the N+3 goal.

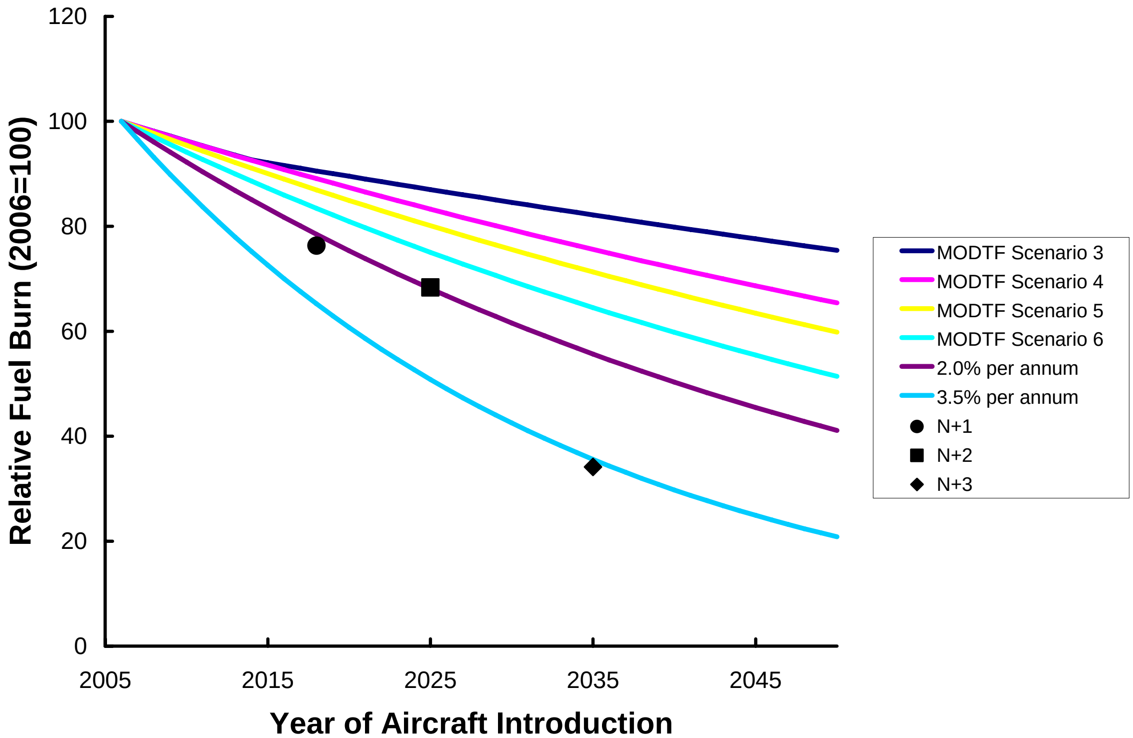

Figure 1, Comparison of Fuel Consumption Goals based on Aircraft Technology Improvements

Summary of MODTF fuel consumption goals analysis

The MODTF scenarios take into account improvements in both aircraft and in the airspace system in which the aircraft operate. The scenarios range from assuming no aircraft fuel consumption reductions and no airspace operational improvements (scenario 1) to assuming significant aircraft fuel consumption reductions combined with operational improvements in given years (scenario 6). The descriptions of the individual scenarios below are taken directly from the MODTF paper.

<u>Scenario 1 (*Current Aircraft/Operations*)</u>: This scenario assumes no improvements in aircraft technology beyond those available today and no improvements from Communication, Navigation, and Surveillance systems for Air Traffic Management (CNS/ATM) investment or from planned initiatives, e.g., those planned in NextGen and SESAR (Single European Sky ATM Research).

<u>Scenario 2 (*CAEP7 Baseline*)</u>: This scenario includes the CNS/ATM improvements necessary to maintain current ATM efficiency levels, but does not include any technology improvements beyond those available today.

<u>Scenario 3 (*Low Aircraft Technology and Moderate Operational Improvement*)</u>: In addition to including the improvements associated with the migration to the latest CNS/ATM initiatives, e.g., those planned in NextGen and SESAR (Scenario 2), this scenario includes fuel consumption improvements of 0.95 percent 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 of 0.5, 1.4 and 2.3 percent in 2016, 2026 and 2036, respectively.

<u>Scenario 4 (*Moderate Aircraft Technology and Operational Improvement*)</u>: In addition to including the improvements associated with the migration to the latest CNS/ATM initiatives, e.g., those planned in NextGen and SESAR (Scenario 2), this scenario includes fuel consumption improvements of 0.96 percent per annum for all aircraft entering the fleet after 2006 out to 2036, and additional fleet-wide moderate operational improvements of 0.5, 1.4 and 2.3 percent by 2016, 2026 and 2036, respectively.

<u>Scenario 5 (*Advanced Technology and Operational Improvement*)</u>: In addition to including the improvements associated with the migration to the latest CNS/ATM initiatives, e.g., those planned in NextGen and SESAR (Scenario 2), this scenario includes fuel consumption improvements of 1.16 percent per annum for all aircraft entering the fleet after 2006 out to 2036, and additional fleet-wide advanced operational improvements of 1.0, 1.6 and 3.0 percent by 2016, 2026 and 2036, respectively.

<u>Scenario 6 (*Optimistic Technology and Operational Improvement*)</u>: In addition to including the improvements associated with the migration to the latest CNS/ATM initiatives, e.g., those planned in NextGen and SESAR (Scenario 2), this sensitivity study includes an optimistic fuel consumption improvement of 1.5 percent per annum for all aircraft entering the fleet after 2006 out to 2036, and additional fleet-wide optimistic operational improvements of 3.0, 6.0 and 6.0 percent by 2016, 2026 and 2036, respectively. This scenario goes beyond the improvements based on industry-based recommendations.

The table below summarizes the technology and operational improvements of each of the MODTF scenarios. Note that the Operational Improvement percentages are not on a per annum basis, but rather represent steps along the way to an aspirational goal of a 6% improvement in total system efficiency through operational improvements. The highest rate of increase, 3% to 2016, continuing to a total 6% improvement by 2026, is equal to about a 0.3% improvement per annum. Note no assumption is made of any additional improvement between 2026 and 2036.

Table 1, MODTF Technology and Operational Improvement Summary

Scenario	Technology Improvement (per Annum)		Operational Improvement		
	2006-2014	2015-2036	2016	2026	2036
1	None	None	None	None	None
2	None	None	As required	As required	As required
3	0.95%	0.57%	0.5%	1.4%	2.3%
4	0.96%	0.96%	0.5%	1.4%	2.3%
5	1.16%	1.16%	1.0%	1.6%	3.0%
6	1.5%	1.5%	3.0%	6.0%	6.0%

Figure 2 below presents the total aviation system fuel consumption for the various scenarios given above, starting with the 2006 baseline. The FESG forecast growth is implicit in these system totals. The FESG forecast is a function of aircraft operations both within a given region and between regions; because these operations change from year to year, the FESG forecast growth can't be summarized into a single per annum number. However, the general trend for the FESG forecast is approximately 40% growth per decade.

Figure 2 shows the FESG forecast growth in the number of aircraft operating in the global system out-running technology and operational improvements, even in the most optimistic MODTF scenario. Slowing the growth in global fleet fuel consumption would require more aggressive technology and operational improvements than modeled in the MODTF scenarios; such improvements are represented by the U. S. National goals, and could be used by the GIACC as part of the basis for establishing aspirational goals.

Concluding Observations

Combining air traffic management improvements and aircraft technology enhancements one arrives at a forecast of about 1.8% per year improvement in fuel efficiency for the forecast period through 2036. The Group on International Aviation and Climate Change (GIACC) is trying to set "aspirational" global goals for the international aviation sector. The aviation sector might aspire to 2.5 to 3 per cent fuel efficiency improvement annually under a set of assumptions. First, it would require a large commitment of resources by government and industry to accelerate the research and development of both N+2 and N+3 technologies. Second, it would need meaningful investment by both air navigation service providers and airlines to develop and implement operational improvements in air traffic management to produce continued gains after 2026. Finally, it would require very aggressive implementation of new technology into aircraft fleets and the very large investment that this path would involve. It should be clear that reaching such improved fuel efficiency levels would be a substantial stretch. Not only would such goals require much higher levels of investment by governments and industry than currently planned, but there are considerably greater inherent risks in maturing and implementing the technology concepts upon which these ambitious predictions are predicated.

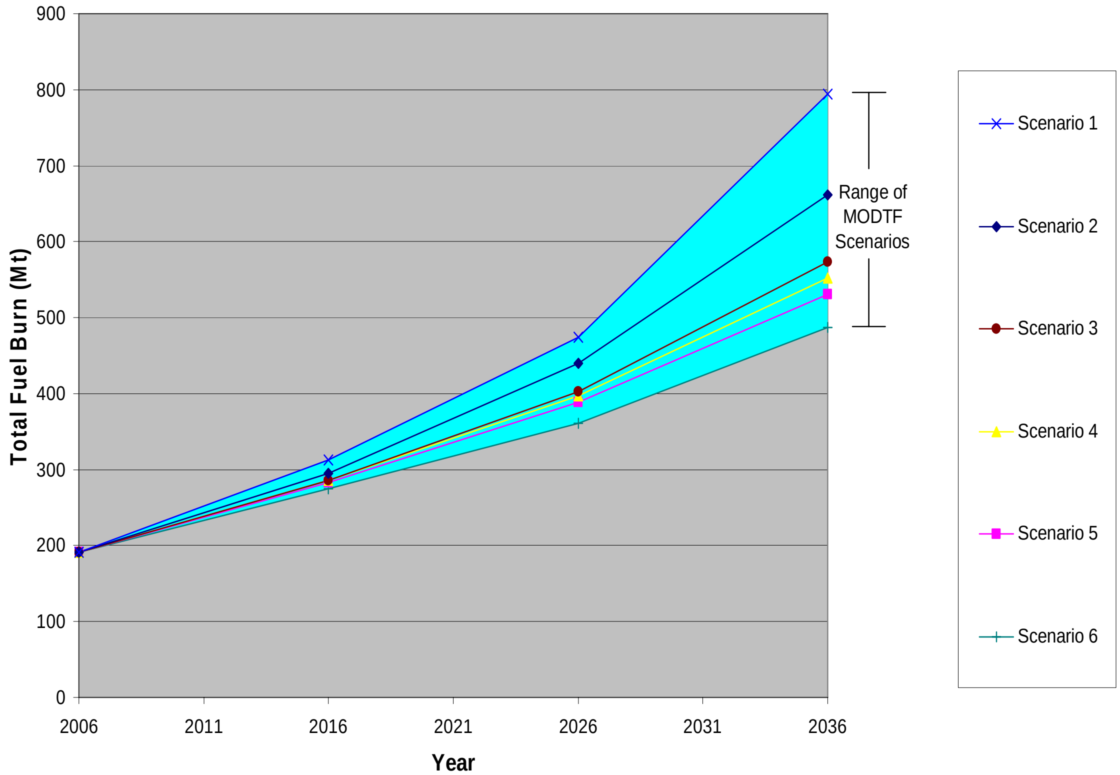

Figure 2, MODTF projections of Global Aviation Fuel Consumption

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Appendix D
English only

Traffic by region of air carrier registration
International schedueld and non-scheduled traffic of scheduled airlines of ICAO Contracting States

Tonne-km performed
Total (thousand)

Region	1990	1995	2000	2005
Africa	4,678,621	5,372,000	7,860,173	9,862,179
Asia/Pacific	37,797,021	63,243,000	87,952,232	105,989,874
Europe	52,841,427	75,347,000	126,400,679	143,710,980
Latin America/Caribbean	7,628,140	10,216,000	12,433,813	13,544,022
Middle East	6,169,230	9,354,000	12,902,501	23,838,934
North America	31,725,006	38,956,000	57,758,282	69,923,638
World	140,839,445	202,488,000	305,307,680	366,869,627

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