国际航空与气候变化组（GIACC）

第四次会议

2009 年 5 月 25 日至 27 日，蒙特利尔

议程项目 3：报告工作组制定的行动和政策要素

制定目标工作组的进展报告

（由工作组主席提交）

1. 背景

1.1 在航空气变组第二次会议和第三次会议之间，第一工作组查明了一系列根本性问题，供航空气变组在其第三次会议上审议。其中最为重要的，是该工作组建议了两个短期燃油效率目标：（1）2012 年之前拟达到的全球燃油效率指标（即 XX 升燃油/100 收入吨公里），和（2）1990 年至 2012 年拟达到的年度燃油效率改进比率 X%/年。在审议了国际民航组织、正式的航空公司指南（OAG）和业界提交的数据后，第一工作组注意到，在 2012 年之前，年度燃油效率改进范围可能在 1.7%/年至 2.1%/年之间。航空气变组第三次会议注意到，会议就 2.0%/年的改进比率这一短期燃油效率目标达成指示性一致意见，并将根据进一步的信息再对此加以审议。

1.2 第一工作组认识到，确定中期和长期目标有一定困难。第一工作组指出，时间跨度应与气候变化框架公约的基本上一致（即 2020 年为中期、2050 年为长期），但也注意到有一个国家建议采用 2025 年作为划定中期的年份。会议对于界定中期和长期燃油效率目标的讨论，重点是明确此种目标应以何种可靠数据为依据方面的困难。此外，有的成员表示，应制定伸缩度更大的目标；而其他成员则认为，理想目标应仅采用燃油效率的形式。

1.3 成立了制定目标工作组（第四工作组），以便继续开展和推进第一工作组的努力。同时，第四工作组还拟审议业界向航空气变组第三次会议提供的信息，其中介绍了其为拟定可能的中期和长期目标以供航空气变组审查的各项工作。应该忆及，当时业界表示，相对于 2005 年的水平，其可以实现的燃油效率改进如下：在 2012 年达到 15%（约每年 2.1%），在 2020 年达到 29%（约每年 1.9%），和在 2050 年达到 50%（约每年 1.1%）。曾邀请业界向第四工作组提供进一步的情况，但业界未应邀提供。

2. 衡量基准

2.1 工作组对界定为碳含量而调整的燃油效率和燃油效率衡量基准（虑及从可再生来源提炼的燃料和基于市场的措施）的讨论演变为对衡量基准的讨论。

2.2 就燃油效率而言，会议的总体协商一致意见是，由第一工作组拟定的容量/收入吨公里是一项良好的初始衡量基准。但是，有的国家认为，有必要在衡量基准中虑及碳浓度，以便能确定通过可持续的航空替代燃料或基于市场的措施所实现的效率改进。燃油效率衡量基准应该是这一更广泛的衡量基准中的一个组成部分，为我们讨论的目的，将其称为**“净二氧化碳浓度衡量基准”**。欧洲各国的代表提出了一个虑及此种发展情况的公式。

2.3 工作组讨论了抵消措施和碳浓度公式可在何种程度上准确地反映其他部门的减排。同样，有的成员关切碳浓度公式会在何种程度上虑及燃油的质量而不是容量。工作组指出，第一工作组提出了两项可能的燃油效率公式，一项使用质量，另一项则使用容量。工作组建议，容量/收入吨公里的燃油效率公式可扩展为一项更大的公式，在其中包括公斤/容量（燃油密度）、二氧化碳/公斤（碳系数）和基于市场的措施（MBM）的减排量/收入吨公里（由基于市场的措施所产生的碳减排量）：

$$\text{"净二氧化碳浓度衡量基准"} = \overbrace{\left(\frac{\text{容量}_{\text{燃油}}}{\text{收入吨公里}}\right)}^{\text{燃油效率衡量基准}} \cdot \overbrace{\left(\frac{\text{质量}_{\text{燃油}}}{\text{容量}_{\text{燃油}}}\right)}^{\text{燃油密度}} \cdot \overbrace{\left(\frac{\text{质量}_{\text{二氧化碳}}}{\text{质量}_{\text{燃油}}}\right)}^{\text{二氧化碳系数}} - \overbrace{\left(\frac{\text{基于市场的措施减排量}}{\text{收入吨公里}}\right)}^{\text{基于市场的措施}}$$

2.4 日本指出，应以容量/收入吨公里为基础制定目标；对于可持续的替代燃料，则应为其拟定适当的换算系数（参阅第一工作组报告第 29 段），并应避免采用燃油密度这样的复杂条件。

2.5 还讨论了这样一种概念，即制定每一目标截止日期（即 2020 年/2025 年和 2050 年）之前拟达到的用每 100 收入吨公里消耗的固定燃油容量（容量/100 收入吨公里）表示的效率目标。这是第一工作组建议的（参阅 GIACC/3-WP/2 号文件第 38 段）。制定这一全球目标将以所讨论的适用于国际航空系统的减排百分比为基础。用绝对数值表示的全球理想目标更有优势，因为这一目标将在单个航空系统中考虑，不同的系统可采取不同的行动以实现这一全球目标。采用绝对数值还有助于传达一个更为具体和透明的目标。日本指出，如果要采用绝对的燃油效率目标，则应该依据实际数据而不是在某些设想的基础上进行计算的结果。

3. 定义

3.1 工作组根据由澳大利亚提交的文件（副本附后）审议了如何界定碳中和增长和碳中和的问题。工作组考虑了航空部门仅凭技术和运行改进可在全球实现碳中和增长的程度。一些成员认为这是不可能的。针对这种情况，工作组讨论了文件的意向，即对通过另外采用抵消措施而实现碳中和增长和碳中和加以界定。其中，文件特别规定：

"碳中和增长的出现系指航空业界的净碳足迹在任何给定年份均不超出选定的基线值。"

"碳中和的实现系指航空业界的净碳足迹等于零 —— 即总碳足迹被完全抵消。最有可能实现这一目标的途径是通过至少为可预见的将来购买二氧化碳抵消额度。业界的宏大理想是通过使用生物燃料在长期实现碳中和。"

3.2 会议认识到最好是使用"二氧化碳排放"而不是"碳足迹"，以避免误解和进一步讨论的必要。这些概念对于工作组随后的对话交流是有用的。

4. 选择基线年份

4.1 由于需要回应向每位与会者提出的一整套指导性问题（副本附后），因此第四工作组举行了面对面的会议进行对话交流。问题的目的在于理解每个国家对于有关问题的考虑，包括可能的基线年；燃油效率形式的可能的短期、中期和长期目标；以及更为宏大的理想目标的可能性。

4.2 关于对中期和长期基线年的选择问题，有 2000 年和 2005 年两项具体建议。有的国家建议将基线设定在今后，而这引起了其他国家的关切，认为这发出了可能鼓励更多排放的信号。还有国家要求获得信息，以更好地了解 2000 年和 2005 年全球和地区一级的排放情况（表格附后，由国际民航组织秘书处提供）。工作组还指出，各项目标的时间跨度应与气候变化框架公约的时间表基本上一致。

5. 燃油效率目标

5.1 工作组一致认为，包括燃油效率目标在内的所有目标均应是全球一级的，没有约束力，仅适用于国际航空，而且国际民航组织的任何缔约国对此均无采取行动的责任或义务。各国可选择以某种速度实现这些目标，以使其有充分的余地根据各自的国情和能力发展其航空业。中国强调指出，发达国家带头实现这些目标是关键所在。此外，中国和巴西还着重指出，发达国家帮助发展中国家进行能力建设以改进燃油效率并促成上述目标十分重要。

5.2 **短期** —— 根据在航空气变组第三次会议上的讨论，而且由于没有新的信息，工作组一致同意，根据历史趋势，2012 年之前的年度燃油效率改进拟为 2％。

5.3 **中期** —— 小组的讨论围绕着一系列选择， 2013 年至 2020 年或 2025 年的年度改进从拟为 2％至 2.5％不等。绝大多数成员建议将 2020 年作为中期的目标日期，而美国则提议 2025 年，认为这会有更多的时间以实现更为宏大的目标，尤其是使空中交通管理（ATM）程序和技术发挥作用。还就 2.5％是否过于宏大进行了讨论。有的国家强调，必须使中期目标尽量能够实现。美国指出，航空气变组拟提出的框架是理想性的，因此，据其定义，就必须超出今天可能实现的程度，应该更为宏大，并设定一个标杆，以鼓励创新和投资。

5.4 **长期** —— 有一系列选择， 2021 年或 2026 年至 2050 年的年度改进从拟为 2%至 3%不等。关于这一点，有成员对将目前预见的可能的燃油效率改进延续到今后的确定性表示了关切。一个国家建议，发表一份附带各种可能情景的政治声明或许是一个更为合适的做法。还就 3%是否过于宏大进行了讨论。美国表示愿提供一份文件，解释该国为何支持将 2.5%至 3%的年度改进理想目标保持到 2050 年（附后）。

6. 更为宏大的目标

6.1 会议认识到，仅靠燃油效率改进，航空部门不能实现全球碳中和增长，而可能还需要超出燃油效率之外的额外措施，供选择这样做的国家采用。工作组审议了更为宏大的额外目标。就中期而言，讨论的中心问题是碳中和增长这一目标。会议普遍认识到，碳浓度公式会是一项有用的工具，以展示迈向这一目标的进展。

6.2 就长期而言，讨论的中心问题是碳减排。欧洲的提案是，2050 年，航空应保持其 1990 年在全球排放中的同样百分比份额。由于这引起了严重的关切，但又没有其他提案，因此需要就可能的长期目标作进一步讨论。

6.3 工作组讨论了目标“集束”或范围这一概念。这可能是非常有用的，因为这可为所有国家制定一个宽泛的目标，而有些有能力的国家则可超出这一目标以展示领导风范。但是，有些国家表示了关切，担心目标中的下限会被批评意见视为允许不求上进。

6.4 中国在衡量基准方面介绍了人均排放的概念，但经过讨论后，有些国家指出，这一概念更有可能作为一个门限值，用以说明一个国家应在何时寻求实现更为宏大的目标。但是，这引起了一些关切，并将作进一步讨论，以更好地理解这项意见。

6.5 巴西和中国均表示，超出燃油效率之外的中期和长期目标应虑及正在进行的气候变化框架公约的气候谈判。但是，其他国家表示，这会使航空气变组履行其职责的工作复杂化。还需要就更为宏大的目标作进一步讨论。

7. 对发展中国家的协助

7.1 航空气变组全面审议了这项意见，即发达国家应采取措施协助发展中国家，使其能对全球理想目标做出贡献。第二工作组本着这一精神提出了措施和原则清单。虽然这不是第四工作组的直接权限，但工作组参加方仍一如既往地认识到，国家之间的协助举措和发展银行社团的参与，对于全面和成功地执行航空气变组的建议至关重要。

8. 可能的目标和时间跨度摘要

基线：2000 年或 2005 年

燃油效率目标选择方案：

	目标：效率改进	目标日期	评论
短期	2%的年度效率改进	2012 年	现行趋势的延展。
中期	自 2012 年起每年 2.0%-2.5%（需作进一步讨论）	2020 年或 2025 年	宏大。目标范围的做法将更好地反应实现目标的风险和各国为航空系统设定的宏大程度。对实现的可能性存在某些关切。
长期	自 2020 年或 2025 年起每年 2.0%-3%（需作进一步讨论）	2050 年	非常宏大。这一范围的上限将比业界的指标高出近 50%。在技术和国家的宏大程度方面存在严重不确定性。对实现的可能性存在某些关切。

表示更为宏大的目标的选择方案：需作进一步讨论

	目标	时间表	评论
中期	碳中和增长	2020 年或 2025 年	宏大。对某些国家而言，只有采取基于市场的措施才可能。必须用净碳密度公式计算。其他目标、理想和全球目标也如此。人均等启动因素可说明一个国家何时应尽最大努力以促成目标的实现。需作进一步讨论。
长期	减排：全球航空部门所占排放百分比与 1990 年持平	2050 年	欧洲的提案。会上表示了某些关切。讨论认识到需要拟定/讨论其他选择方案。

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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

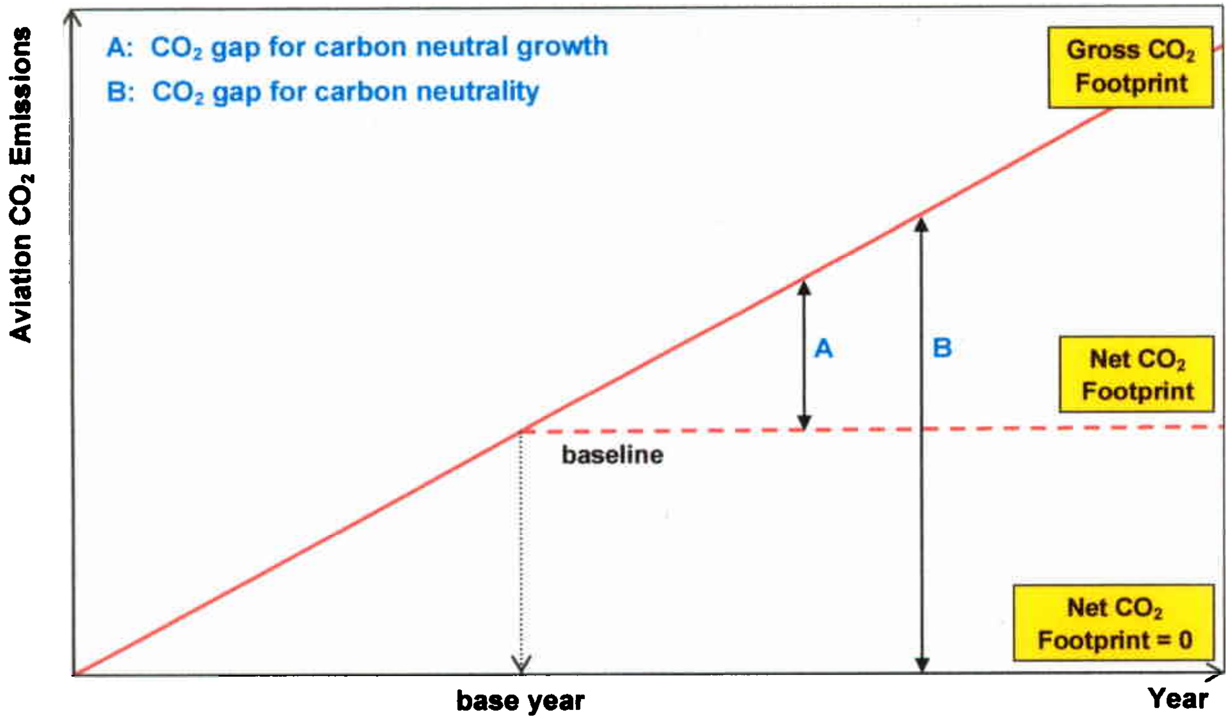
2.5.1 The concepts described in sections 2.1 to 2.4 are illustrated in Figure 1.

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

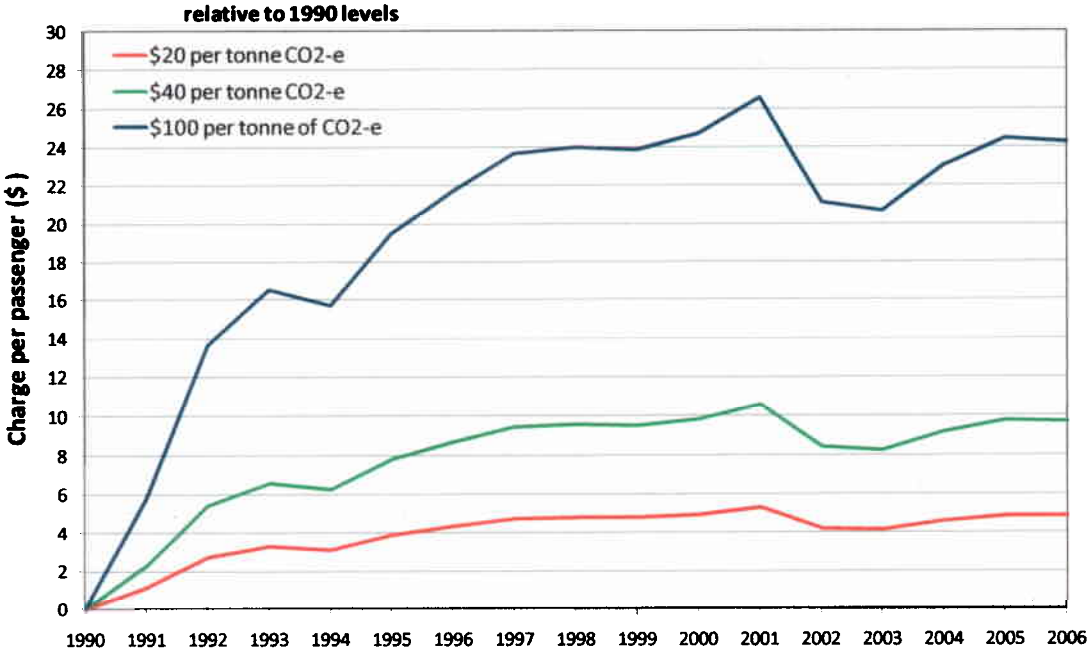
4.3.1 Figure 3 indicates that if a carbon neutral growth policy were adopted using 2000 as the base year, costs would currently be of the order of $1/passenger at a CO_2 cost of $20/tonne. It can be seen that for the years 2002 and 2003 carbon neutral growth would have been achieved without the need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

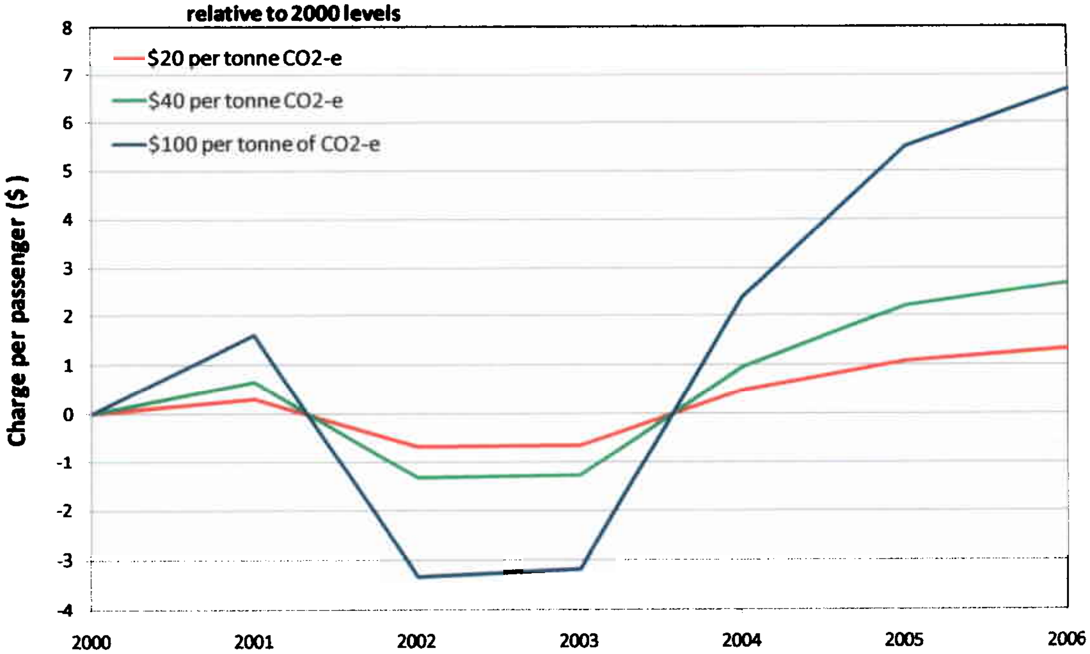
i) 4.4.1 Figure 4 shows the annual costs of achieving carbon neutrality for international aviation since 1990. It can be seen that the magnitude of this cost has been steadily declining as efficiency gains have been achieved. Carbon neutrality could be achieved at a cost of approximately $10/passenger at a CO2 cost of $20/tonne.

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



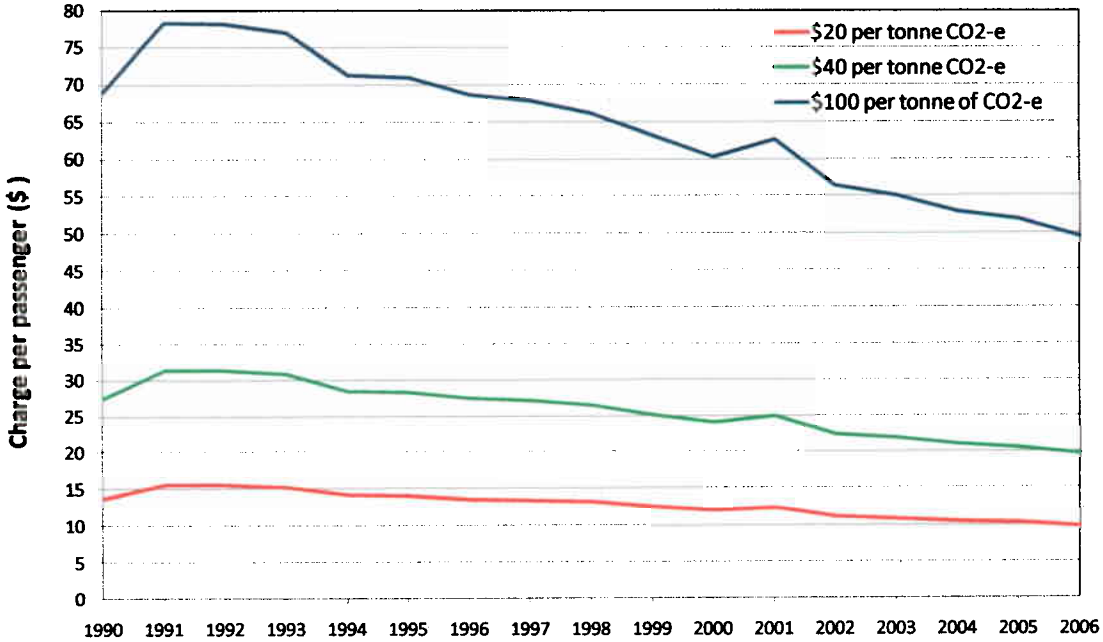
Source: Emissions were calculated using ICAO fuel consumption estimates of global international scheduled services based on OAG data, Economic Analyses and Databases Section, Air Transport Bureau, ICAO. Passenger data is from ICAO, *Annual Report of the Council*, various years (http://www.icao.int/annualreports).

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.

* 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.

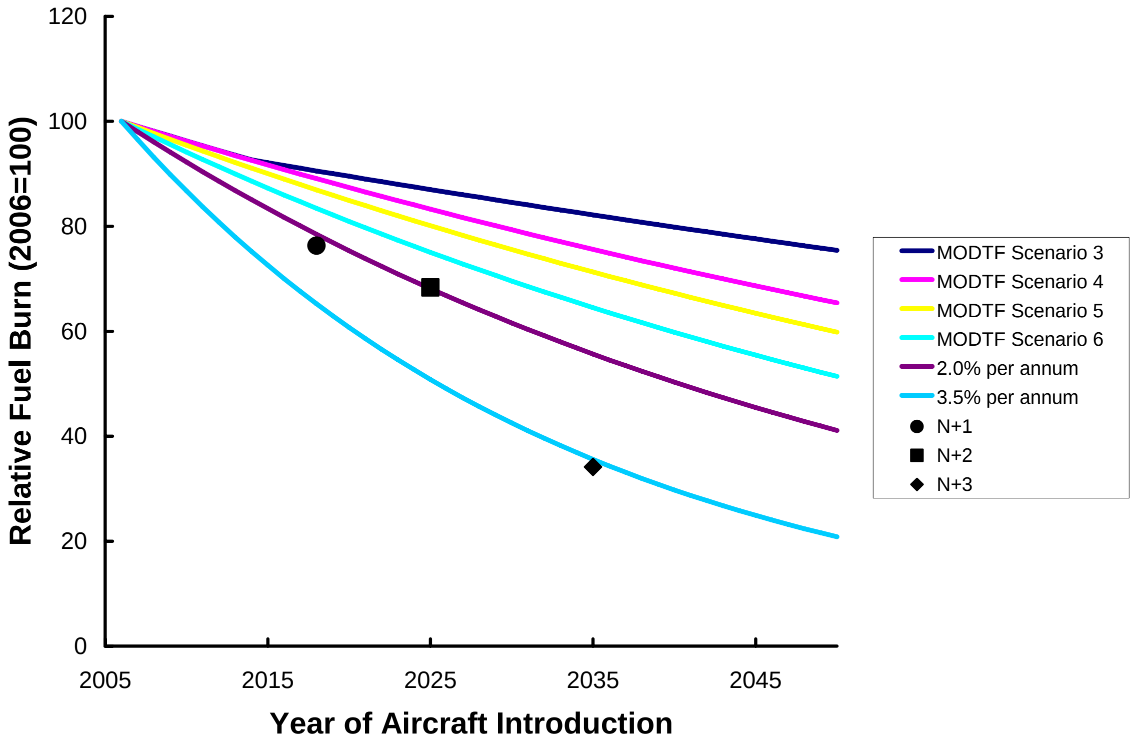

Figure 1, Comparison of Fuel Consumption Goals based on Aircraft Technology Improvements

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.

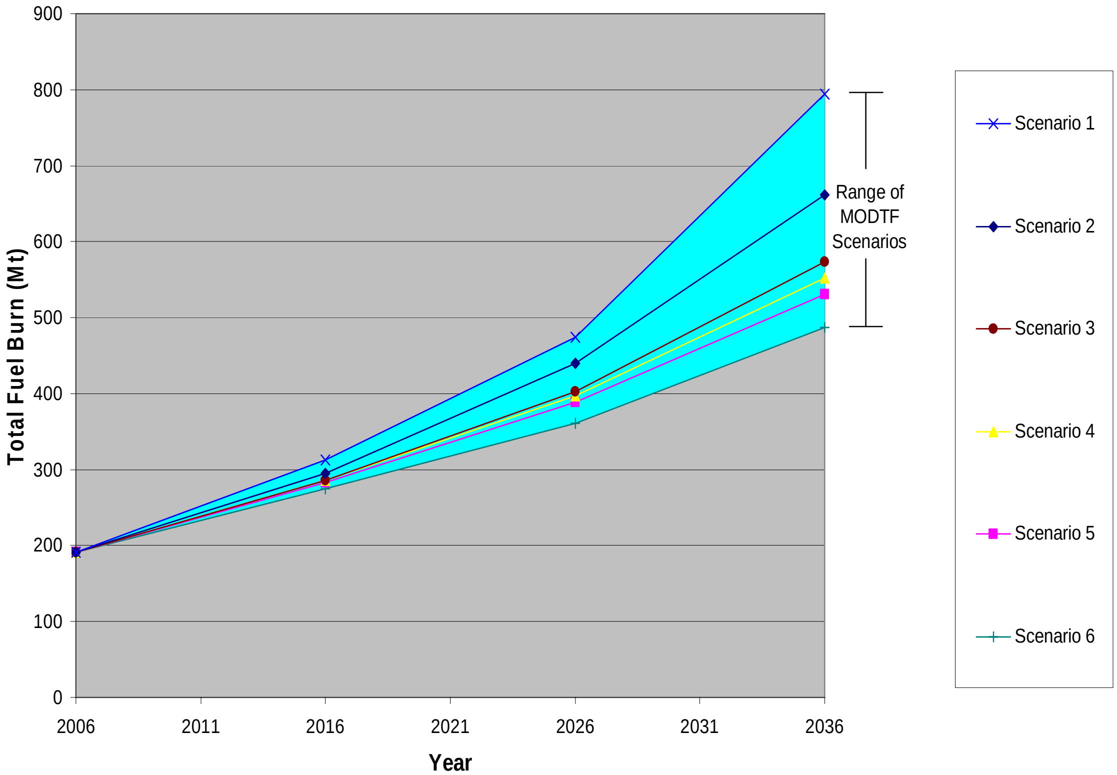

Figure 2, MODTF projections of Global Aviation Fuel Consumption

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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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