International Civil Aviation Organization

INFORMATION PAPER

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# GROUP ON INTERNATIONAL AVIATION AND CLIMATE CHANGE (GIACC)

## FOURTH MEETING

**Montréal, 25 to 27 May 2009**

**Agenda Item 2: Review of aviation emissions-related activities within ICAO and internationally**

## U.S. FUEL TRENDS ANALYSIS AND COMPARISON TO GIACC/4-IP/1

(Presented by the United States)

**SUMMARY**

The extent to which global aviation fuel consumption may change over time will be influenced by a number of factors, including improvements in aircraft technology and airspace management, and fluctuations in jet fuel availability and price. The extent to which global aviation carbon dioxide ($CO_2$) emissions may change overtime is influenced by the same factors as aviation fuel consumption, as well as the availability of renewable aviation fuels that offer $CO_2$ reductions over their life cycle. This paper summarizes the findings from an analysis of a range of potential scenarios undertaken by the U.S. to inform GIACC discussions regarding what fuel consumption $CO_2$ emissions savings may be achieved from a combination of measures. These findings are then compared to the results presented in GIACC/4-IP/1. The comparison of scenarios exemplifies that reflecting economic and aviation activity from 2006 to the present in the scenarios makes a marked difference in the projected 2050 levels.

## 1. INTRODUCTION

1.1 The prominence of aviation climate change issues and the associated debate during the 36th Session of the International Civil Aviation Organization (ICAO) Assembly led to the creation of the Group on International Aviation and Climate Change (GIACC). The mandate of GIACC is to develop and recommend to the ICAO Council a Programme of Action and common strategy consistent with Appendix K of Resolution A36-22. The work of GIACC involves consideration of options to limit or reduce greenhouse gas (GHG) emissions attributable to international civil aviation.

1.2 The U.S. has undertaken an analysis that reflects economic and aviation activity from 2006 to the present, and the projects fuel consumption and $CO_2$ emissions savings scenarios that the U.S. believes may be achieved from a combination of measures. That analysis documented in this paper was conducted to inform the GIACC deliberations.

1.3 The range of fuel price and aviation scenarios considered in the U.S. analyses covered – in broad terms – the following areas. Additional information appears in Appendix A.

a) Air Traffic Management: improvements in the movement of air traffic to further reduce fuel burn and $CO_2$ emissions from the aviation sector;

b) Technology: advances in engine performance and airframe design that would enhance the energy efficiency of the aviation sector;

c) Business Measures: efficiencies in the operation and maintenance of aircraft, airports and airlines; and

d) Market-Based Measures: options, such as emissions trading, that are cost-beneficial in managing aviation GHG emissions growth (modelled as adjustment to fuel price).

f) Alternative Fuels and their potential use in aviation to improve environmental performance were considered separately from the fuel burn scenarios analysis delineated immediately below. The alternative fuels analysis is covered in Section 5 and Appendix B.

## 2. SCENARIOS AND ASSUMPTIONS

2.1 The U.S. analysis was conducted using the Aviation Environmental Portfolio Management Tool for Economics (APMT-Economics), which has been approved by the ICAO Committee on Aviation Environmental Protection (CAEP) Forecasting and Economics Support Group (FESG) for use to conduct the CAEP/8 cost-effectiveness analyses.

2.2 The forecast analysis considers both ICAO and US Next Generation Air Transportation System (NextGen)[1] reference data. The initial point of reference for the projection of aviation growth is the FESG forecast from a 2006 base year data set (Datum) where forecasts of demand and supply for 2016, 2026 and 2036, by route-group and seat class were applied. The forecasts were projected out to 2050 by extrapolating the 2026 to 2036 aviation activity growth trends. The underlying aviation activity projections from FESG (which were formulated in June-2007) were then adapted for this analysis to account for actual aviation activities and the economic realities from 2006 to the present, based on information supplied by the U.S. Federal Aviation Administration (FAA). The following assumptions are included in the FAA Analysis Baseline scenario projection.

a) Aviation growth is relatively stagnant for the period 2006 to 2011, with a recovery in general economic growth and aviation activity in line with a historic elasticity of airline traffic growth to economic growth from 2012.

b) Cost components are unchanged through time; fuel price, labor costs, landing fees, route charges, volume-related costs and maintenance costs all remain the same.

c) Costs pass-through to fares; thus, both higher and lower (fuel) operating costs incurred by airlines are passed through to consumers such that unit profit margins are maintained.

d) Aviation-sector profitability and growth are assumed to be in a reasonable and sustainable continuing balance.

e) Aircraft are retired in accordance with the FESG retirement curves that were based on historic data.

[1] The Next Generation Air Transportation System (NextGen) is a long-term transformation initiative to increase the efficiency, safety, and capacity of the U.S. national airspace system and at the same time reduce aviation emissions, in part, by transforming the current air traffic control system. This effort involves new technologies and air traffic procedures that will contribute to reducing aviation emissions and incorporates research, development and maturation of emissions-reduction technologies.

f) Aircraft technology improvement related to fuel use is considered through a low trend-based new aircraft technology improvement, which is assumed to be available at no additional cost to the industry and that equates to an average 1% per annum improvement in fuel use for new aircraft entering service over the entire forecast period.

g) Penetration of new aircraft technology into the operational fleet is assumed to occur over a period of time; specifically, a single one-time technology improvement would take fifteen years to achieve 50% penetration.

h) Enhanced airspace management and operational improvements that ensure airborne delays remain at the 2006 base year levels.

2.3 The underlying aviation activity for the analyses was a one-week sample of 2006 passenger aircraft operations drawn from the ICAO-CAEP Modelling and Database Task Force (MODTF) Common Operations Database, which excluded passenger aircraft with fewer than 20 seats.[2] The base year data is described as the Datum. This data provided the starting point for considering various assumptions that lead to the FAA Alternative Scenario A and Scenario B forecasts, which are covered in this paper.

2.4 Scenarios A and B include a combination of assumptions for: air transport growth, new aircraft fuel use technology, airspace operational efficiency, market-based options and fuel prices. A summary of the input assumptions is provided in Table 1; additional information appears in the subsequent text and in Appendix A.

**Table-1 Scenario Input Summary**

| Core Scenario | Air Transport Growth | New Aircraft Fuel Use Technology | Operational Efficiency | Fuel Price |
|---|---|---|---|---|
| FAA Analysis Baseline | Short-term demand adjusted to reflect economic downturn | Low Trend-based new aircraft improvement (average 1% per annum) | No Additional Delays | None/EIA Low |
| FAA Analysis Baseline with Alternative Scenario A | Short-term demand adjusted to reflect economic downturn | Optimistic trend new aircraft improvement (average 1.5% per annum) | High for US, with a 5 year lag before equivalent global improvement | None/EIA Low |
| FAA Analysis Baseline with Alternative Scenario B | Short-term demand adjusted to reflect economic downturn | Optimistic trend new aircraft improvement (average 1.5% per annum) | High for US, with a 5 year lag before equivalent global improvement | High-plus phased over 5 years |

*Assumptions for new aircraft fuel use technology are further described in paragraph 2.5; operational efficiency in paragraph 2.6 and fuel price in paragraph 2.7.*

2.5 New aircraft fuel use technology for FAA Alternative Scenarios A and B were considered through a further level improvement, beyond the Baseline, that equates to an average 1.5% per annum improvement in fuel use for new aircraft entering service over the entire forecast period.

[2] The underlying data was drawn from a development version of the CAEP MODTF 2006 Common Operations Database. Some detailed aspects of this underlying database have since been revised for use in CAEP/8 analysis; however, the revised data were not available in time to be incorporated as the underlying aviation activity database for this analysis using APMT-Economics.

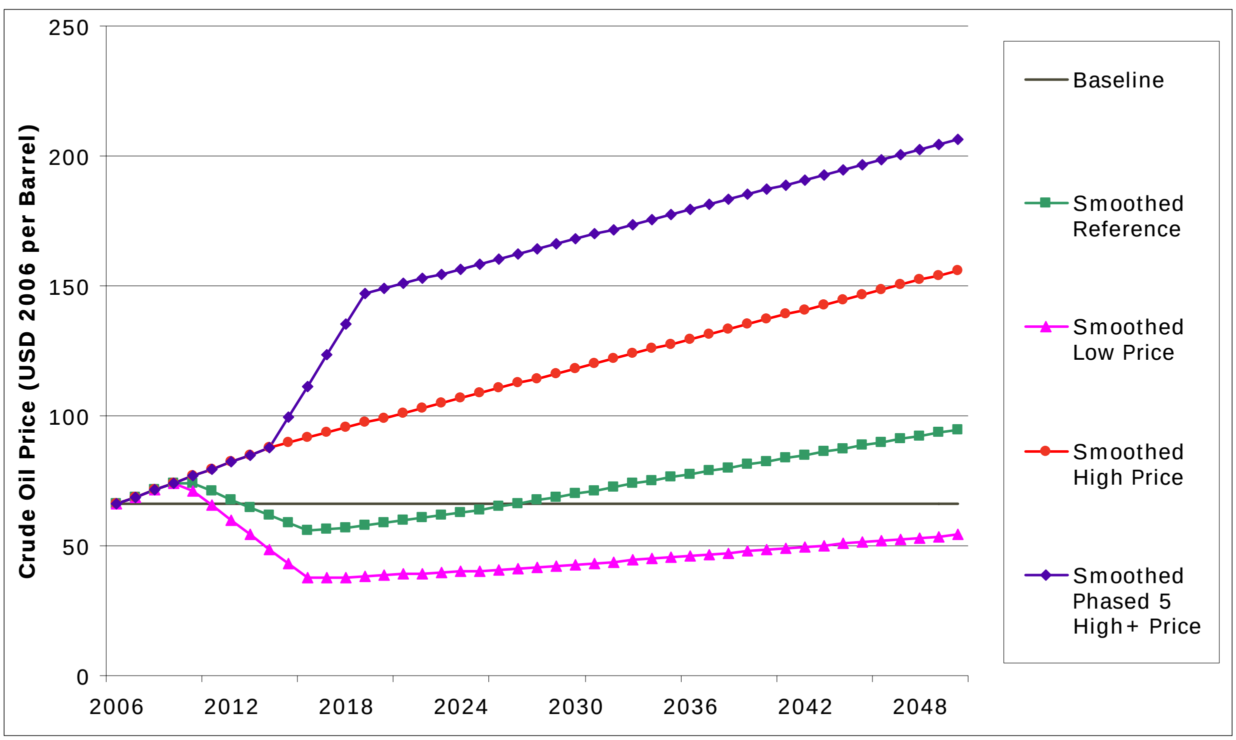
2.6 The airspace operational improvements for Scenarios A and B were based on those used in the NextGen High Density[3] case, which as applied in this analysis is summarized in Table 2. It was assumed that these airspace improvements were implemented at no additional cost to the industry.

**Table-2 Airspace Operational Improvement Assumptions Relative to the Baseline**

| Geographic Scope | Operational Efficiency Improvement |
|---|---|
| United States | Flight distance was assumed to be reduced by 3% at 2015 and by 10% at 2025 |
| Rest of World | Flight distance was assumed to be reduced by 3% at 2020 and by 10% at 2030 |

2.7 The fuel price scenarios used for the FAA Baseline, A and B scenarios were drawn from the US Energy Information Administration (EIA) International Energy Outlook for 2008. The Baseline Scenario and Scenario A uses the 2006 base year (Datum) fuel price, which equates to the EIA low scenario. The fuel price for Scenario B began by assuming the EIA High Price trend, and then the price was increased to represent additional market-based GHG measures phased in over five years. The fuel price scenarios are illustrated in Figure 1 in terms of the real price per barrel to 2026, which were then extrapolated out to 2050.

**Figure-1 Fuel Price Scenarios**

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[3] The NextGen High Density solution set involves airports and adjacent airspaces that require all the capabilities of the NextGen flexible terminals and airspace, plus integrated tactical and strategic flow capabilities. They may require higher performance navigation and communications capabilities for air traffic and the aircraft to support these additional operational requirements. http://www.faa.gov/about/initiatives/nextgen/resources/sol_sets/hd/index.cfm

## 3. PROJECTIONS

3.1 The projected global fuel burn in 2050 ranges from 473 Mt for Scenario B to 690 Mt for the FAA Analysis Baseline, as shown in Figure 2. For the U.S. the projected fuel burn in 2050 ranges from 115 Mt for Scenario B to 167 Mt for the FAA Analysis Baseline. Data resulting for both the U.S. and global projected fuel burn is presented in Table 3.

3.2 Global passenger km growth, as projected from 2006 to 2050 for scenarios A and B, ranges between 460% and 550%, as shown in Figure 3. The projections for U.S. passenger km growth from 2006 to 2050 for scenarios A and B range between 235% and 290%; which equates to the average fuel use per passenger kilometer reducing between 36% and 50%.

**Table-3 Annual global aviation fuel burn for the FAA Analysis scenarios, million tonnes (Mt)**

| | U.S. Operations | | | Global Operations | | |
|---|---|---|---|---|---|---|
| | FAA Analysis Baseline | FAA Analysis Baseline with Alternative Scenario A | FAA Analysis Baseline with Alternative Scenario B | FAA Analysis Baseline | FAA Analysis Baseline with Alternative Scenario A | FAA Analysis Baseline with Alternative Scenario B |
| 2006 | 68 | 68 | 68 | 174 | 174 | 174 |
| 2012 | 71 | 71 | 69 | 193 | 193 | 188 |
| 2016 | 79 | 77 | 73 | 224 | 221 | 207 |
| 2020 | 90 | 87 | 76 | 267 | 262 | 225 |
| 2025 | 101 | 96 | 82 | 312 | 297 | 253 |
| 2026 | 103 | 95 | 81 | 321 | 303 | 257 |
| 2036 | 129 | 113 | 95 | 448 | 392 | 329 |
| 2050 | 167 | 137 | 115 | 690 | 565 | 473 |

**Figure 2: Global Fuel use Projected to 2050**

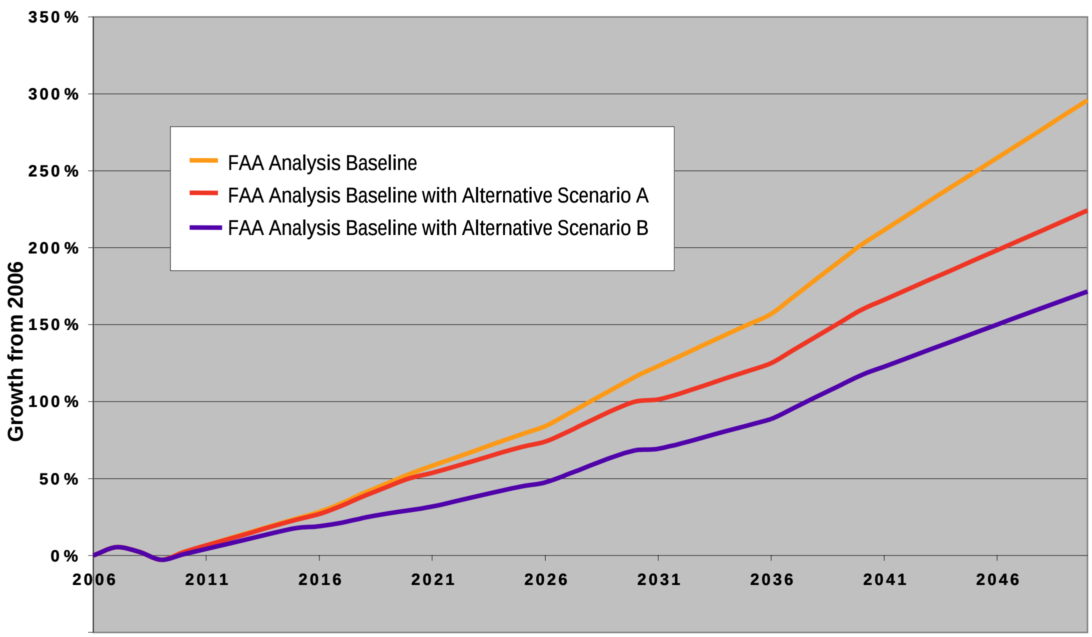
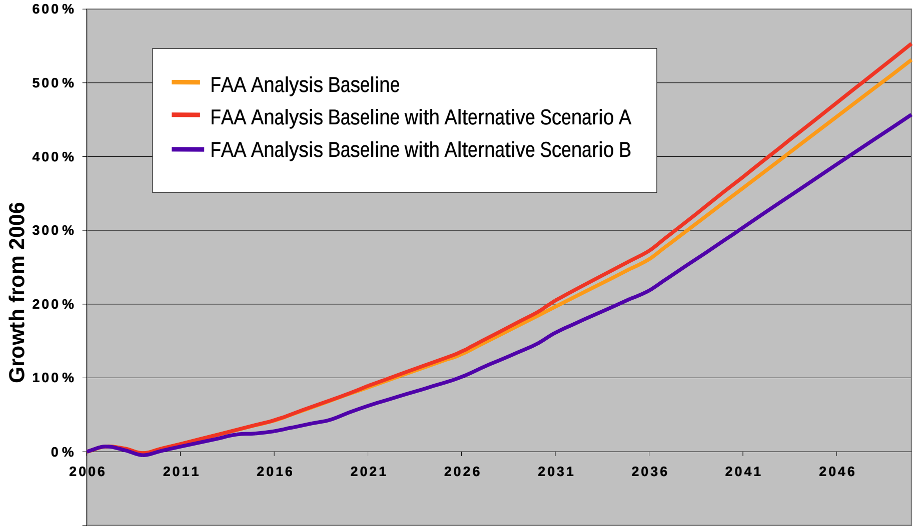


**Figure 3: Global Passenger km Projected to 2050**




## 4. PROJECTIONS COMPARED

4.1 Work conducted by the ICAO-CAEP FESG Projections Task Group (PTG) and MODTF in response to a request by the GIACC resulted in GIACC/4-IP/1, entitled *Global Aviation $CO_2$ Emissions Projections to 2050*. Data from that paper are compared with the FAA Analysis Baseline, Scenario A and Scenario B in Table 4 and Figure 4.[4] Table 5 contains a summary of the MODTF scenario assumptions.

**Table-4 Annual Global Fuel Burn for MODTF and FAA Analysis Scenarios (million tonnes of fuel)**

| Year | MODTF Scenario 3^ | MODTF Scenario 4^ | MODTF Scenario 5^ | MODTF Scenario 6^ | FAA Analysis Baseline | FAA Scenario A | FAA Scenario B | MODTF S3 + FESG central demand | MODTF S4 + MMU A1 demand scenario | MODTF S4 + FESG central demand | MODTF S4 + CONSAVE A1_ULS demand scenario | MODTF S5 + FESG central demand | MODTF S5 + MMU B1 demand scenario | MODTF S3 + MMU A2 demand scenario | MODTF S5 + CONSAVE B1_DtE demand scenario |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | **187** | **187** | **187** | **187** | **174** | **174** | **174** | **187** | **187** | **187** | **187** | **187** | **187** | **187** | **187** |
| 2012 | *240* | *240* | *238* | *238* | **193** | **193** | **188** | | | | | | | | |
| 2016 | **276** | **276** | **273** | **271** | **224** | **221** | **207** | | | | | | | | |
| 2020 | *316* | *314* | *310* | *305* | **267** | **262** | **225** | | | | | | | | |
| 2025 | *372* | *368* | *361* | *351* | **312** | **297** | **253** | | | | | | | | |
| 2026 | **385** | **397** | **372** | **361** | **321** | **303** | **257** | | | | | | | | |
| 2036 | **542** | **523** | **503** | **477** | **448** | **392** | **329** | | | | | | | | |
| 2050 | *883* | *835* | *790* | *730* | **690** | **565** | **473** | **795** | **760** | **741** | **738** | **693** | **452** | **443** | **282** |

The MODTF and FESG-PTG data derived from GIACC/4-IP/1 are *pending review and acceptance by CAEP/8.*
^Data for MODTF Scenarios 3 through 6 came from GIACC/4-IP/1, Table 1 and are based on the FESG consensus (central) forecast. The data in *italics* were interpolated by MODTF to meet the years requested by the GIACC. MODTF Scenario 6 "goes beyond the improvements based on industry-based recommendations."
+ Data for the FESG-PTG developed scenarios came from GIACC/4-IP/1, Table A2.1

[4] MODTF scenarios 1 and 2 are not included in Table 4 or Figure 4 in this document since GIACC/4-IP/1, paragraph 20 noted "the assumptions used in these scenarios (1&2) regarding fuel burn improvements are not considered to be a realistic outcome."

**Table-5 Summary of MODTF Scenario Assumptions**

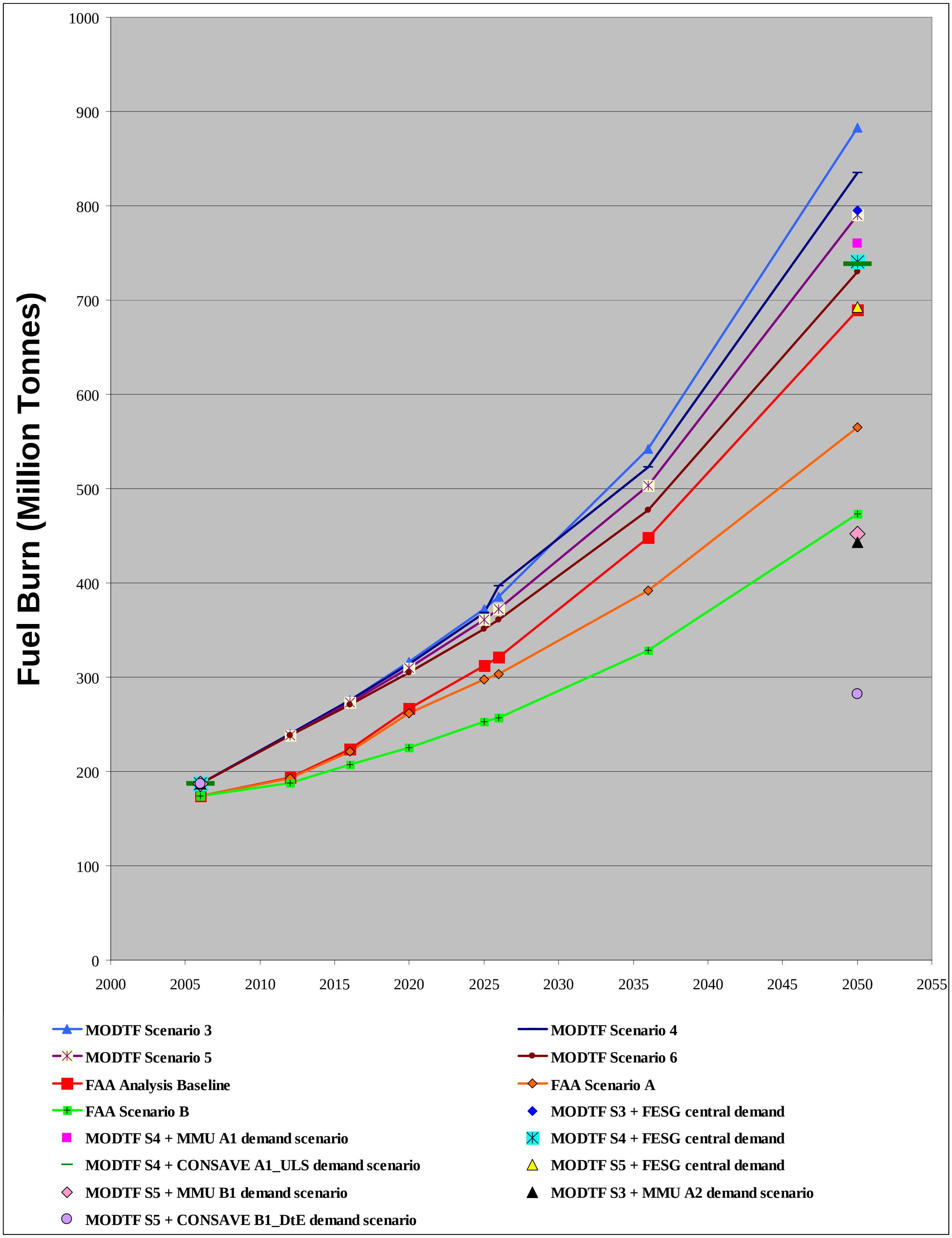
| | Forecast | CNS/ ATM | Fleet-Wide Operational improvements in 2016 | Fleet-Wide Operational improvements in 2026 | Fleet-Wide Operational improvements in 2036 | New Aircraft technology entering the fleet 2006> <2015 | New Aircraft technology entering the fleet 2015=>2036 | New Aircraft technology entering the fleet 2006>2036 |
|---|---|---|---|---|---|---|---|---|
| MODTF Scenario 1 | FESG consensus | No improvements beyond those available today | 0 | 0 | 0 | no improvements beyond those available today | | |
| MODTF Scenario 2 | FESG consensus | Only improvements to maintain current ATM efficiency levels | 0 | 0 | 0 | no improvements beyond those available today | | |
| MODTF Scenario 3 | FESG consensus | Fleet-Wide Moderate Operational Improvement | 0.5 percent | 1.4 percent | 2.3 percent | 0.95 percent per annum | 0.57 percent per annum | |
| MODTF Scenario 4 | FESG consensus | Fleet-Wide Moderate Operational Improvement | 0.5 percent | 1.4 percent | 2.3 percent | | | 0.96 percent per annum |
| MODTF Scenario 5 | FESG consensus | Fleet-Wide Advanced Operational Improvements | 1.0 percent | 1.6 percent | 3.0 percent | | | 1.16 percent per annum |
| MODTF Scenario 6 | FESG consensus | Fleet-Wide Optimistic Operational Improvements | 3.0 percent | 6.0 percent | 6.0 percent | | | 1.5 percent per annum |

Information contained in this table was derived from GIACC/4-IP/1, *Global Aviation $CO_2$ Emissions Projections to 2050*.
MODTF Scenarios 1 and 2: “assumptions… regarding fuel burn improvements are not considered to be a realistic outcome.”
MODTF Scenario 6: “goes beyond the improvements based on industry-based recommendations.”

4.2 MODTF computed global aviation fuel burn (and hence CO2 emissions) for 2006, 2016, 2026 and 2036 consistent with the FESG CAEP/8 central traffic forecast (developed at the global level for passenger and freight services) for a range of modelling scenarios, summarized in Table 5. MODTF results are currently only available for the FESG CAEP/8 central forecast. It is anticipated that application of the FESG CAEP/8 low scenario will reduce results by 15 to 20%. In addition, the MODTF extrapolation approach does not allow the effects of market maturity to be captured, which would constrain the growth in global aviation demand and hence in emissions.

**Figure 4: MODTF and FAA Analysis Scenarios Compared for Global Aviation Fuel Burn Projections to 2050 (million tonnes of fuel used)**

(MODTF/FESG-PTG results are pending review and acceptance by CAEP/8)



4.3 MODTF scenarios presented in GIACC/4-IP/1 were accompanied by the following note: *"Results presented in (the GIACC/4-IP/1) paper should be considered illustrative. They demonstrate the order of magnitude of global aviation CO2 emissions in 2050 under a range of assumptions. The uncertainties when looking out to 2050 must be acknowledged when interpreting the results presented."*

4.4 The APMT-Economics tool, used to model the FAA Analysis Scenarios, was developed to work with the Aviation Environmental Design Tool (AEDT); and, when used together AEDT generates the fuel burn and emissions. For this analysis, however, APMT-Economics modeled the fuel burn based on aircraft specific fuel burn characteristics extracted from an AEDT generated 2005 global inventory.[5] While the fuel burn component within APMT-Economics is primarily used to establish a reasonable estimate for the fuel cost component of total aircraft type-specific operating costs, the ability of APMT-Economics to estimate fuel burn was verified against AEDT and found to be within the range of other MODTF models.

4.5 As depicted in Figure 4, the FAA Analysis Baseline level at 2050 approximately coincides with the FESG-PTG modelled MODTF Scenario 5 with FESG central demand. FAA Scenarios A and B show higher global fuel burn projections at 2050 than the following three FESG-PTG modelled scenarios: MODTF Scenario 5 with MMU B1 demand scenario, MODTF Scenario 3 with MMU A2 demand scenario, and MODTF Scenario 5 with CONSAVE B1_DtE demand scenario.

## 5. **ALTERNATIVE FUELS**

5.1 Appendix B presents an update on the research that was presented in GIACC/3-IP/4. The major changes are an update on the life cycle greenhouse gas emissions of Hydro-treated Renewable Jet bio fuel created from algae, an analysis of jatropha as a Hydro-treated Renewable Jet bio fuel feedstock, and a revised examination of the potential for bio fuels to replace 50% and 100% of jet fuel in the year 2050.

## 6. **CONCLUSIONS**

6.1 Results presented in this paper should be considered illustrative. They attempt to demonstrate the order of magnitude of global aviation $CO_2$ emissions in 2050 under a range of assumptions. The uncertainties when looking out to 2050 must be acknowledged when interpreting the results presented.

6.2 While the results of the FESG-MODTF work and the FAA Analysis Scenarios are considered illustrative, the comparison of scenarios exemplifies that the FAA scenario results are within the range projected by the FESG-PTG, and will likely be in the range of the FESG CAEP/8 low forecast. In addition, the results from the FAA Analysis Scenarios demonstrate that reflecting more up to date information on the economic and aviation activity from 2006 to the present makes a marked difference in the projected 2050 fuel burn levels. For example, compared to earlier MODTF projections, global fuel burn by 2050 could be 20-50% lower under some alternative scenarios. This is potentially significant as it could make it either more feasible to use alternative fuels (less supply required) or less costly for market measures (fewer charges or emission permits to purchase) to offset fully aviation's carbon growth in the longer-term.

[5] APMT-Economics analyses for CAEP/8 incorporate inputs from the 2006 reference data set.

6.3 We offer this information to GIACC to consider as it discusses the range of potential aspirational goals being developed in the medium and long term for the international aviation sector.

— END —