CAEP Report on the Feasibility of a Long-Term Aspirational Goal for International Civil Aviation CO_2 Emissions reductions (LTAG)

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Introduction

The 40th Session of the ICAO Assembly in October 2019 requested the Council to explore the feasibility of a long-term global aspirational goal (LTAG) for international aviation for consideration by its 41st Session (Resolution A40-18, paragraph 9). The CAEP LTAG Task Group (LTAG-TG) was established in March 2020 with the agreement of the ICAO Council to provide technical support to the Council in exploring the feasibility of a LTAG.

CAEP LTAG-TG undertook:

- **data gathering** from internal and external sources in a transparent and inclusive manner,
- **development of combined in-sector scenarios** from technology, fuels, and operations that represent a range of readiness and attainability based on the data gathering, and
- **conducted final analysis** of the scenarios to understand those **impacts on CO_2 emissions** and **cost associated with the scenarios** and **economic impacts on aviation growth, noise and air quality**, in all countries especially developing countries and the results was placed **in context of the latest consensus scientific knowledge**.

The final report from CAEP consolidates cumulative efforts of over 280 experts and provides a technical assessment of the feasibility of an LTAG.

Methodology: Overview

Figure 1 illustrates the overall methodology used for the LTAG feasibility study. The LTAG feasibility study started from the Data Gathering process, embracing Aircraft Technology, Operations and Fuels areas, which contributed to each element of the Integrated Scenarios.

On the Economic Modeling and Traffic Forecast, the Fleet Evolution was evaluated, which was fed into the CO_2 emissions modeling. Additionally, the consensus scientific knowledge on climate change formed the basis and context for the output of the analysis.

The detailed results from each subgroup of LTAG-TG will be covered in a separate subsequent articles and will cover:

- CO_2 Emissions Trends;
- Cost and Investment Estimations;
- Additional Analyses results, such as sensitivity analyses, for example;
- Results on Aviation in Context of Scientific Knowledge.

1 Hajime Yoshimura (Japan Civil Aviation Bureau), Chairperson of the Long-Term Aspirational Goal Task Group of the ICAO CAEP, and Michael Lunter (Ministry of Infrastructure and Water Management, the Netherlands) and Mohammed Habib (Delegation of The Kingdom of Saudi Arabia on the Council of ICAO), LTAG-TG Vice-Chairpersons would like to acknowledge the invaluable contribution of the 287 members of the Long-Term Aspirational Goal Task Group.

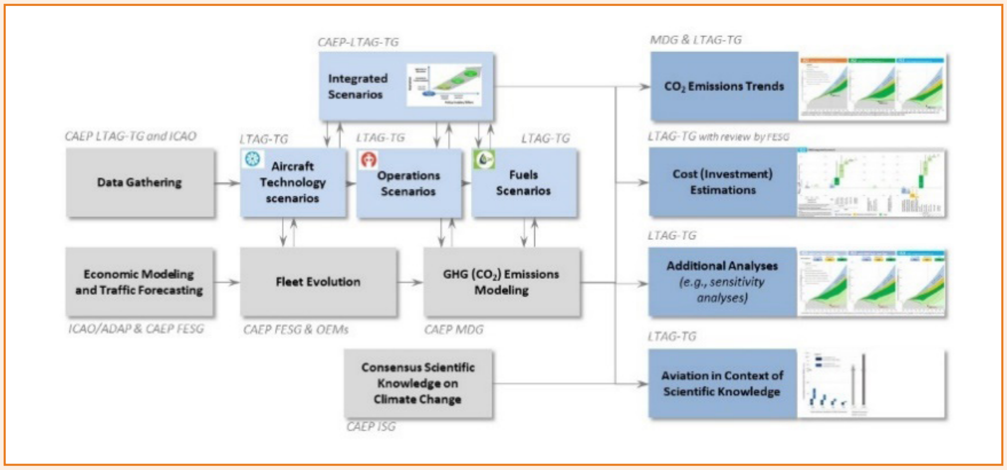


FIGURE 1: Overall Methodology used for the LTAG feasibility study

LTAG integrated scenarios

The LTAG analysis is not aimed at forecasting future emissions trends in aviation but is explicitly a scenario-based analysis. A set of scenarios (Integrated Scenarios) were developed to represent the level of effort and aspiration needed with the degree of readiness and attainability (Figure 2). With the baseline scenario numbered as zero, the Integrated Scenario 1 (IS1) represents the pathway with highest readiness level and attainability but with the lowest aspiration. While Integrated Scenario 3 (IS3) offers the highest aspiration, but requires greater efforts to attain. The Integrated Scenario 2 (IS2) is the middle path between scenarios 1 and 3.

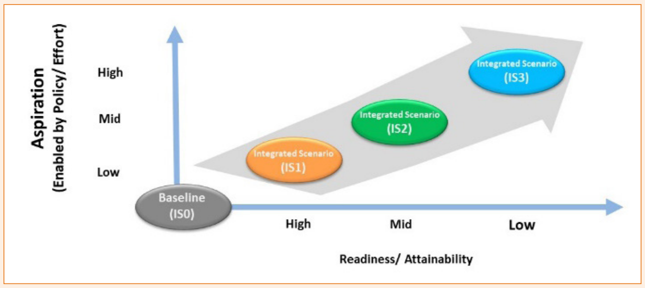


FIGURE 2: Integrated scenarios

Question 1: How could in-sector measures (i.e., technology, operations, and fuels) help reduce CO_2 emissions from international aviation through 2050 and beyond?

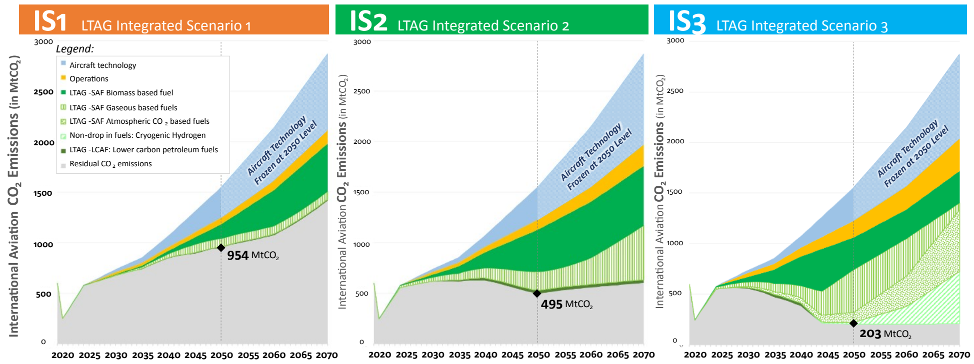
In terms of CO_2 emissions in 2050 taking into account reductions from aircraft technology, operations, and fuels, CO_2 emissions could reach from 950 $MtCO_2$ for IS1, to 200 $MtCO_2$ for IS3, equivalent to a 39–87% reduction from the baseline scenario. In terms of a breakdown, the fuels part is the biggest with 15–55% range, followed by the technology with around a 20% share, and with operations ranging from 4 to 11% (Figure 3).

For your reference, the cumulative residual CO_2 Emissions from 2020 to 2070 are also provided. These are the following points with regard to the high-level observations from the LTAG analysis:

- Scenarios show the potential for substantial CO_2 reduction, however none of them reach zero CO_2 emissions using in-sector measures only.
- There will be residual emissions despite 100% replacement of conventional jet fuel with novel fuels, due to consideration of fuels' life cycle emissions.
- As other aspects of economies reduce their emissions, the life cycle value should drop as well.
- As per the LTAG Terms of Reference, out of sector measures were not considered in the LTAG-TG analysis.

Advanced tube and wing aircraft have a clear potential to improve the fuel and energy efficiency of the international aviation system with some incremental contribution from aircraft with unconventional configurations.

The technology wedge continues to grow after 2050 as these aircraft penetrate the fleet. Hydrogen powered aircraft would exhibit worse energy efficiency, relative to aircraft operating on drop-in fuels, noting that emissions reductions would come from life cycle emissions reductions from the hydrogen.



Metrics	IS1	IS2	IS3
CO_2 Emissions in 2050 after Reductions	**≈950 $MtCO_2$** in 2050 *(**160%** of 2019 CO_2 emissions)*	**≈500 $MtCO_2$** in 2050 *(**80%** of 2019 CO_2 emissions)*	**≈200 $MtCO_2$** in 2050 *(**35%** of 2019 CO_2 emissions)*
Reduction in 2050 from the Baseline	**39% total** through: Technologies - 20%, Operations - 4%, Fuels - 15%	**68% total** through: Technologies - 21%, Operations - 6%, Fuels - 41%)	**87% total** through: Technologies - 21%, Operations - 11%, Fuels - 55%
Cumulative residual Emissions from 2020 to 2070	23 $GtCO_2$ (2020 to 2050) 23 $GtCO_2$ (2051 to 2070)	17 $GtCO_2$ (2020 to 2050) 11 $GtCO_2$ (2051 to 2070)	12 $GtCO_2$ (2020 to 2050) 4 $GtCO_2$ (2051 to 2070)

FIGURE 3: Reductions in CO_2 emissions from international aviation through in-sector measures through 2050 and beyond

The overall traffic growth rate has an important impact on residual CO_2 emissions by 2050 and after.

The analysis shows there are opportunities for operations to reduce CO_2 emissions through improvements in the performance of flights across all phases of flights, including unconventional measures such as formation flying.

Drop-in fuels have the largest impact on residual CO_2 emissions driving overall reductions by 2050, being independent—to some extent—of technology and operations scenarios.

Hydrogen is not expected to have a significant contribution by 2050 (with only 1.9% of energy share in 2050) but may increase in the 2050s and 2060s if technically feasible and commercially viable.

Question 2: How do cumulative aviation emissions compare to requirements to limit the global temperature increase to 1.5°C and 2°C?

Estimated cumulative residual global anthropogenic CO_2 emissions from the start of 2020 to limit global warming to 1.5°C is 400 $GtCO_2$ at 67% probability, i.e. the international aviation share could be around 4.1 to 11.3 % of this total.

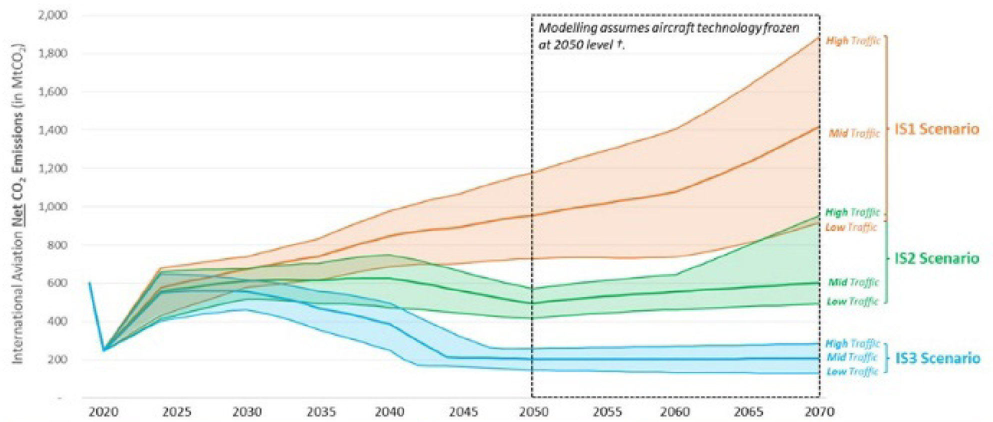
For a warming limit of 2°C, the remaining allowed global carbon emissions are estimated to be 1150 $GtCO_2$ at 67% probability, i.e. the international aviation share could range from 1.4 to 3.9% of this total.

Question 3: What investments are required to support the implementation of the in-sector measures associated with each scenario?

Costs and investments associated with the three scenarios are largely driven by fuels. Incremental costs of fuels (i.e. minimum selling price of SAF compared to conventional jet fuels) further motivates fuel and energy efficiency improvements from aircraft technology and operations. Aircraft technology and operational measures will require investments from governments and industry. More details on placing costs associated with LTAG Integrated Scenarios in context are provided in a dedicated article of this special supplement.

Question 4: What would be the impacts of various future aviation traffic levels?

Figure 4 provides CO_2 emissions in 2050 after the implemented emissions reductions from technology, operations and fuels. After 2050, the uncertainty grows



CO_2 **emissions in 2050 after emissions reductions** (from tech., ops and fuels)	IS1	IS2	IS3
High (traffic)	1160 $MtCO_2$	590 $MtCO_2$	260 $MtCO_2$
Medium (traffic)	950 $MtCO_2$	495 $MtCO_2$	200 $MtCO_2$
Low (traffic)	730 $MtCO_2$	420 $MtCO_2$	150 $MtCO_2$

FIGURE 4: Impact of Aviation Traffic Forecast

towards 2070, with an increasing range between high, mid and low options within the scenarios. The table at the bottom shows the CO_2 emissions remaining in 2050 following the implementation of the reduction measures.

Question 5: How sensitive are the results to scenario assumptions?

In developing the integrated scenarios, LTAG-TG recognised that there could be multiple combinations of technology, operations and fuels measures to form alternative integrated scenarios. In particular, sensitivity analysis was conducted to examine the impact of lower technology and operations improvements, coupled with high reductions from fuels.

This shows that there are multiple paths that may result in similar levels of emissions. However, in all cases, the contribution from fuels is critical to decouple the growth in international air traffic from its emissions.

Considerations regarding LTAG Options

Based on the results of the LTAG feasibility study, technical options for LTAG metrics were identified. This is not an exhaustive list and other formulations may be considered.

One type of option could use annual levels of emissions:

- The annual level of emissions, for example: 950, 500 or 200 Mt CO_2 in 2050.
- Using a reference year earlier than 2050 may not give the long-term certainty expected to be a key benefit of adopting an LTAG, while using a reference year after 2070 would be subject to increased uncertainty.
- Additional intermediate waypoints in milestone years could layout a trajectory to the emissions profile.

Another option could use cumulative total emissions:

- The cumulative total emissions from the international aviation sector: for example 23, 17 or 12 $GtCO_2$ by 2050.
- This would most closely translate into an atmospheric temperature response.

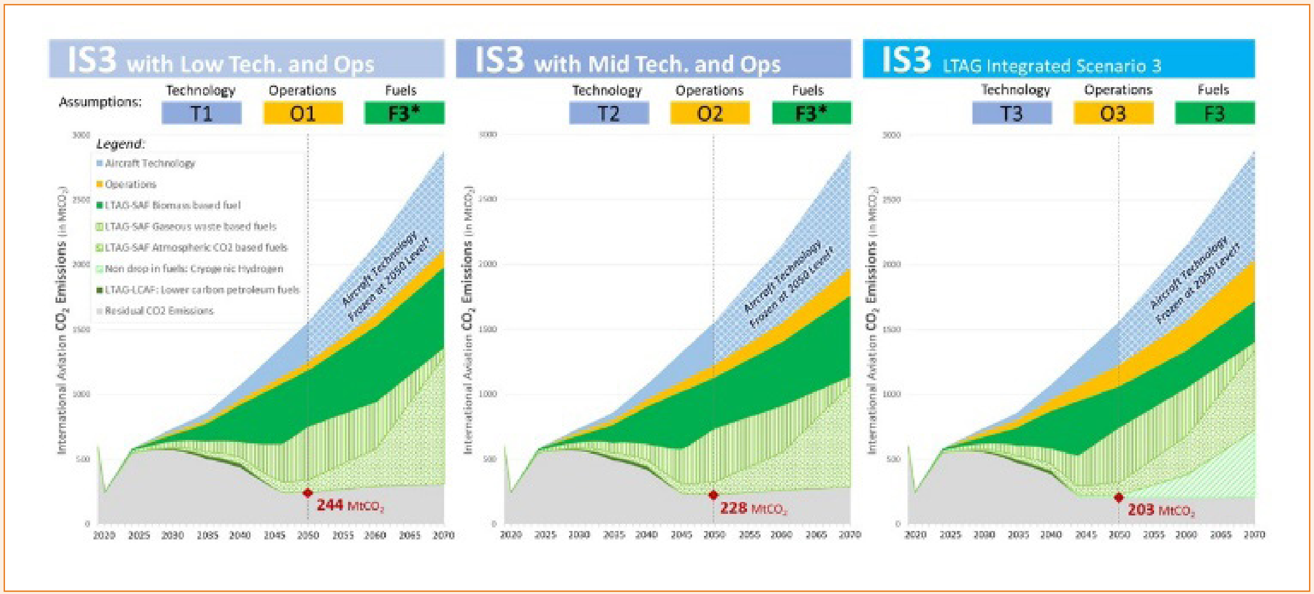


FIGURE 5: Sensitivity analysis of IS3 Scenario demonstrates the importance of fuels

Other impacts

The LTAG analysis also included consideration of the other impacts. Potential impacts on aviation growth were qualitatively considered, finding that an LTAG may increase operating costs and some costs may be passed on to passengers. This impact may be limited, however, and aviation will continue to deliver national, regional and global benefits.

Most significant regional variations are expected in production and uptake of fuels due to, for example, regional availability of feedstocks, renewable energy, and infrastructure.

With regard to the impacts on noise and air quality, in all scenarios, the traffic growth increased total noise and NOx emissions.

However, technology improvements typically reduced noise and emissions alongside fuel burn. Additionally, operational efficiencies may have co-benefits for noise but did not impact air quality. Another observation is that LTAG SAF and cryogenic hydrogen have co-benefits, for local air quality and contrail formation with no impact on noise.

Roadmaps for LTAG Implementation

On roadmaps, CAEP considered technical aspects of implementation without prejudging any future decisions. For monitoring of progress, State Action Plans may be used for States to report progress towards a goal, without duplicating existing processes.

If a goal were adopted, CAEP could conduct future work on possible metrics, reporting mechanisms, etc.

ICAO may need to review any goal to ensure it remains appropriate. For this purpose, a triennial review process could be considered similar to the CORSIA Periodic Review, for example. Finally, capacity building and assistance may be needed, for example:

- Workshops on measures, including understanding costs;
- Assistance on monitoring and measuring CO_2 emissions;
- An overarching training programme similar to ACT-CORSIA.