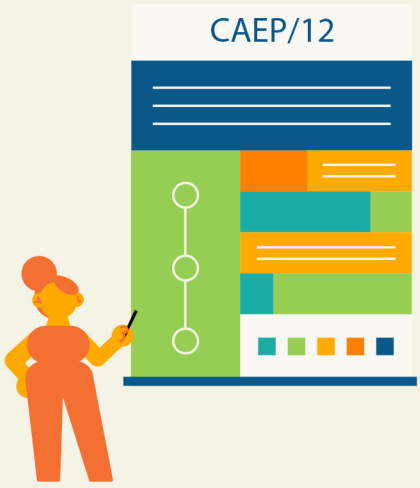
ICAO

INTERNATIONAL CIVIL AVIATION ORGANIZATION

REPORT ON THE FEASIBILITY OF A LONG-TERM ASPIRATIONAL GOAL (LTAG) FOR INTERNATIONAL CIVIL AVIATION CO_2 EMISSION REDUCTIONS

Appendix R2 Comparison to CAEP/12 Trends



ICAO COMMITTEE ON AVIATION ENVIRONMENTAL PROTECTION
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APPENDIX R2

COMPARISON TO TRENDS

1. INTRODUCTION

1.1 This appendix compares the fuel burn and CO_2 emissions from international aviation of each LTAG integrated scenario to the results of the CAEP/12 Environmental Trends Assessment.

1.2 The purpose of this comparative analysis is to show the differences between the CAEP/12 Trends Assessment and the LTAG analysis. While the input to the trends technology scenarios are based primarily on historical per annum improvements in technology, the LTAG technology scenarios explicitly consider more aggressive improvements in technology, e.g. departure from the classic tube-and-wing design, electric propulsion, etc. While the trends operational improvement scenarios are represented in the LTAG operational improvements, the LTAG operational improvements also consider some more aggressive improvement measures. The fuels-related scenario used in trends is identical to Integrated Scenario 2 used in LTAG.

2. SCOPE OF THE EXERCISES

2.1 It must first be recognised that, while the CAEP/12 Trends Assessment and LTAG analysis model the fuel burn and CO_2 from international aviation for overlapping periods (2018-2050 for trends and 2018-2070 for LTAG) and leverage the same modelling tools, these exercises are intended to fulfil different purposes. This appendix compares the results only for the period common to both studies, 2018-2050.

2.2 While the CAEP/12 Trends Assessment is CAEP's best assessment of future fuel burn and CO_2 from international aviation, with scenarios to demonstrate the uncertainty in the assessment, the LTAG analysis has been conducted to fulfil the LTAG-TG Terms of Reference (see **Appendix B1**), which require it to analyse scenarios "that represent a range of readiness and attainability". In practice, this means that the LTAG analysis represents additional 'ambition' over and above what is considered in the Trends Assessment.

2.3 The following Table 1 summarises the key similarities and differences between the two tasks.

Table 1 Summary of the key similarities and differences between CAEP/12 Trends Assessment and LTAG Analysis

	CAEP/12 Trends Assessment	LTAG Analysis	Additional Remarks
Scope			
Primary purpose	Quantify the evolution of global aviation's noise, emissions and fuel burn over the ICAO long-term forecast period (i.e. what is expected?)	Feasibility assessment to reduce in-sector international aviation CO_2 emissions, including beyond the ICAO long-term forecast period (i.e. what is possible?)	
Base year	2018		LTAG was extended to 2070 to ensure additional penetration of new technology in the fleet.
Final Year	2050	2070	
Sector	International, domestic and global aviation	International aviation	
Pollutants modelled	Fuel burn, CO_2, Noise, NOx, PM	Fuel burn, CO_2. Others qualitatively.	
Measures			
Types of measures	Technology, operations, fuels		Neither analysis includes out of sector measures, e.g. offsetting.
Level of certainty in measures	Existing and foreseen measures	Existing, foreseen, and innovative in-sector measures, taking into account enablers	
Technology measures	Historical per annum improvements extrapolated	More radical changes: hybrid-electric and hydrogen propulsion, departure from the classic tube-and-wing design	
Fuels measures	Central LTAG scenario (IS2) used	Increasingly aggressive assumptions about feedstocks and production volumes	
Operational measures	ASBU elements	Additional, more aggressive assumptions about possible operational improvements, in addition to ASBU elements	
Methods and forecasts			
Traffic forecasts	FESG CAEP/12 COVID-19 traffic demand forecast scenarios (low, mid and high)		
Scenarios	A range of possible scenarios depending upon pollutant and domain (technology, operations/ATM, fuels).	Integrated scenarios 1, 2 and 3 representing increasing 'aspiration' and lower 'readiness' and 'attainability'.	
Type of analysis	Assessment based on expected technology scenarios defined by WG1, WG2, WG3 and FTG.	Assessment based on scenarios representing additional ambition / more aggressive improvements over and above business as usual	

3. RESULTS OF THE LTAG ANALYSIS

3.1 This section presents a summary of the results of the analysis. For fuller results, please see **Appendix R1**.

3.2 The global CO_2 emissions from international aviation in the mid traffic forecast are shown below.

3.3 The baseline (IS0) scenario is exactly the same as the Trends mid traffic baseline "technology freeze" scenario which results in 29 Gt CO_2 from international aviation from 2019 to 2050. To ensure consistency with the Trends traffic demand forecast, 2018 was agreed to be used as the reference base year for LTAG. For more information about the scenarios, please see **Appendix M1**.

Table 2 Summary of CO_2 emissions from international aviation ($MtCO_2$), mid traffic forecast, 2019-2050

LTAG IS	2019	2030	2040	2050	Cumulative, 2019-2050
IS0	600	740	1070	1,600	29,000
IS1		670	850	950	23,000
IS2		610	620	500	18,000
IS3		550	390	200[1]	13,000

Note: Annual values rounded to nearest 10Mt. Cumulative values rounded to nearest 1,000Mt.

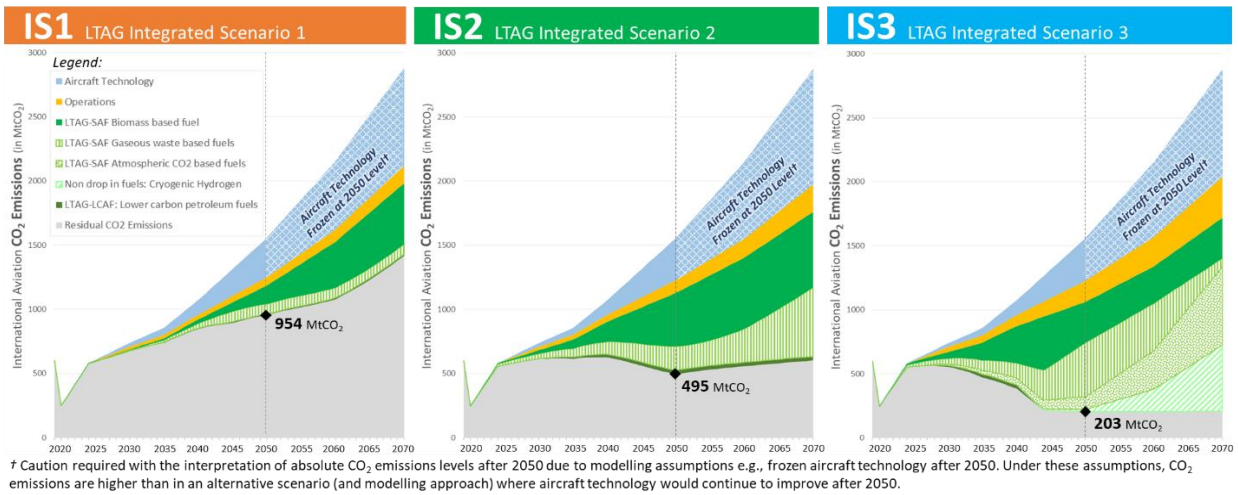


Figure 1 CO_2 emissions from international aviation for the LTAG Integrated Scenarios

[1] This takes into account the emissions reductions due to most aggressive alternative fuels scenario and those reductions mostly occur during the production process.

4. SUMMARY OF TRENDS ASSESSMENT

4.1 The GHG portion of the Trends Assessment conducted by the MDG evaluates potential contributions of operational and technology improvements to reducing projected fuel demand and associated future emissions, focusing on combustion CO_2 emissions. The results are based on the CAEP/12 2018-2050 post-COVID traffic and fleet forecast as documented in **Appendix M2**.

4.2 Figure 2 presents the CO_2 emissions from international aviation from 2005 to 2050. It includes the range of scenarios considered in the trends assessment. For the comparative analysis below, the CAEP/12 Trends Fuel Scenario 4 is carried forward. This is the most aggressive scenario in terms of technology and operational improvements and is based on the Independent Expert Integrated Review (IEIR) Technology and CAEP/12 WG2 High Operational Improvement.

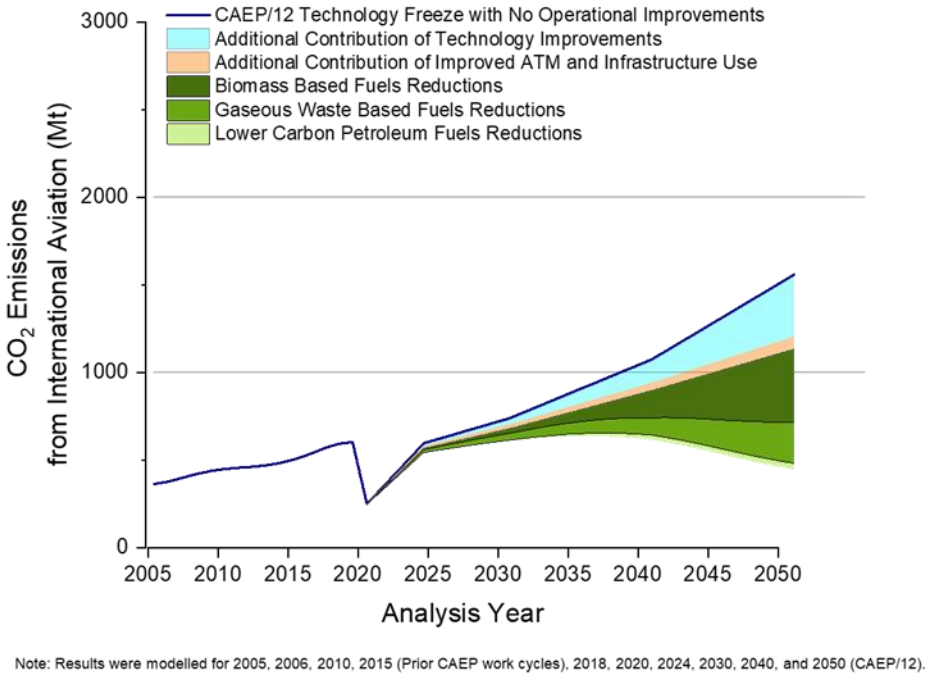


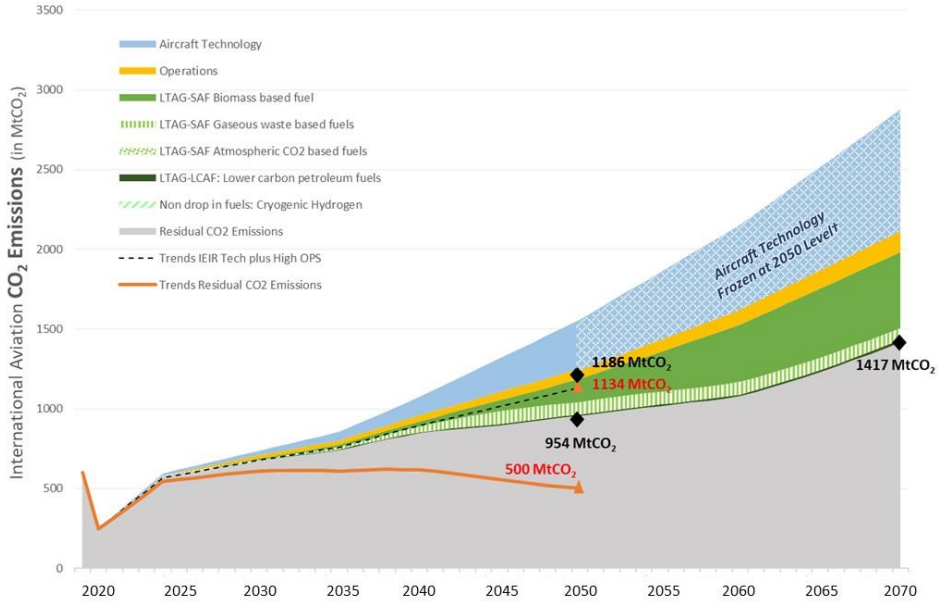
Figure 2 CO_2 Emissions from International Aviation, 2005 to 2050, Including Alternative Fuels Net Life-Cycle Emissions Reductions

5. COMPARATIVE ANALYSIS

5.1 The comparative analysis is shown for the mid traffic forecast. Figure 3 shows how the CAEP/12 Trends Fuel Scenario 4 compares with LTAG IS1 scenario. Figures 4 and 5 shows how the CAEP/12 Trends Fuel Scenario 4 compares with LTAG IS2 and IS3 scenarios, respectively.

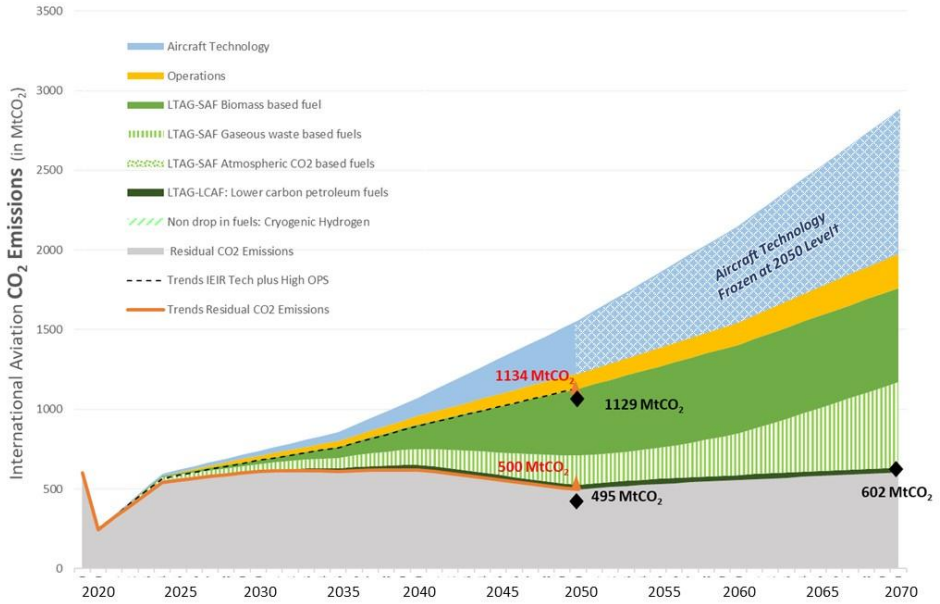
5.2 In addition to including the improvements associated with the migration to the latest operational initiatives, e.g. those planned in NextGen and SESAR, Fuel Scenario 4 (*Independent Expert Integrated Review (IEIR) Technology and CAEP/12 WG2 High Operational Improvements*) includes the IEIR per annum fuel burn improvement (which varies by aircraft type) for all aircraft entering the fleet after

2018 out to 2050. It also includes additional fleet-wide CAEP/12 WG2 high Operational Improvements by route group.



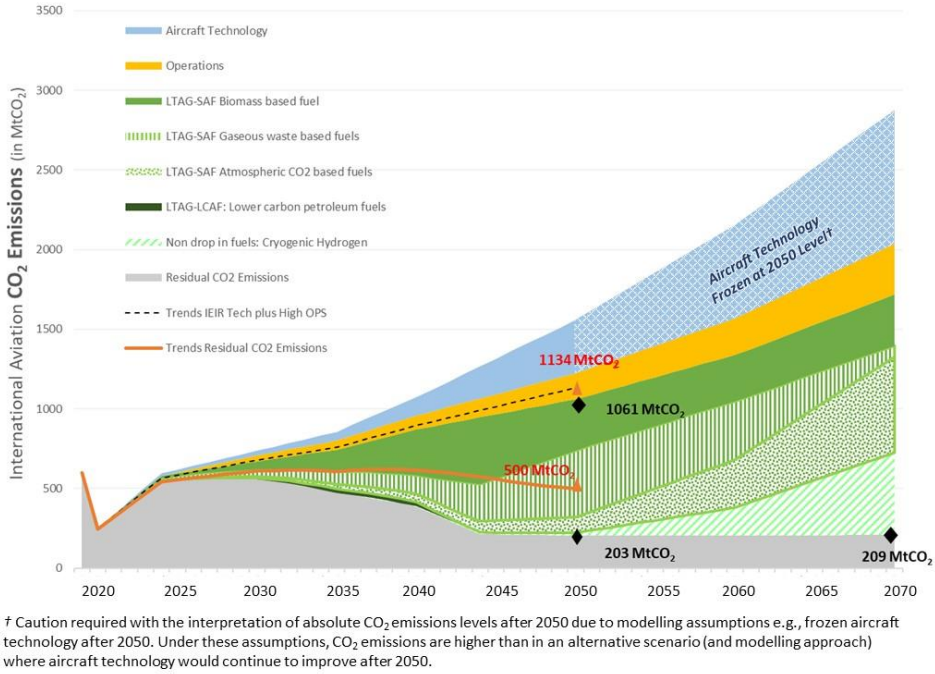
† Caution required with the interpretation of absolute CO_2 emissions levels after 2050 due to modelling assumptions e.g., frozen aircraft technology after 2050. Under these assumptions, CO_2 emissions are higher than in an alternative scenario (and modelling approach) where aircraft technology would continue to improve after 2050.

Figure 3 Comparison of Trends Fuel Scenario 4 with and LTAG IS1 Scenario



† Caution required with the interpretation of absolute CO_2 emissions levels after 2050 due to modelling assumptions e.g., frozen aircraft technology after 2050. Under these assumptions, CO_2 emissions are higher than in an alternative scenario (and modelling approach) where aircraft technology would continue to improve after 2050.

Figure 4 Comparison of Trends Fuel Scenario 4 with and LTAG IS2 Scenario



† Caution required with the interpretation of absolute CO_2 emissions levels after 2050 due to modelling assumptions e.g., frozen aircraft technology after 2050. Under these assumptions, CO_2 emissions are higher than in an alternative scenario (and modelling approach) where aircraft technology would continue to improve after 2050.

Figure 5 Comparison of Trends Fuel Scenario 4 with and LTAG IS3 Scenario

5.3 With the contribution of technology, operations and fuels measures, the gap between the final emissions of 2050 in the integrated scenarios and the IS0 is shown in table 3.

Table 3 The relative emissions of integrated scenarios to the baseline (IS0) scenario, in 2050

LTAG IS	2050		
	Emission reduction compared to IS0		Percentage contribution from measures
	Mt CO_2	Percentage	
IS1	-650	39%	Tech: 20%
			Ops: 4%
			Fuels: 15%
IS2	-1100	68%	Tech: 21%
			Ops: 6%
			Fuels: 41%
IS3	-1400	87%	Tech: 21%
			Ops: 11%
			Fuels: 55%

6. SUMMARY

6.1 Comparisons have been made between residual in-sector (after technological, operational and fuels measures) international aviation emissions under the three LTAG scenarios (IS1, IS2 and IS3) and those calculated under Fuel Scenario 4 of the CAEP/12 Environmental Trends Assessment out to 2050. The baselines (termed IS0 for LTAG) are identical between the two sets of analyses. The residual in-sector emissions under LTAG scenario IS2 are very close to those under the Trends Fuel Scenario 4. LTAG Scenarios IS1 and IS3 give, respectively, higher and lower emissions than the Trends scenario in 2050. This is due to the LTAG-TG Terms of Reference, which require the Task Group to analyse scenarios “that represent a range of readiness and attainability”.

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