Emissions Technical: Progress of CAEP/13 Working Group 3

By Bethan Owen (UK)[1] and ICAO Secretariat

The ICAO Committee on Aviation Environmental Protection (CAEP), through its working groups, has advanced a broad range of activities in the field of aircraft environmental performance under its thirteenth cycle.

While historically CAEP has considered CO_2 Emissions and Noise stringency analyses independently (i.e., in different cycles), this was the first time when both were analysed at the same time. This integrated approach — known as the *Integrated Dual Stringency* (IDS) analysis — was a major step forward in understanding how environmental and cost impacts interact when multiple standards are applied simultaneously. It required a new and integrated approach to consider interdependencies between CO_2 emissions (fuel burn) and noise.

The execution of the integrated dual stringency analysis for aeroplane CO_2 emissions and Landing and Take-off (LTO) noise was jointly conducted by CAEP Working Group 1 (WG1, *Noise Technical*), Working Group 3 (WG3, *Emissions Technical*), the Modelling and Databases Group (MDG), and the Forecasting and Economic Support Group (FESG). This integrated effort has culminated in the completion of a comprehensive analysis presented for CAEP's consideration.

The Integrated Dual Stringency Analysis

Following the agreement reached at CAEP/12 in February 2022, the integrated stringency work was developed to support a dual standard-setting process for aeroplane CO_2 and noise emissions. The collaboration between WG1, WG3, MDG, and FESG was coordinated under the Integrated Stringency Coordination Group (ISCG), ensuring consistency and alignment across technical analyses and modelling assumptions.

The CAEP/13 integrated dual stringency analysis includes the assessment of stringency options (SOs) concerning (1) New Type (NT) standards for aeroplane CO_2 emissions and Noise and (2) the In-Production (InP) standard for aeroplane CO_2 emissions (only).

Summary of Results: Dual CO_2 and Noise Stringency Analysis for New Type Aircraft (NT)

To carry out this assessment, two modelling methods were used to simulate future aircraft fleet responses: the A1 approach, which assumes aircraft respond immediately once a standard is in place, and the M.07 approach, developed during CAEP/13, which reflects a scenario in which responses are delayed—representing the time required for new technologies to enter the market. Both modelling approaches are scenarios and the "reality" is likely to lie in between these.

The analysis considered various combinations of CO_2 Stringency Options (CSOs) and Noise Stringency Options (NSOs). CSOs and NSOs represented different levels of stringency for the New Type aeroplane CO_2 and noise standards, labelled progressively from A to G and A to E respectively. Each higher letter (e.g., CSO D compared to CSO A) indicated a more stringent emissions requirement,

1 Bethan Owen is Co-Rapporteur of Working Group 3 of the ICAO Council's Committee on Aviation Environmental Protection (CAEP).

meaning fewer aeroplanes can comply without requiring a Technology Response — design or performance adjustments made by manufacturers to meet the standard.

A1 Approach Results

Under the A1 method, results showed a clear pattern: more stringent CSOs led to greater reductions in cumulative CO_2 emissions. As stringency increased from CSO A to CSO D, the share of aircraft passing without needing TRs dropped significantly—from 76% at CSO A to just 38% at CSO D. A major drop in emissions occurred at CSO D, particularly because no aircraft in a specific sub-market segment could meet the standard. In such cases, a modelling rule called Empty Competition Bin Management (ECBM) was applied: demand was fulfilled using larger aircraft from the next market segment, leading to fewer total flights and reduced fuel use.

For noise, increasing NSOs led to greater reductions in population and area exposed to 55 dB levels. The highest noise reductions were achieved with NSO E, the most stringent level. Cost outcomes followed a similar trend to emissions, with more stringent CSOs and NSOs (especially scenario CSOD\NSOE) resulting in larger reductions in total cumulative costs — driven by fewer operations, lower fuel consumption, and reduced capital and operating expenses.

M.07 Approach Results

The M.07 approach allowed assessment of scenarios that were not possible under A1 due to ECBM constraints. Unlike A1, M.07 assumes aircraft take longer to adapt to new standards. As a result, environmental benefits under M.07 tend to emerge later and can be more moderate especially in view of the fixed analysis time out to 2050.

In CO_2 terms, results under M.07 were mixed. For example, CSO D and the highest level, CSO G, showed lower emission reductions than some less stringent options. This is because, when no aeroplane(s) in a Competition Bin can be modified to meet a given CSO, M.07 reverts that bin to its original 2029 baseline configuration. That means no environmental improvement from that segment—unlike A1, which fills the gap with larger, more efficient aeroplanes. Nonetheless, CSO E and F scenarios still showed strong CO_2 reductions under M.07.

For noise, as in A1, greater NSO stringency led to better (quieter) results.

Top-Performing Scenarios

In summary:

- Under the A1 approach, scenario CSO D\NSO E delivered the strongest combination of benefits in cost, CO_2, and noise.
- Under the M.07 approach, CSO F\NSO C ranked highest in cost and CO_2 reductions, while CSO C\NSO E performed best for noise.

Scenario rankings remained stable even when discount rates (3%, 7%, 9%) were applied, especially for the top performers. This consistency reinforces the reliability of the analysis and provides a solid technical foundation for decision-making on future international standards.

As part of the CAEP/13 integrated assessment, the CO_2 standard for In-Production (InP) aeroplanes were also evaluated using the A1 fleet evolution modelling approach. Results showed that higher stringency levels led to greater reductions in CO_2 and costs. CAEP considered the purpose of an InP standard for CO_2, recognizing that the InP regulatory level was established in CAEP/10 as part of the first CO_2 standard to prevent backsliding of in production products over time and to provide a production cut off for low performing products. The CAEP agreed that the regulatory focus for a technology standard should be the New Type regulatory level which can influence the clean sheet designs of future aeroplane designs.

Summary of Integrated Dual Stringency Results

After consideration of the stringency options for the Annex 16, Volume III provisions, CAEP recommended amendments to the CO_2 Standard for subsonic aeroplanes with 10 per cent / 3 per cent more stringent limits for large / small aeroplanes with an applicability date on 31 December 2031 for new aeroplane types, and more stringent emissions standard for in-production aeroplane types applicable on 1 January 2035. CAEP also recommended amendments to the Noise Standard for subsonic aeroplanes with 6dB

/ 2dB more stringent limits for large / small aeroplanes applicable on 1 January 2029.

These recommendations, along with other recommendations agreed during the 13th CAEP meeting held at ICAO Headquarters from 17 to 28 February, will be considered by the Council in due course in 2025.

Other WG3 Work during the CAEP/13 Cycle

Beyond the dual stringency analysis, WG3 advanced several other activities across its full Work Programme for the CAEP/13 cycle. These included work on emissions characterization, certification requirements, supersonic transport, fuel composition effects, and coordination with other groups on environmental trends.

For example, WG3 Emissions Characterisation Task Group addressed a wide range of topics including:

- Updates to ICAO Doc 9889 *Airport Air Quality Manual* to reflect new modelling methodologies and emissions data;
- Assessment of nvPM and NO_x emissions and their relation to cruise operations;
- Review of potential new NO_x metric systems for future aircraft engine emissions standard setting processes;
- Study of ambient conditions corrections and particle size changes affecting nvPM emissions.

The WG3 Certification Task Group worked to maintain and update Annex 16, Volume II (engine emissions) and Volume III (aeroplane CO_2 emissions) with the associated Environmental Technical Manual (ETM) Volumes II and III, as well as CO_2 and emissions engine certification databases.

Notably, the CTG submitted drafted amendments to align Volume III with the new CAEP/13 Aeroplane CO_2 Standards for NT and InP. These updates addressed clarity in compliance methods (direct flight testing or performance models), definitions, SARPs applicability, and editorial improvements to ensure consistency across regulatory material.

The WG3 Supersonic Transport Task Group STG addressed certification requirements and environmental impacts associated with supersonic transport aircraft. The group worked in parallel with WG1's related activities and assessed appropriate regulatory paths and timeline considerations.

Additionally, WG3 worked in close coordination with the Fuels Task Group (FTG, WG5 in the current CAEP/14 cycle) and the Impacts Science Group (ISG) to assess emissions effects of fuel composition, particularly Sustainable Aviation Fuels (SAF). The cross-cutting work supported the integration of SAF effects into emissions quantification and ensured coordinated input to MDG and other groups.

WG3 also contributed to the ICAO Environmental Trends Assessment, including providing assumptions for emissions projections and delivering inputs for the modelling activities led by MDG.

Finally, WG3 collaborated with WG1 and MDG on public data analysis reflecting interest in leveraging public datasets for future stringency assessments.

Conclusion

The CAEP/13 cycle has marked a significant advancement in the ICAO community's ability to assess and develop certification standards for improved aircraft environmental performance. Through the integrated dual stringency work—spearheaded jointly by WG1, WG3, MDG, and FESG—and the broader programme of technical development under WG3's Work Programme, ICAO continues to deliver the data-driven, collaborative foundation needed to inform regulatory progress. The extensive technical work conducted, culminated in the CAEP/13 Report with the related appendix containing regulatory impact assessment information to support the rulemaking processes of ICAO Member States for implementation of the integrated CO_2 and noise standards stringencies, provides the basis for critical decisions on the integrated dual stringency in support of the Organization's long-term environmental goals.

The CAEP/13 work developed by Working Group 3 is now under ICAO Council consideration for final approval.