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EPA Technical Report on Aircraft Emissions Inventory and Stringency Analysis (March 2019): Peer Review

Revised Final Report

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Table 1.2. Selected Peer Reviewers		
Name	**Modeling of aircraft emissions inventory from aircraft operations**	**Methods for assessing regulatory impact from stringency scenarios**
Selected Peer Reviewers:		
Sarav Arunachalam, PhD	SME	SME (G)*
Gregg Fleming	G	SME
Ling L. Lim, PhD	SME	G (SME)**
Mark Lowenberg, PhD AND Dudley Shallcross, PhD (joint review)	SME	G
Selected Overlapping Peer Reviewer from Technology/Cost Draft Report:		
Gaudy Bezos-O'Connor	G	SME

Notes:

*EnDyna's review of Dr. Arunachalam's CV/resume indicated his experience/expertise would be rated "G," although when asked to review EnDyna's ratings, Dr. Arunachalam suggested revising that to "SME."

**EnDyna's review of Dr. Lim's CV/resume indicated her experience/expertise would be rated "SME," although when asked to review EnDyna's ratings, Dr. Lim suggested revising that to "G."

1.3 Scope of Peer Review

EPA carefully defined the scope of this peer review for the emissions draft report to focus the peer review process effectively on EPA's charge questions (see Section 2). The peer reviewers were directed to keep their written peer review comments within the EPA scope, as defined below:

> **The scope of this letter-style peer review is technical in nature, reviewing the selected methods, data quality, data sources, underlying assumptions, and the overall strengths and limitations of the study. EPA is especially interested in comments that focus on the validity or scientific merit of the methodology and that identify any significant weaknesses in the scientific information from the methodology. As such, peer reviewers should focus on providing comments on the technical nature of the report, and its consistency with the state of current science as you understand it and whether it will result in appropriate predictions and conclusions for EPA's aircraft CO_2 emissions**

inventory and impact assessment. Because the review is technical in nature, the peer reviewers should <u>not</u> focus on editorial style.

1.4 Supplementary Materials

The emissions draft report referenced the September 30, 2018, ICF report entitled *Aircraft CO_2 Cost and Technology Refresh* and *Aerospace Industry Characterization*. EnDyna provided this final ICF report to the peer reviewers as supplementary materials. Because the ICF technology/cost draft report had already been separately peer reviewed in 2017–2018 under WA 1-15, it was provided for reference only and was <u>not</u> part of this peer review.

EnDyna provided the peer reviewers with the following supplementary materials:

- *Aircraft CO_2 Cost and Technology Refresh* (Volume 1) and *Aerospace Industry Characterization* (Volume 2), both dated September 30, 2018, and
- *Technology Response Spreadsheet*, September 30, 2018 (this spreadsheet is a reference to understand selected figures, tables, and equations in Volume 1).

Similar to the emissions draft report, the supplementary materials were covered by the confidentiality requirements for this peer review.

1.5 EPA's Written Responses to Peer Reviewer Questions

To facilitate an effective peer review process, EnDyna's Peer Review Lead requested any peer reviewer questions about the emissions draft report. The EnDyna Peer Review Lead synthesized and clarified each of the peer reviewer questions, compiled them, and submitted those questions to EPA OTAQ on March 26, 2019, with the identity of each peer reviewer kept anonymous. EnDyna requested that EPA OTAQ provide responses to those peer reviewer questions in writing so that EnDyna could distribute the written EPA responses to all five peer reviewers.

Section 6 provides the peer reviewer questions that were compiled by the EnDyna Peer Review Lead and submitted to EPA on March 26, 2019, and the EPA responses that the EnDyna Peer Review Lead received from EPA OTAQ on April 2, 2019. The EnDyna Peer Review Lead sent those written EPA responses to the peer reviewers on April 4, 2019.

1.6 Organization of Report

This peer review report comprises seven sections:

- ***Section 1*** describes the process for this external letter-style peer review.
- ***Section 2*** presents the charge questions sent to each of the peer reviewers for comments.
- ***Section 3*** includes the synthesis of the peer reviewer comments.
- ***Section 4*** provides the peer review comments of each reviewer organized by charge question and includes EPA's responses to the peer review comments of each reviewer.
- ***Section 5*** consists of the individual peer reviewer comments.
- ***Section 6*** provides the questions from the peer reviewers and the written EPA responses to the peer reviewer questions.
- ***Section 7*** notes that the peer review materials packages were attached separately.

2. CHARGE QUESTIONS

The objective of this external letter-style peer review was to obtain written peer review comments from individual experts to support EPA's goal of providing independent peer review for the methodology and results found in the March 2019 emissions draft report *EPA Technical Report on Aircraft Emissions Inventory and Stringency Analysis* and to assure EPA that this study incorporates the highest quality science. Each peer reviewer was charged with evaluating the emissions draft report, providing their overall impressions of the scientific merit of the report, and responding to 16 charge questions.

The 16 charge questions provided to the peer reviewers are presented in Table 2.1.

Table 2.1. Charge Questions

1. Questions for entire emissions draft technical report
1.1. **–** Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant underlying scientific disciplines (engineering, mathematics, and statistics)? • If yes, explain why. • If not, describe all issues identified with the methods and procedures. As relevant, recommend alternate approaches that might better achieve the goal of developing an accurate and representative inventory model and stringency analysis. In making recommendations, distinguish between instances involving reasonable disagreement in adoption of methods as opposed to instances where you conclude that the methods employed involve specific technical errors.
1.2. **–** Is the description of analytical methods and procedures clear and detailed enough to allow the reader to develop an adequate understanding of the steps taken and assumptions made by EPA while developing the inventory model and stringency analysis? Are the selected tables and figures well-chosen and effective in improving the reader's understanding of analytical methods and procedures? • If yes, explain why. • If not, describe issues with clarity and presentation. As relevant, describe how to improve clarity and presentation of analytical methods and procedures.
1.3. **–** Does the report describe the selected data sources sufficiently to allow the reader to form a general view of the quantity, quality and representativeness of data used in the analysis? • If yes, explain why. • If not, describe all issues with data sources. As relevant, recommend alternate data sources that might allow the model to better estimate national or global aircraft emissions inventories and stringency option impacts.
1.4. **–** Where EPA has concluded in the report that applicable data is limited or unavailable, and consequently has made assumptions to frame approaches and arrive at solutions, do you agree that the assumptions are appropriate and reasonable?

Table 2.1. Charge Questions
• If yes, explain why. • If not, describe all issues identified with the assumptions. As relevant, suggest alternative assumptions that might lead to more reasonable or accurate inventory model.
1.5. – Is the overall inventory model and its analytical techniques appropriately and reasonably constructed to adequately support an effective aircraft emissions inventory and impact assessment? • If yes, explain why. • If not, describe all the issues identified with the model and its analytical techniques. Are the model results empirically consistent with the body of data and literature with which you are familiar? • If yes, explain why. • If not, describe the inconsistencies.
2. Fleet Evolution and Stringency Analysis Methodology, Modeling Assumptions, and Data Sources (Section 2)
2.1. – This section describes the methodology, assumptions, and data sources that EPA used to model CO_2 emissions inventories of the aviation sector for baseline and control scenarios. Are the modeling methodology, data sources, and assumptions reasonable and adequate for the purpose of the impact analysis? • If yes, explain why. • If not, explain how alternative modeling methods, assumptions, and data sources can be used to improve modeling of the aviation CO_2 emissions inventories.
2.2. – One of the challenges in the EPA fleet evolution model is to match the base year activity data (by route and aircraft used) in FAA's 2015 Inventory Database with that in FAA's TAF (Terminal Area Forecast) Database and assign the appropriate growth rate to the corresponding route/aircraft. Since the two databases do not match exactly, significant effort was devoted to find methods to overcome those database mismatch and incompatibility issues. Is the EPA's multi-tier approach in the report reasonable and adequate in handling the data incompatibility problem? • If yes, explain why. • If not, explain how alternative methods could help resolve the database mismatch problem better.
2.3. – In terms of data sources, if there are any publicly available data sources you know about that can help resolve the database mismatches or validate the datasets, provide references for such data sources.
3. Main Analysis based on Emissions Inventories for Selected Stringency Scenarios and Business-As-Usual Baseline (Section 3)
3.1. – EPA's main impact analysis is based on the analysis in the September 30, 2018 ICF report, which was already separately peer reviewed, and thus, EPA is not asking for a review of the ICF technology responses. However, is there validity in EPA's approach in

Table 2.1. Charge Questions
implementing the ICF technology responses? Can you suggest ways EPA could improve the approach to incorporate the continuous improvements and near-/mid-term and long-term aircraft replacements for better quantifying emissions inventories in the baseline and control scenarios?
3.2. **–** Is the forecast data for business jets, turboprops, and freighters appropriate? Can you provide suggestions (with references) of alternative publicly available data sources on forecasts for these subcategories and explain how they can be used to improve EPA's inventory analysis?
3.3. **–** Are the conclusions on fleet evolution results (Section 3.1.1) and the discussions on baseline modeling (Section 3.2.1) valid? • If yes, explain why. • If not, explain what alternative conclusions can be drawn from the fleet evolution results and what contrary points can be made on baseline modeling.
3.4. **–** Are the results of the main analysis clearly explained? Are the selected figures, tables, and equations well-chosen and helpful in assisting the reader in understanding the approach, methods, results, and conclusions? • If yes, explain why. • If not, explain how the figures, tables, and equations can be improved to more clearly describe the approach, methods, results, and conclusions in this report.
3.5. **–** Given the technology response that A380* is the only aircraft impacted by the Stringency Scenario 3, do you think the emissions results for A380 and the very large twin aisle (TA-4) market segment are reasonable? Are the associated emissions reductions (for Scenario 3) for U.S. domestic, U.S. international, and global assessments appropriate? • If yes, explain why. • If not, describe all issues with the results and provide possible alternative conclusions. *(*EPA realizes that Airbus recently made an announcement to end production of the A380 in 2021. Since EPA's analysis was completed prior to this Airbus announcement, it does not account for this latest information. However, the emissions draft technical report notes this recent development.)*
4. Sensitivity Studies (Section 4)
4.1. **–** For the sensitivity studies, are the selected variables (end-of-production timing and with/without continuous improvement) appropriate to provide useful and quantitative assessment of their effects on impact analysis results? • If yes, explain why. • If not, suggest alternative variables that would better illustrate the influence of such variables on impact analysis results.
4.2. **–** Are the selected figures/tables appropriate to clearly explain the effects of these variables on impact analysis results? • If yes, explain why. • If not, suggest other figures/tables that would better illustrate the sensitivity of these variables on impact analysis results.

Table 2.1. Charge Questions
4.3. **–** An important premise of this impact analysis is to model the stringency impact based on a business-as-usual baseline. The purpose of this business-as-usual baseline is to define market-driven improvements that separate their contributions to the net emissions reductions from the actual expected stringency impacts. From the sensitivity studies in this section, it is clear the results are highly sensitive to this baseline assumption. Although a full-scale uncertainty analysis is outside the scope of this report, EPA is interested in suggestions to better quantify the uncertainty associated with this baseline assumption. Provide alternative ways to quantify the uncertainty of the business-as-usual assumption so the contribution of these two distinct drivers (market versus regulation) can be better assessed.