ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 87 and 1030

[EPA–HQ–OAR–2018–0276; FRL–10018–45–OAR]

RIN 2060–AT26

Control of Air Pollution From Airplanes and Airplane Engines: GHG Emission Standards and Test Procedures

AGENCY: Environmental Protection Agency (EPA).

ACTION: Final rule.

SUMMARY: The Environmental Protection Agency (EPA) is adopting greenhouse gas (GHG) emission standards applicable to certain classes of engines used by certain civil subsonic jet airplanes with a maximum takeoff mass greater than 5,700 kilograms and by certain civil larger subsonic propeller-driven airplanes with turboprop engines having a maximum takeoff mass greater than 8,618 kilograms. These standards are equivalent to the airplane carbon dioxide (CO_2) standards adopted by the International Civil Aviation Organization (ICAO) in 2017 and apply to both new type design airplanes and in-production airplanes. The standards in this rule reflect U.S. efforts to secure the highest practicable degree of international uniformity in aviation regulations and standards. The standards also meet the EPA's obligation under section 231 of the Clean Air Act (CAA) to adopt GHG standards for certain classes of airplanes as a result of the 2016 ''Finding That Greenhouse Gas Emissions From Aircraft Cause or Contribute to Air Pollution That May Reasonably Be Anticipated To Endanger Public Health and Welfare'' (hereinafter ''2016 Findings'')—for six well-mixed GHGs emitted by certain classes of airplane engines. Airplane engines emit only two of the six well-mixed GHGs, CO_2 and nitrous oxide (N_2O). Accordingly, EPA is adopting the fuel-efficiency-based metric established by ICAO, which will control both the GHGs emitted by airplane engines, CO_2 and N_2O.

DATES: This final rule is effective on January 11, 2021. The incorporation by reference of certain publications listed in this regulation is approved by the Director of the Federal Register as of January 11, 2021.

ADDRESSES: EPA has established a docket for this action under Docket ID No. EPA–HQ–OAR–2018–0276. All documents are listed on the *http://www.regulations.gov* website. Although listed in the index, some information is not publicly available, *e.g.,* confidential business information (CBI) or other information whose disclosure is restricted by statute. Certain other material, such as copyrighted material, is not placed on the internet and will be publicly available only in hard copy form. Publicly available docket materials are available either electronically through *http://www.regulations.gov* or in hard copy at Air and Radiation Docket and Information Center, EPA Docket Center, EPA/DC, EPA WJC West Building, 1301 Constitution Ave. NW, Room 3334, Washington, DC. Note that the EPA Docket Center and Reading Room were closed to public visitors on March 31, 2020, to reduce the risk of transmitting COVID–19. The Docket Center staff will continue to provide remote customer service via email, phone, and webform. The telephone number for the Public Reading Room is (202) 566–1744, and the telephone number for the Air Docket is (202) 566–1742. For further information on EPA Docket Center services and the current status, go to *https://www.epa.gov/dockets.*

FOR FURTHER INFORMATION CONTACT: Bryan Manning, Office of Transportation and Air Quality, Assessment and Standards Division (ASD), Environmental Protection Agency, 2000 Traverwood Drive, Ann Arbor, MI 48105; telephone number: (734) 214–4832; email address: *manning.bryan@epa.gov.*

SUPPLEMENTARY INFORMATION:

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I. General Information

A. Does this action apply to me?

This action will affect companies that manufacture civil subsonic jet airplanes that have a maximum takeoff mass (MTOM) of greater than 5,700 kilograms and civil subsonic propeller driven airplanes (*e.g.,* turboprops) that have a MTOM greater than 8,618 kilograms, including the manufacturers of the engines used on these airplanes. Affected entities include the following:

Category	NAICS code [a]	Examples of potentially affected entities
Industry	336412	Manufacturers of new aircraft engines.

Category	NAICS code [a]	Examples of potentially affected entities
Industry	336411	Manufacturers of new aircraft.

[a] North American Industry Classification System (NAICS)

This table lists the types of entities that EPA is now aware could potentially be affected by this action. Other types of entities not listed in the table might also be subject to these regulations. To determine whether your activities are regulated by this action, you should carefully examine the relevant applicability criteria in 40 CFR parts 87 and 1030. If you have any questions regarding the applicability of this action to a particular entity, consult the person listed in the preceding **FOR FURTHER INFORMATION CONTACT** section.

For consistency purposes across the United States Code of Federal Regulations (CFR), the terms ''airplane,'' ''aircraft,'' and ''civil aircraft'' have the meanings found in title 14 CFR 1.1 and are used as appropriate throughout the new regulation under 40 CFR part 1030.

B. Did EPA conduct a peer review before issuing this action?

This regulatory action is supported by influential scientific information. Therefore, the EPA conducted peer reviews consistent with the Office of Management and Budget's (OMB's) Final Information Quality Bulletin for Peer Review.[1] Two different reports used in support of this action underwent peer review; a report detailing the technologies likely to be used in compliance with the standards and their associated costs [2] and a report detailing the methodology and results of the emissions inventory modeling.[3] These reports were each peer-reviewed through external letter reviews by multiple independent subject matter experts (including experts from academia and other government agencies, as well as independent technical experts).[4 5] The peer review reports and the Agency's response to the peer review comments are available in Docket ID No. EPA–HQ–OAR–2018–0276.

C. Basis for Immediate Effective Date

This rule is subject to the rulemaking procedures in section 307(d) of the Clean Air Act (CAA). See CAA section 307(d)(1)(F). Section 307(d)(1) of the CAA states that: ''The provisions of section 553 through 557 * * * of Title 5 shall not, except as expressly provided in this subsection, apply to actions to which this subsection applies.'' Thus, section 553(d) of the Administrative Procedure Act (APA), which requires publication of a substantive rule to be made ''not less than 30 days before its effective date'' subject to limited exceptions, does not apply to this action. In the alternative, the EPA concludes that it is consistent with APA section 553(d) to make this action effective January 11, 2021.

Section 553(d)(3) of the APA, 5 U.S.C. 553(d)(3), provides that final rules shall not become effective until 30 days after publication in the **Federal Register** ''except . . . as otherwise provided by the agency for good cause found and published with the rule.'' ''In determining whether good cause exists, an agency should 'balance the necessity for immediate implementation against principles of fundamental fairness which require that all affected persons be afforded a reasonable amount of time to prepare for the effective date of its ruling.'' *Omnipoint Corp.* v. *Fed. Commc'n Comm'n,* 78 F.3d 620, 630 (D.C. Cir. 1996) (quoting *United States* v. *Gavrilovic,* 551 F.2d 1099, 1105 (8th Cir. 1977)). The purpose of this provision is to ''give affected parties a reasonable time to adjust their behavior before the final rule takes effect.'' *Id.; see also Gavrilovic,* 551 F.2d at 1104 (quoting legislative history).

As discussed in the notice of proposed rulemaking, and below, the standards adopted here are meant to be technology following standards that align with international standards that were previously adopted in 2017 by ICAO. This means the rule reflects the performance and technology achieved by existing airplanes. Moreover, the EPA is not aware of any manufacturers who would seek certification of any new type design airplanes in the near future, such that making the rule effective immediately upon publication could disrupt their certification plans. The EPA is determining that in light of the nature of this action, good cause exists to make this final rule effective immediately because the Agency seeks to provide regulatory certainty as soon as possible and no party will be harmed by an immediate effective date since there is no need to provide a delay of 30 days after publication for parties to adjust their behavior prior to the effective date. Accordingly, the EPA is making this rule effective immediately upon publication.

D. Judicial Review and Administrative Reconsideration

Under Clean Air Act (CAA) section 307(b)(1), judicial review of this final action is available only by filing a petition for review in the United States Court of Appeals for the District of Columbia Circuit by March 12, 2021. Under CAA section 307(b)(2), the requirements established by this final rule may not be challenged separately in any civil or criminal proceedings brought by the EPA to enforce the requirements.

Section 307(d)(7)(B) of the CAA further provides that only an objection to a rule or procedure which was raised with reasonable specificity during the period for public comment (including any public hearing) may be raised during judicial review. This section also provides a mechanism for the EPA to reconsider the rule if the person raising an objection can demonstrate to the Administrator that it was impracticable to raise such objection within the period for public comment or if the grounds for such objection arose after the period for public comment (but within the time specified for judicial review) and if such objection is of central relevance to the outcome of the rule. Any person seeking to make such a demonstration should submit a Petition for Reconsideration to the Office of the Administrator, U.S. EPA, Room 3000, WJC South Building, 1200 Pennsylvania Ave. NW, Washington, DC 20460, with a copy to both the person(s) listed in the preceding **FOR FURTHER INFORMATION CONTACT** section, and the Associate General Counsel for the Air and Radiation Law Office, Office of General Counsel (Mail Code 2344A), U.S. EPA, 1200 Pennsylvania Ave. NW, Washington, DC 20460

E. Executive Summary

1. Purpose of This Regulatory Action

One of the core functions of the International Civil Aviation Organization (ICAO) is to adopt Standards and Recommended Practices on a wide range of aviation-related matters, including aircraft emissions. As

[1] OMB, 2004: Memorandum for Heads of Departments and Agencies, *Final Information Quality Bulletin for Peer Review.* Available at *https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/memoranda/2005/m05-03.pdf.*

[2] ICF, 2018: *Aircraft CO_2 Cost and Technology Refresh and Industry Characterization,* Final Report, EPA Contract Number EP–C–16–020, September 30, 2018.

[3] U.S. EPA, 2020: *Technical Report on Aircraft Emissions Inventory and Stringency Analysis,* July 2020, 52pp.

[4] RTI International and EnDyna, *Aircraft CO2 Cost and Technology Refresh and Aerospace Industry Characterization: Peer Review,* June 2018, 114pp.

[5] RTI International and EnDyna, *EPA Technical Report on Aircraft Emissions Inventory and Stringency Analysis: Peer Review,* July 2019, 157pp.

a member State of ICAO, the United States seeks to secure the highest practicable degree of international uniformity in aviation regulations and standards.[6] ICAO adopted airplane CO_2 standards in 2017. The adoption of these aviation standards into U.S. law will align with the ICAO standards. For reasons discussed herein, the EPA is adopting standards for GHG emissions from certain classes of engines used on covered airplanes (hereinafter ''covered airplanes'' or ''airplanes'') that are equivalent in scope, stringency and timing to the CO_2 standards adopted by ICAO.

These standards will ensure control of GHG emissions, maintain international uniformity of airplane standards, and allow U.S. manufacturers of covered airplanes to remain competitive in the global marketplace. In the absence of U.S. standards for implementing the ICAO Airplane CO_2 Emission Standards, U.S. civil airplane manufacturers could be forced to seek CO_2 emissions certification from an aviation certification authority of another country (not the Federal Aviation Administration (FAA)) in order to market and operate their airplanes internationally. We anticipate U.S. manufacturers would be at a significant disadvantage if the U.S. failed to adopt standards that are harmonized with the ICAO standards for CO_2 emissions. The ICAO Airplane CO_2 Emission Standards have been adopted by other ICAO member states that certify airplanes. The action to adopt in the U.S. GHG standards that match the ICAO Airplane CO_2 Emission Standards will help ensure international consistency and acceptance of U.S. manufactured airplanes worldwide.

In August 2016, the EPA issued two findings regarding GHG emissions from aircraft engines (the 2016 Findings).[7] First, the EPA found that elevated concentrations of GHGs in the atmosphere endanger the public health and welfare of current and future generations within the meaning of section 231(a)(2)(A) of the CAA. Second, EPA found that emissions of GHGs from certain classes of engines used in certain aircraft are contributing to the air pollution that endangers public health and welfare under CAA section 231(a)(2)(A). Additional details of the 2016 Findings are described in Section III. As a result of the 2016 Findings, CAA sections 231(a)(2)(A) and (3) obligate the EPA to propose and adopt, respectively, GHG standards for these covered aircraft engines.

2. Summary of the Major Provisions of This Regulatory Action

The EPA is regulating GHG emissions from covered airplanes through the adoption of domestic GHG regulations that match international standards to control CO_2 emissions. The GHG standards finalized in this action are equivalent to the CO_2 standards adopted by ICAO and will be implemented and enforced in the U.S. The standards apply to covered airplanes: Civil subsonic jet airplanes (those powered by turbojet or turbofan engines and with a MTOM greater than 5,700 kilograms), as well as larger civil subsonic propeller-driven airplanes (those powered by turboprop engines and with a MTOM greater than 8,618 kilograms). The timing and stringencies of the standards differ depending on whether the covered airplane is a new type design (*i.e.,* a design that has not previously been type certificated under title 14 CFR) or an in-production model (*i.e.,* an existing design that had been type certificated under title 14 CFR prior to the effective date of the GHG standards). The standards for new type designs apply to covered airplanes for which an application for certification is submitted to the FAA on or after January 11, 2021 (January 1, 2023, for new type designs that have a maximum takeoff mass (MTOM) of 60,000 kilograms MTOM or less and have 19 passenger seats or fewer). The in-production standards apply to covered airplanes beginning January 1, 2028. Additionally, consistent with ICAO standards, before the in-production standards otherwise apply in 2028, certain modifications made to airplanes (*i.e.,* changes that result in an increase in GHG emissions) will trigger a requirement to certify to the in-production regulation beginning January 1, 2023. Some minor technical corrections have been made to the proposed regulatory text in this action to further clarify that the standards do not apply to in-service airplanes or military airplanes.

The EPA is adopting the ICAO CO_2 metric, which measures fuel efficiency, for demonstrating compliance with the GHG emission standards. This metric is a mathematical function that incorporates the specific air range (SAR) of an airplane/engine combination (a traditional measure of airplane cruise performance in units of kilometer/kilogram of fuel) and the reference geometric factor (RGF), a measure of fuselage size. The metric is further discussed in Section IV.A.

To measure airplane fuel efficiency, the EPA is adopting the ICAO test procedures whereby the airplane/engine SAR value is measured at three specific operating test points, and a composite of those results is used in the metric to determine compliance with the GHG standards. The test procedures are discussed in Section IV.G.

The EPA proposed an annual reporting provision which would have required manufacturers of covered airplanes to submit to the EPA information on airplane characteristics, emissions characteristics and production volumes. Commenters raised several issues such as duplicative reporting burdens with FAA and ICAO, risks to confidential business information, and higher costs associated with the reporting requirement than EPA projections. The Agency is not adopting the proposed annual reporting provisions. Further information on those comments and the EPA's response can be found in the Response to Comments (RTC) document accompanying this action. Further information on all aspects of the GHG standards can be found in Section IV.

Finally, as proposed, the EPA is updating the existing incorporation by reference of the ICAO test procedures for hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_X) and smoke to reference the most recent edition of the ICAO procedures. This update will improve clarity in the existing test procedures and includes a minor change to the composition of the test fuel used for engine certification. Further details on this technical amendment can be found in Section VII.

3. Costs and Benefits

Given the significant international market pressures to continually improve the fuel efficiency of their airplanes, U.S. manufacturers have already developed or are developing technologies that will allow affected airplanes to comply with the ICAO standards, in advance of EPA's adoption of standards. Many airplanes manufactured by U.S. manufacturers already met the ICAO standards at the time of their adoption and thus already meet the standards contained in this action. Furthermore, based on the manufacturers' expectation that the ICAO standards will be implemented globally, the EPA anticipates nearly all affected airplanes to be compliant by the respective effective dates for new type designs and for in-production airplanes

[6] ICAO, 2006: Convention on International Civil Aviation, Ninth Edition, Document 7300/9, Article 37, 114 pp. Available at: *http://www.icao.int/publications/Documents/7300_9ed.pdf* (last accessed October 27, 2020).

[7] U.S. EPA, 2016: *Finding That Greenhouse Gas Emissions From Aircraft Cause or Contribute To Air Pollution That May Reasonably Be Anticipated To Endanger Public Health and Welfare; Final Rule,* 81 FR 54422 (August 15, 2016).

(see Section IV.I.2 for further information on affected airplanes). The EPA's business as usual baseline projects that even independent of the ICAO standards, nearly all airplanes produced by U.S. manufacturers will meet the ICAO in-production standards in 2028. This result is not surprising, given the significant market pressure on airplane manufacturers to continually improve the fuel efficiency of aircraft, the significant annual research and development expenditures from the aircraft industry (much of which is focused on fuel efficiency), and the more than 50 year track record of the industry in developing and selling aircraft which have shown continuous improvement in fuel efficiency. EPA's assessment includes the expectation that existing in-production airplanes that are non-compliant will either be modified and re-certificated as compliant, will likely go out of production before the production compliance date of January 1, 2028, or will seek exemptions from the GHG standard. For these reasons, the EPA is not projecting emission reductions associated with these GHG regulations. However, the EPA does note that consistency with the international standards will prevent backsliding by ensuring that all new type design and in-production airplanes are at least as efficient as today's airplanes. For further details on the benefits and costs associated with these GHG standards, see Sections V and VI, respectively.

II. Introduction: Overview and Context for this Action

This section provides a summary of the final rule. This section describes the EPA's statutory authority, the U.S. airplane engine regulations and the relationship with ICAO's international standards, and consideration of the whole airplane in addressing airplane engine GHG emissions.

A. Summary of Final Rule

In February 2016, ICAO's Committee on Aviation Environmental Protection (CAEP) agreed to international Airplane CO_2 Emission Standards, which ICAO approved in 2017. The EPA is adopting GHG standards that are equivalent to the international Airplane CO_2 Emission Standards promulgated by ICAO in Annex 16.[8]

As a result of the 2016 Findings,[9] [10] the EPA is obligated under section 231(a) of the CAA to issue emission standards applicable to GHG emissions from the classes of engines used by covered aircraft included in the 2016 Findings. As described later in further detail in Section III, we are regulating the air pollutant that is the aggregate of the six well-mixed GHGs. Only two of the six well-mixed GHGs—CO_2 and N_2O—have non-zero emissions for total civil subsonic airplanes and U.S. covered airplanes. CO_2 represents 99 percent of all GHGs emitted from both total U.S. civil airplanes and U.S. covered airplanes, and N_2O represents 1 percent of GHGs emitted from total airplanes and U.S. covered airplanes. Promulgation of the GHG emission standards for the certain classes of engines used by covered airplanes will fulfill EPA's obligations under the CAA and is the next step for the United States in implementing the ICAO standards promulgated in Annex 16 under the Chicago Convention. We are issuing a new rule that controls aircraft engine GHG emissions through the use of the ICAO regulatory metric that quantifies airplane fuel efficiency.

The rule will establish GHG standards applicable to U.S. airplane manufacturers that are no less stringent than the Airplane CO_2 Emission Standards adopted by ICAO.[11] This rule incorporates the same compliance schedule as the ICAO Airplane CO_2 Emission Standards. The standards will apply to both new type designs and in-production airplanes. The in-production standards have later applicability dates and different emission levels than do the standards for new type designs. The different emission levels for new type designs and in-production airplanes depend on the airplane size, weight, and availability of fuel efficiency technologies.

Apart from the GHG requirements, we are updating the engine emissions testing and measurement procedures applicable to HC, NO_X, CO, and smoke in current regulations. The updates will implement recent amendments to ICAO standards in Annex 16, Volume II, and these updates will be accomplished by incorporating provisions of the Annex by reference, as has historically been done in previous EPA rulemakings.[12]

B. EPA Statutory Authority and Responsibilities Under the Clean Air Act

Section 231(a)(2)(A) of the CAA directs the Administrator of the EPA to, from time to time, propose aircraft engine emission standards applicable to the emission of any air pollutant from classes of aircraft engines which in the Administrator's judgment causes or contributes to air pollution that may reasonably be anticipated to endanger public health or welfare. (See 42 U.S.C. 7571(a)(2)(A)). Section 231(a)(2)(B) directs the EPA to consult with the Administrator of the FAA on such standards, and it prohibits the EPA from changing aircraft engine emission standards if such a change would significantly increase noise and adversely affect safety (see 42 U.S.C. 7571(a)(2)(B)(i)–(ii)). Section 231(a)(3) provides that after we propose standards, the Administrator shall issue such standards ''with such modifications as he deems appropriate.'' (see 42 U.S.C. 7571(a)(3)). The U.S. Court of Appeals for the D.C. Circuit has held that this provision confers an unusually broad degree of discretion on the EPA to adopt aircraft engine emission standards that the Agency determines are reasonable. *Nat'l Ass'n of Clean Air Agencies* v. *EPA,* 489 F.3d 1221, 1229–30 (D.C. Cir. 2007) (*NACAA*).

In addition, under CAA section 231(b) the EPA is required to ensure, in consultation with the U.S. Department of Transportation (DOT), that the effective date of any standard provides the necessary time to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance

[8] ICAO, 2006: Convention on International Civil Aviation, Ninth Edition, Document 7300/9, 114 pp. Available at: *http://www.icao.int/publications/Documents/7300_9ed.pdf* (last accessed October 27, 2020).

[9] U.S. EPA, 2016: *Finding That Greenhouse Gas Emissions From Aircraft Cause or Contribute To Air Pollution That May Reasonably Be Anticipated To Endanger Public Health and Welfare and Advance Notice of Proposed Rulemaking; Final Rule,* 81 FR 54422 (August 15, 2016).

[10] Covered airplanes are those airplanes to which the international CO_2 standards and the GHG standards apply: subsonic jet airplanes with a maximum takeoff mass (MTOM) greater than 5,700 kilograms and subsonic propeller-driven (*e.g.,* turboprop) airplanes with a MTOM greater than 8,618 kilograms. Section IV describes covered and non-covered airplanes in further detail.

ICAO, 2016: *Tenth Meeting Committee on Aviation Environmental Protection Report,* Doc 10069, CAEP/10, 432 pp, Available at: *http://www.icao.int/publications/Pages/catalogue.aspx* (last accessed October 27, 2020). The ICAO CAEP/10 report is found on page 27 of the English Edition 2020 catalog and is copyright protected; Order No. 10069.

[11] ICAO's certification standards and test procedures for airplane CO_2 emissions are based on the consumption of fuel (or fuel burn) under prescribed conditions at optimum cruise altitude. ICAO uses the term, CO_2, for its standards and procedures, but ICAO is actually regulating or measuring the rate of an airplane's fuel burn (fuel efficiency). For jet fuel, the emissions index or emissions factor for CO_2 is 3.16 kilograms of CO_2 per kilogram of fuel burn (or 3,160 grams of CO_2 per kilogram of fuel burn). Thus, to convert an airplane's rate of fuel burn to a CO_2 emissions rate, this emission index needs to be applied.

[12] Previous EPA rulemakings for aircraft engine regulations are described later in section II.D.2.

(see 42 U.S.C. 7571(b)). Section 232 then directs the Secretary of Transportation to prescribe regulations to ensure compliance with the EPA's standards (see 42 U.S.C. 7572). Finally, section 233 of the CAA vests the authority to promulgate emission standards for aircraft engines only in the Federal Government. States are preempted from adopting or enforcing any standard respecting emissions from aircraft or aircraft engines unless such standard is identical to the EPA's standards (see 42 U.S.C. 7573).

C. Background Information Helpful to Understanding This Action

Civil airplanes and associated engines are international commodities that are manufactured and sold around the world. The member States of ICAO and the world's airplane and airplane engine manufacturers participated in the deliberations leading up to ICAO's adoption of the international Airplane CO_2 Emission Standards. However, ICAO's standards are not directly applicable to nor enforceable against member States' airplane and engine manufacturers. Instead, after adoption of the standards by ICAO, a member State is required (as described later in Section II.D.1) to adopt domestic standards at least as stringent as ICAO standards and apply them, as applicable, to subject airplane and airplane engine manufacturers in order to ensure recognition of their airworthiness and type certificate by other member State's civil aviation authorities. This rulemaking is a necessary step to meet this obligation for the United States.

D. U.S. Airplane Regulations and the International Community

The EPA and the FAA work within the standard-setting process of ICAO's CAEP to help establish international emission standards and related requirements, which individual member States adopt into domestic law and regulations. Historically, under this approach, international emission standards have first been adopted by ICAO, and subsequently the EPA has initiated rulemakings under CAA section 231 to establish domestic standards that are harmonized with ICAO's standards. After EPA promulgates aircraft engine emission standards, CAA section 232 requires the FAA to issue regulations to ensure compliance with the EPA aircraft engine emission standards when issuing airworthiness certificates pursuant to its authority under Title 49 of the United States Code. This rule continues this historical rulemaking approach.

1. International Regulations and U.S. Obligations

The EPA has worked with the FAA since 1973, and later with ICAO, to develop domestic and international standards and other recommended practices pertaining to aircraft engine emissions. The Convention on International Civil Aviation (commonly known as the 'Chicago Convention') was signed in 1944 at the Diplomatic Conference held in Chicago. The Chicago Convention establishes the legal framework for the development of international civil aviation. The primary objective is ''that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically.'' [13] In 1947, ICAO was established, and later in that same year ICAO became a specialized agency of the United Nations (UN). ICAO sets international standards for aviation safety, security, efficiency, capacity, and environmental protection and serves as the forum for cooperation in all fields of international civil aviation. ICAO works with the Chicago Convention's member States and global aviation organizations to develop international Standards and Recommended Practices (SARPs), which member States reference when developing their domestic civil aviation regulations. The United States is one of 193 currently participating ICAO member States.[14 15]

In the interest of global harmonization and international air commerce, the Chicago Convention urges its member States to ''collaborate in securing the highest practicable degree of uniformity in regulations, standards, procedures and organization in relation to aircraft, . . . in all matters which such uniformity will facilitate and improve air navigation.'' The Chicago Convention also recognizes that member States may adopt national standards that are more or less stringent than those agreed upon by ICAO or standards that are different in character or that comply with the ICAO standards by other means. Any member State that finds it impracticable to comply in all respects with any international standard or procedure, or that determines it is necessary to adopt regulations or practices differing in any particular respect from those established by an international standard, is required to give notification to ICAO of the differences between its own practice and that established by the international standard.[16]

ICAO's work on the environment focuses primarily on those problems that benefit most from a common and coordinated approach on a worldwide basis, namely aircraft noise and engine emissions. SARPs for the certification of aircraft noise and aircraft engine emissions are contained in Annex 16 to the Chicago Convention. To continue to address aviation environmental issues, in 2004, ICAO established three environmental goals: (1) Limit or reduce the number of people affected by significant aircraft noise; (2) limit or reduce the impact of aviation emissions on local air quality; and (3) limit or reduce the impact of aviation GHG emissions on the global climate.

The Chicago Convention has a number of other features that govern international commerce. First, member States that wish to use aircraft in international transportation must adopt emission standards that are at least as stringent as ICAO's standards if they want to ensure recognition of their airworthiness certificates. Member States may ban the use of any aircraft within their airspace that does not meet ICAO standards.[17] Second, the Chicago Convention indicates that member States are required to recognize the airworthiness certificates issued or rendered valid by the contracting State in which the aircraft is registered provided the requirements under which the certificates were issued are equal to or above ICAO's minimum standards.[18] Third, to ensure that international commerce is not unreasonably constrained, a member State that cannot meet or deems it necessary to adopt regulations differing from the international standard is obligated to notify ICAO of the differences between

[13] ICAO, 2006: *Convention on International Civil Aviation, Ninth Edition,* Document 7300/9, 114 pp. Available at: *http://www.icao.int/publications/Documents/7300_9ed.pdf* (last accessed October 27, 2020).

[14] Members of ICAO's Assembly are generally termed member States or contracting States. These terms are used interchangeably throughout this preamble.

[15] There are currently 193 contracting states according to ICAO's website: *https://www.icao.int/MemberStates/Member%20States.English.pdf* (last accessed March 16, 2020).

[16] ICAO, 2006: *Doc 7300-Convention on International Civil Aviation, Ninth Edition,* Document 7300/9, 114 pp. Available at *http://www.icao.int/publications/Documents/7300_9ed.pdf* (last accessed October 27, 2020).

[17] ICAO, 2006: *Convention on International Civil Aviation, Article* 33, *Ninth Edition,* Document 7300/9, 114 pp. Available at *http://www.icao.int/publications/Documents/7300_9ed.pdf*(last accessed October 27, 2020).

[18] ICAO, 2006: *Convention on International Civil Aviation, Article 33, Ninth Edition,* Document 7300/9, 114 pp. Available at *http://www.icao.int/publications/Documents/7300_9ed.pdf* (last accessed October 27, 2020).

its domestic regulations and ICAO standards.[19]

ICAO's CAEP, which consists of members and observers from States, intergovernmental and non-governmental organizations representing the aviation industry and environmental interests, undertakes ICAO's technical work in the environmental field. The Committee is responsible for evaluating, researching, and recommending measures to the ICAO Council that address the environmental impacts of international civil aviation. CAEP's terms of reference indicate that ''CAEP's assessments and proposals are pursued taking into account: Technical feasibility; environmental benefit; economic reasonableness; interdependencies of measures (for example, among others, measures taken to minimize noise and emissions); developments in other fields; and international and national programs.'' [20] The ICAO Council reviews and adopts the recommendations made by CAEP. It then reports to the ICAO Assembly, the highest body of the organization, where the main policies on aviation environmental protection are adopted and translated into Assembly Resolutions. If ICAO adopts a CAEP proposal for a new environmental standard, it then becomes part of ICAO standards and recommended practices (Annex 16 to the Chicago Convention).[21] [22]

The FAA plays an active role in ICAO/CAEP, including serving as the representative (member) of the United States at annual ICAO/CAEP Steering Group meetings, as well as the ICAO/CAEP triennial meetings, and contributing technical expertise to CAEP's working groups. The EPA serves as an advisor to the U.S. member at the annual ICAO/CAEP Steering Group and triennial ICAO/CAEP meetings, while also contributing technical expertise to CAEP's working groups and assisting and advising the FAA on aviation emissions, technology, and environmental policy matters. In turn, the FAA assists and advises the EPA on aviation environmental issues, technology and airworthiness certification matters.

CAEP's predecessor at ICAO, the Committee on Aircraft Engine Emissions (CAEE), adopted the first international SARPs for aircraft engine emissions that were proposed in 1981.[23] These standards limited aircraft engine emissions of hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_X). The 1981 standards applied to newly manufactured engines, which are those engines built after the effective date of the regulations—also referred to as in-production engines. In 1993, ICAO adopted a CAEP/2 proposal to tighten the original NO_X standard by 20 percent and amend the test procedures.[24] These 1993 standards applied both to newly certificated turbofan engines (those engine models that received their initial type certificate after the effective date of the regulations, referred to as newly certificated engines or new type design engines) and to in-production engines; the standards had different effective dates for newly certificated engines and in-production engines. In 1995, CAEP/3 recommended a further tightening of the NO_X standards by 16 percent and additional test procedure amendments, but in 1997 the ICAO Council rejected this stringency proposal and approved only the test procedure amendments. At the CAEP/4 meeting in 1998, the Committee adopted a similar 16 percent NO_X reduction proposal, which ICAO approved in 1998. Unlike the CAEP/2 standards, the CAEP/4 standards applied only to new type design engines after December 31, 2003, and not to in-production engines, leaving the CAEP/2 standards applicable to in-production engines. In 2004, CAEP/6 recommended a 12 percent NO_X reduction, which ICAO approved in 2005.[25] [26] The CAEP/6 standards applied to new engine designs certificated after December 31, 2007, again leaving the CAEP/2 standards in place for in-production engines before January 1, 2013. In 2010, CAEP/8 recommended a further tightening of the NO_X standards by 15 percent for new engine designs certificated after December 31, 2013.[27] [28] The Committee also recommended that the CAEP/6 standards be applied to in-production engines on or after January 1, 2013, which cut off the production of CAEP/2 and CAEP/4 compliant engines with the exception of spare engines; ICAO adopted these as standards in 2011.[29]

[19] ICAO, 2006: *Convention on International Civil Aviation, Article 38, Ninth Edition,* Document 7300/9, 114 pp. Available at *http://www.icao.int/publications/Documents/7300_9ed.pdf* (last accessed October 27, 2020).

[20] ICAO: CAEP Terms of Reference. Available at *http://www.icao.int/environmental-protection/Pages/Caep.aspx#ToR* (last accessed March 16, 2020).

[21] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017, 174 pp. Available at *http://www.icao.int/publications/Pages/catalogue.aspx* (last accessed March 16, 2020). The ICAO Annex 16 Volume II is found on page 16 of the ICAO Products & Services English Edition of the 2020 catalog, and it is copyright protected; Order No. AN16–2. Also see: ICAO, 2020: Supplement No.7, August 2020, *Annex 16 Environmental Protection—Volume II—Aircraft Engine Emissions, Amendment 10* (20/7/20).76pp. Available at *https://www.icao.int/publications/catalogue/cat_2020_Sup07_en.pdf* (last accessed October 27, 2020). The ICAO Annex 16, Volume II, Amendment 10 is found on page 3 of Supplement No. 7—August 2020; English Edition, Order No. AN16–2/E/12.

[22] CAEP develops new emission standards based on an assessment of the technical feasibility, cost, and environmental benefit of potential requirements.

[23] ICAO, 2017: *Aircraft Engine Emissions: Foreword,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017, 174pp. Available at *https://www.icao.int/publications/Pages/catalogue.aspx* (last accessed March 16, 2020). The ICAO Annex 16 Volume II is found on page 16 of the ICAO Products & Services English Edition 2020 catalog and is copyright protected; Order No. AN16–2. Also see: ICAO, 2020: Supplement No. 7, August 2020, Annex 16 Environmental Protection-Volume II-Aircraft Engine Emissions, Amendment 10 (20/7/20).76pp. Available at *https://www.icao.int/publications/catalogue/cat_2020_Sup07_en.pdf* (last accessed October 27, 2020). The ICAO Annex 16, Volume II, Amendment 10 is found on page 3 of Supplement No. 7—August 2020; English Edition, Order No. AN16–2/E/12.

[24] CAEP conducts its work triennially. Each 3-year work cycle is numbered sequentially and that identifier is used to differentiate the results from one CAEP meeting to another by convention. The first technical meeting on aircraft emission standards was CAEP's predecessor, *i.e.,* CAEE. The first meeting of CAEP, therefore, is referred to as CAEP/2.

[25] CAEP/5 did not address new airplane engine emission standards.

[26] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16,Volume II, Fourth Edition, July 2017, 174pp. Available at *https://www.icao.int/publications/Pages/catalogue.aspx* (last accessed March 16, 2020). The ICAO Annex 16 Volume II is found on page 16 of the ICAO Products & Services English Edition of the 2020 catalog, and it is copyright protected; Order No. AN16–2. Also see: ICAO, 2020: Supplement No. 7, August 2020, *Annex 16 Environmental Protection-Volume II-Aircraft Engine Emissions, Amendment 10* (20/7/20).76pp. Available at *https://www.icao.int/publications/catalogue/cat_2020_Sup07_en.pdf* (last accessed October 27, 2020). The ICAO Annex 16, Volume II, Amendment 10 is found on page 3 of Supplement No. 7—August 2020; English Edition, Order No. AN16–2/E/12.

[27] CAEP/7 did not address new aircraft engine emission standards.

[28] ICAO, 2010: *Committee on Aviation Environmental Protection (CAEP), Report of the Eighth Meeting, Montreal, February 1–12, 2010,* CAEP/8–WP/80 Available in Docket EPA–HQ–OAR–2010–0687.

[29] ICAO, 2017: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Fourth Edition, July 2017, Amendment 9, 174 pp. CAEP/8 corresponds to Amendment 7 effective on July 18, 2011. Available at *https://www.icao.int/publications/Pages/catalogue.aspx* (last accessed March 16, 2020). The ICAO Annex 16 Volume II is found on page 16 of the ICAO Products & Services English Edition of the 2020 catalog, and it is copyright protected; Order No. AN16–2. Also see: ICAO, 2020: Supplement No. 7, August 2020, *Annex 16 Environmental Protection—Volume II—Aircraft Engine Emissions, Amendment 10* (20/7/20).76pp. Available at *https://www.icao.int/publications/catalogue/cat_2020_Sup07_en.pdf*

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At the CAEP/10 meeting in 2016, the Committee agreed to the first airplane CO_2 emission standards, which ICAO approved in 2017. The CAEP/10 CO_2 standards apply to new type design airplanes for which the application for a type certificate will be submitted on or after January 1, 2020, some modified in-production airplanes on or after January 1, 2023, and all applicable in-production airplanes built on or after January 1, 2028.

2. EPA's Regulation of Aircraft Engine Emissions and the Relationship to International Aircraft Standards

As required by the CAA, the EPA has been engaged in reducing harmful air pollution from airplane engines for over 40 years, regulating gaseous exhaust emissions, smoke, and fuel venting from engines.[30] We have periodically revised these regulations. In a 1997 rulemaking, for example, we made our emission standards and test procedures more consistent with those of ICAO's CAEP for turbofan engines used in commercial aviation with rated thrusts greater than 26.7 kilonewtons.[31] These ICAO requirements are generally referred to as CAEP/2 standards.[32] The 1997 rulemaking included new NO_X emission standards for newly manufactured commercial turbofan engines [33] [34] and for newly certificated commercial turbofan engines.[35] [36] It also included a CO emission standard for in-production commercial turbofan engines.[37] In 2005, we promulgated more stringent NO_X emission standards for newly certificated commercial turbofan engines.[38] That final rule brought the U.S. standards closer to alignment with ICAO CAEP/4 requirements that became effective in 2004. In 2012, we issued more stringent two-tiered NO_X emission standards for newly certificated and in-production commercial and non-commercial turbofan engines, and these NO_X standards align with ICAO's CAEP/6 and CAEP/8 standards that became effective in 2013 and 2014, respectively.[39] [40] The EPA's actions to regulate certain pollutants emitted from aircraft engines come directly from the authority in section 231 of the CAA, and we have aligned the U.S. emissions requirements with those promulgated by ICAO. All of these previous ICAO emission standards, and the EPA's standards reflecting them, have generally been considered anti-backsliding standards (most aircraft engines meet the standards), which are technology following.

The EPA and the FAA worked from 2009 to 2016 within the ICAO/CAEP standard-setting process on the development of the international Airplane CO_2 Emission Standards. In this action, we are adopting GHG standards equivalent to the ICAO Airplane CO_2 Emission Standards. As stated earlier in this Section II, the standards established in the United States need to be at least as stringent as the ICAO Airplane CO_2 Emission Standards in order to ensure global acceptance of FAA airworthiness certification. Also, as a result of the 2016 Findings, as described later in Section IV, the EPA is obligated under section 231 of the CAA to propose and issue emission standards applicable to GHG emissions from the classes of engines used by covered aircraft included in the 2016 Findings.

When the EPA proposed the aircraft GHG findings in 2015, we included an aircraft GHG emission standards advance notice of proposed rulemaking (henceforth the ''2015 ANPR'') [41] that provided information on the international process for setting the ICAO Airplane CO_2 Emission Standards. Also, the 2015 ANPR described and sought input on the potential use of section 231 of the CAA to adopt and implement the corresponding international Airplane CO_2 Emission Standards domestically as a CAA section 231 GHG standard.

E. Consideration of Whole Airplane Characteristics

In addressing CO_2 emissions, ICAO adopted an approach that measures the fuel efficiency from the perspective of whole airplane design—an airframe and engine combination. Specifically, ICAO adopted CO_2 emissions test procedures based on measuring the performance of the whole airplane rather than the airplane engines alone.[42] The ICAO standards account for three factors: Aerodynamics, airplane weight, and engine propulsion technologies. These airplane performance characteristics determine the overall CO_2 emissions. Rather than measuring a single chemical compound, the ICAO CO_2 emissions test procedures measure fuel efficiency based on how far an airplane can fly on a single unit of fuel at the optimum cruise altitude and speed.

The three factors—and technology categories that improve these factors—are described as follows: [43]

- *Weight:* Reducing basic airplane weight [44] via structural changes to

(last accessed October 27, 2020). The ICAO Annex 16, Volume II, Amendment 10 is found on page 3 of Supplement No. 7—August 2020; English Edition, Order No. AN16–2/E/12.

[30] U.S. EPA, 1973: Emission Standards and Test Procedures for Aircraft; Final Rule, 38 FR 19088 (July 17, 1973).

[31] U.S. EPA, 1997: *Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures; Final Rule,* 62 FR 25355 (May 8, 1997).

[32] The full CAEP membership meets every three years and each session is denoted by a numerical identifier. For example, the second meeting of CAEP is referred to as CAEP/2, and CAEP/2 occurred in 1994.

[33] This does not mean that in 1997 we promulgated requirements for the re-certification or retrofit of existing in-use engines.

[34] Those engines built after the effective date of the regulations that were already certificated to pre-existing standards are also referred to as in-production engines.

[35] In the existing EPA regulations, 40 CFR part 87, newly certificated aircraft engines are described as engines of a type or model of which the date of manufacture of the first individual production model was after the implementation date. Newly manufactured aircraft engines are characterized as engines of a type or model for which the date of manufacturer of the individual engine was after the implementation date.

[36] Those engine models that received their initial type certificate after the effective date of the regulations are also referred to as new engine designs.

[37] U.S. EPA, 1997: *Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures; Final Rule,* 62 FR 25355 (May 8, 1997).

[38] U.S. EPA, 2005: *Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures; Final Rule,* 70 FR 69664 (November 17, 2005).

[39] U.S. EPA, 2012: *Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures; Final Rule,* 77 FR 36342 (June 18, 2012).

[40] While ICAO's standards were not limited to ''commercial'' airplane engines, our 1997 standards were explicitly limited to commercial engines, as our finding that NO_X and carbon monoxide emissions from airplane engines cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare was so limited. See 62 FR 25358 (May 8, 1997). In the 2012 rulemaking, we expanded the scope of that finding and of our standards pursuant to CAA section 231(a)(2)(A) to include such emissions from both commercial and non-commercial airplane engines based on the physical and operational similarities between commercial and noncommercial civilian airplane and to bring our standards into full alignment with ICAO's.

[41] U.S. EPA, 2015: *Proposed Finding that Greenhouse Gas Emissions from Aircraft Cause or Contribute to Air Pollution that May Reasonably Be Anticipated to Endanger Public Health and Welfare and Advance Notice of Proposed Rulemaking,* 80 FR 37758 (July 1, 2015).

[42] ICAO, 2016: *Report of Tenth Meeting, Montreal, 1–12 February 2016, Committee on Aviation Environmental Protection,* Document 10069, 432pp. Available at: *https://www.icao.int/publications/Pages/catalogue.aspx* (last accessed March 16, 2020). ICAO Document 10069 is found on page 27 of the ICAO Products & Services English Edition 2020 Catalog, and it is copyright protected; Order No. 10069. See Appendix C (starting on page 5C–1) of this report.

[43] ICAO, *Environmental Report 2010—Aviation and Climate Change,* 2010, which is located at *http://www.icao.int/environmental-protection/Pages/EnvReport10.aspx* (last accessed March 16, 2020).

[44] Although weight reducing technologies affect fuel burn, they do not affect the metric value for the GHG standard. The standard is a function of

increase the commercial payload or extend range for the same amount of thrust and fuel burn;

- *Propulsion (thermodynamic and propulsion efficiency):* Advancing the overall specific performance of the engine, to reduce the fuel burn per unit of delivered thrust; and
- *Aerodynamic:* Advancing the airplane aerodynamics to reduce drag and its associated impacts on thrust.

As examples of technologies that support addressing aircraft engine CO_2 emissions accounting for the airplane as a whole, manufacturers have already achieved significant weight reduction with the introduction of advanced alloys and composite materials and lighter weight control systems (*e.g.,* fly-by-wire) [45] and aerodynamic improvements with advanced wingtip devices such as winglets.

The EPA agrees with ICAO's approach to measure the fuel efficiency based on the performance of the whole airplane. Accordingly, under section 231 of the CAA, the EPA is adopting regulations that are consistent with this approach. We are also adopting GHG test procedures that are the same as the ICAO CO_2 test procedures. (See Section IV.G for details on the test procedures.)

As stated earlier in Section II, section 231(a)(2)(A) of the CAA directs the Administrator of the EPA to, from time to time, propose aircraft engine emission standards applicable to the emission of any air pollutant from classes of aircraft engines which in the Administrator's judgment causes or contributes to air pollution that may reasonably be anticipated to endanger public health or welfare. For a standard promulgated under CAA section 231(a)(2)(A) to be ''applicable to'' emissions of air pollutants from aircraft engines, it could take many forms and include multiple elements in addition to a numeric permissible engine exhaust rate. For example, EPA rules adopted pursuant to CAA section 231 have addressed fuel venting to prevent the discharge of raw fuel from the engine and have adopted test procedures for exhaust emission standards. See 40 CFR part 87, subparts B and G.

Given both the absence of a statutory directive on what form a CAA section 231 standard must take (in contrast to, for example, CAA section 129(a)(4), which requires numerical emissions limitations for emissions of certain pollutants from solid waste incinerators) and the D.C. Circuit's 2007 *NACAA* ruling that section 231 of the CAA confers an unusually broad degree of discretion on the EPA in establishing airplane engine emission standards, the EPA is controlling GHG emissions in a manner identical to how ICAO's standards control CO_2 emissions—with a fuel efficiency standard based on the characteristics of the whole airplane. While this standard incorporates characteristics of airplane design as adopted by ICAO, the EPA is not asserting independent regulatory authority over airplane design.

III. Summary of the 2016 Findings

On August 15, 2016,[46] the EPA issued two findings regarding GHG emissions from aircraft engines. First, the EPA found that elevated concentrations of GHGs in the atmosphere endanger the public health and welfare of current and future generations within the meaning of section 231(a)(2)(A) of the CAA. The EPA made this finding specifically with respect to the same six well-mixed GHGs—CO_2, methane, N_2O, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride—that together were defined as the air pollution in the 2009 Endangerment Finding [47] under section 202(a) of the CAA and that together were found to constitute the primary cause of climate change. Second, the EPA found that emissions of those six well-mixed GHGs from certain classes of engines used in certain aircraft [48] cause or contribute to the air pollution—the aggregate group of the same six GHGs—that endangers public health and welfare under CAA section 231(a)(2)(A).

The EPA identified U.S. covered aircraft as subsonic jet aircraft with a maximum takeoff mass (MTOM) greater than 5,700 kilograms and subsonic propeller-driven (*e.g.,* turboprop) aircraft with a MTOM greater than 8,618 kilograms. See Section IV of this final rulemaking for examples of airplanes that correspond to the U.S. covered aircraft identified in the 2016 Findings.[49] The EPA did not at that time make findings regarding whether other substances emitted from aircraft engines cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare. The EPA also did not make a cause or contribute finding regarding GHG emissions from engines not used in U.S. covered aircraft (*i.e.,* those used in smaller turboprops, smaller jet aircraft, piston-engine aircraft, helicopters and military aircraft). Consequently, the 2016 Findings did not trigger the EPA's authority or duty under the CAA to regulate these other substances or aircraft types.

The EPA explained that the collective GHG emissions from the classes of engines used in U.S. covered aircraft contribute to the national GHG emission inventories [50] and estimated global GHG emissions.[51 52 53 54] The 2016 Findings

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maximum takeoff mass (MTOM). Reductions in airplane empty weight (excluding usable fuel and the payload) can be canceled out or diminished by a corresponding increase in payload, fuel, or both—when MTOM is kept constant. Section IV and VI provide a further description of the metric value and the effects of weight reducing technologies.

[45] Fly-by-wire refers to a system which transmits signals from the cockpit to the airplane's control surfaces electronically rather than mechanically. *AirlineRatings.com,* Available at *https://www.airlineratings.com/did-you-know/what-does-the-term-fly-by-wire-mean/* (last accessed on March 16, 2020).

[46] U.S. EPA, 2016: *Finding That Greenhouse Gas Emissions From Aircraft Cause or Contribute To Air Pollution That May Reasonably Be Anticipated To Endanger Public Health and Welfare; Final Rule,* 81 FR 54422 (August 15, 2016).

[47] U.S. EPA, 2009: *Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act; Final Rule,* 74 FR 66496 (December 15, 2009).

[48] Certain aircraft in this context are referred to interchangeably as ''covered airplanes,'' ''US covered airplanes,'' or airplanes throughout this rulemaking.

[49] 81 FR 54423, August 15, 2016.

[50] In 2014, classes of engines used in U.S. covered airplanes contribute to domestic GHG inventories as follows: 10 percent of all U.S. transportation GHG emissions, representing 2.8 percent of total U.S. emissions.

U.S. EPA, 2016: *Finding That Greenhouse Gas Emissions From Aircraft Cause or Contribute To Air Pollution That May Reasonably Be Anticipated To Endanger Public Health and Welfare; Final Rule,* 81 FR 54422 (August 15, 2016).

U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014,* 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430–R–16–002, April 2016. Available at: *https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2014* (last accessed March 16, 2020).

ERG, 2015: *U.S. Jet Fuel Use and CO_2 Emissions Inventory for Aircraft Below ICAO CO_2 Standard Thresholds,* Final Report, EPA Contract Number EP–D–11–006, 38 pp.

[51] In 2010, classes of engines used in U.S. covered airplanes contribute to global GHG inventories as follows: 26 percent of total global airplane GHG emissions, representing 2.7 percent of total global transportation emissions and 0.4 percent of all global GHG emissions.

U.S. EPA, 2016: *Finding That Greenhouse Gas Emissions From Aircraft Cause or Contribute To Air Pollution That May Reasonably Be Anticipated To Endanger Public Health and Welfare; Final Rule,* 81 FR 54422 (August 15, 2016).

U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014,* 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430–R–16–002, April 2016. Available at: *https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2014* (last accessed March 16, 2020).

ERG, 2015: *U.S. Jet Fuel Use and CO_2 Emissions Inventory for Aircraft Below ICAO CO_2 Standard Thresholds,* Final Report, EPA Contract Number EP–D–11–006, 38 pp.

IPCC, 2014: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum,

Continued

accounted for the majority (89 percent) of total U.S. aircraft GHG emissions.[55] [56]

As explained in the 2016 Findings,[57] only two of the six well-mixed GHGs, CO_2 and N_2O, are emitted from covered aircraft. CO_2 represents 99 percent of all GHGs emitted from both total U.S. aircraft and U.S. covered aircraft, and N_2O represents 1 percent of GHGs emitted from total U.S. aircraft and U.S. covered aircraft.[58] Modern aircraft are overall consumers of methane.[59] Hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are not products of aircraft engine fuel combustion. (Section IV.H discusses controlling two of the six well-mixed GHGs—CO_2 and N_2O— in the context of the details of this rule.)

IV. EPA's Final GHG Standards for Covered Airplanes

This section describes the fuel efficiency metric that will be used as a measure of airplane GHG emissions, the size and types of airplanes that will be affected, the emissions levels, and the applicable test procedures. As explained earlier in Section III and in the 2016 Findings,[60] only two of the six well-mixed GHGs—CO_2 and N_2O—are emitted from covered aircraft. Both CO_2 and N_2O emissions scale with fuel burn, thus allowing them to be controlled through fuel efficiency.

The GHG emission regulations for this rule are being specified in a new part in title 40 of the CFR—40 CFR part 1030. The existing aircraft engine regulations applicable to HC, NO_X, CO, and smoke remain in 40 CFR part 87.

In order to promote international harmonization of aviation standards and to avoid placing U.S. manufacturers at a competitive disadvantage that would result if EPA were to adopt standards different from the standards adopted by ICAO, the EPA is adopting standards for GHG emissions from certain classes of engines used on airplanes that match the scope, stringency, and timing of the CO_2 standards adopted by ICAO. The EPA and the FAA worked within ICAO to help establish the international CO_2 emission standards, which under the Chicago Convention individual member States then adopt into domestic law and regulations in order to implement and enforce them against subject manufacturers. A member State that adopts domestic regulations differing from the international standard—in either scope, stringency or timing—is obligated to notify ICAO of the differences between its domestic regulations and the ICAO standards.[61]

Under the longstanding EPA and FAA rulemaking approach to regulate airplane emissions (as described earlier in Section II.D), international emission standards have been adopted by ICAO, with significant involvement from the FAA and the EPA, and subsequently the EPA has undertaken rulemakings under CAA section 231 to establish domestic standards that are harmonized with ICAO's standards. Then, CAA section 232 requires the FAA to issue regulations to ensure compliance with the EPA standards. In 2015, EPA issued an advance notice of proposed rulemaking [62] which noted EPA and FAA's engagement in ICAO to establish an international CO_2 emissions standard and EPA's potential use of section 231 to adopt corresponding airplane GHG emissions standards domestically. This rulemaking continues this statutory paradigm.

The rule will facilitate the acceptance of U.S. manufactured airplanes and airplane engines by member States and airlines around the world. We anticipate that U.S. manufacturers would be at a significant competitive disadvantage if the U.S. failed to adopt standards that are aligned with the ICAO standards for CO_2 emissions. Member States may ban the use of any airplane within their airspace that does not meet ICAO standards.[63] If the EPA were to adopt no standards or standards that were not as stringent as ICAO's standards, U.S. civil airplane manufacturers could be forced to seek CO_2 emissions certification from an aviation certification authority of another country (other than the FAA) in order to market their airplanes for international operation.

Having invested significant effort and resources, working with FAA and the Department of State, to gain international consensus to adopt the first-ever CO_2 standards for airplanes, the EPA believes that meeting the United States' obligations under the Chicago Convention by aligning domestic standards with the ICAO standards, rather than adopting more stringent standards, will have substantial benefits for future

S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, 1435 pp.

[52] U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014,* 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430–R–16–002, April 2016. Available at: *https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2014* (last accessed March 16, 2020).

[53] IPCC, 2014: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, 1435 pp.

[54] The domestic inventory comparisons are for the year 2014, and global inventory comparisons are for the year 2010. The rationale for the different years is described in section IV.B.4 of the 2016 Findings, 81 FR 54422 (August 15, 2016).

[55] Covered U.S. aircraft GHG emissions in the 2016 Findings were from airplanes that operate in and from the U.S. and thus contribute to emissions in the U.S. This includes emissions from U.S. domestic flights, and emissions from U.S. international bunker flights (emissions from the combustion of fuel used by airplanes departing the U.S., regardless of whether they are a U.S. flagged carrier—also described as emissions from combustion of U.S. international bunker fuels). For example, a flight departing Los Angeles and arriving in Tokyo, regardless of whether it is a U.S. flagged carrier, is considered a U.S. international bunker flight. A flight from London to Hong Kong is not.

[56] U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks:* 1990–2014, 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430–R–16–002, April 2016. Available at: *https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2014* (last accessed March 16, 2020).

[57] U.S. EPA, 2016: *Finding That Greenhouse Gas Emissions From Aircraft Cause or Contribute To Air Pollution That May Reasonably Be Anticipated To Endanger Public Health and Welfare; Final Rule,* 81 FR 54422 (August 15, 2016).

[58] U.S. EPA, 2016: *Finding That Greenhouse Gas Emissions From Aircraft Cause or Contribute To Air Pollution That May Reasonably Be Anticipated To Endanger Public Health and Welfare; Final Rule,* 81 FR 54422 (August 15, 2016).

U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014,* 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430–R–16–002, April 2016. Available at: *https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2014* (last accessed March 16, 2020).

ERG, 2015: *U.S. Jet Fuel Use and CO_2 Emissions Inventory for Aircraft Below ICAO CO_2 Standard Thresholds,* Final Report, EPA Contract Number EP–D–11–006, 38 pp.

[59] Methane emissions are no longer considered to be emitted from aircraft gas turbine engines burning jet fuel A at higher power settings. Modern aircraft jet engines are typically net consumers of methane (Santoni et al. 2011). Methane is emitted at low power and idle operation, but at higher power modes aircraft engines consume methane. Over the range of engine operating modes, aircraft engines are net consumers of methane on average.

[60] U.S. EPA, 2016: *Finding That Greenhouse Gas Emissions From Aircraft Cause or Contribute To Air Pollution That May Reasonably Be Anticipated To Endanger Public Health and Welfare; Final Rule,* 81 FR 54422 (August 15, 2016).

[61] ICAO, 2006: *Convention on International Civil Aviation, Article 38, Ninth Edition,* Document 7300/9, 114 pp. Available at *http://www.icao.int/publications/Documents/7300_9ed.pdf* (last accessed March 16, 2020).

[62] U.S. EPA, 2015: *Proposed Finding That Greenhouse Gas Emissions From Aircraft Cause or Contribute to Air Pollution That May Reasonably Be Anticipated To Endanger Public Health and Welfare and Advance Notice of Proposed Rulemaking; Proposed Rule,* 80 FR 37758 (July 1, 2015).

[63] ICAO, 2006: *Convention on International Civil Aviation, Article* 33, *Ninth Edition,* Document 7300/9, 114 pp. Available at *http://www.icao.int/publications/Documents/7300_9ed.pdf* (last accessed March 16, 2020).

international cooperation on airplane emission standards, and such cooperation is the key for achieving worldwide emission reductions. Nonetheless, the EPA also analyzed the impacts of two more stringent alternatives, and the results of our analyses are described in chapters 4, 5, and 6 of the Technical Support Document (TSD) which can be found in the docket for this rulemaking. The analyses show that one alternative would result in limited additional costs, but no additional costs or GHG emission reductions compared to the final standards. The other alternative would have further limited additional costs and some additional GHG emission reductions compared to the final standards, but the additional emission reductions are relatively small from this alternative and do not justify deviating from the international standards and disrupting international harmonization. ICAO intentionally established its standards at a level which is technology following to adhere to its definition of technical feasibility that is meant to consider the emissions performance of in-production and in-development airplanes, including types that would first enter into service by about 2020. Thus, the additional emission reductions associated with the more stringent alternatives are relatively small because all but one of the affected airplanes either meet the stringency levels or are expected to go out of production by the effective dates. In addition, requiring U.S. manufacturers to certify to a different standard than has been adopted internationally (even one more stringent) could have disruptive effects on manufacturers' ability to market planes for international operation. Consequently, the EPA did not choose to finalize either of these alternatives.

A. Airplane Fuel Efficiency Metric

For the international Airplane CO_2 Emission Standards, ICAO developed a metric system to allow the comparison of a wide range of subsonic airplane types, designs, technology, and uses. While ICAO calls this a CO_2 emissions metric, it is a measure of fuel efficiency, which is directly related to CO_2 emitted by aircraft engines. The ICAO metric system was designed to differentiate between fuel-efficiency technologies of airplanes and to equitably capture improvements in propulsive and aerodynamic technologies that contribute to a reduction in the airplane CO_2 emissions. In addition, the ICAO metric system accommodates a wide range of technologies and designs that manufacturers may choose to implement to reduce CO_2 emissions from their airplanes. However, because of an inability to define a standardized empty weight across manufacturers and types of airplanes, the ICAO CO_2 emissions metric is based on the MTOM of the airplane. This metric does not directly reward weight reduction technologies because the MTOM of an airplane will not be reduced when weight reduction technologies are applied so that cargo carrying capacity or range can be increased. Further, while weight reduction technologies can be used to improve airplane fuel efficiency, they may also be used to allow increases in payload,[64] equipment, and fuel load.[65] Thus, even though weight reducing technologies increase the airplane fuel efficiency, this improvement in efficiency may not be reflected in operation.

The ICAO metric system consists of a CO_2 emissions metric (Equation IV–1) and a correlating parameter.[66]

Equation IV-1: International CO_2 Emissions Metric for airplanes

$$ICAO\ CO_2\ \text{Emissions}\ Metric = \frac{\left(\frac{1}{SAR}\right)_{avg}}{RGF^{0.24}}$$

The ICAO CO_2 emissions metric uses an average of three Specific Air Range (SAR) test points that is normalized by a geometric factor representing the physical size of an airplane. SAR is a measure of airplane cruise performance, which measures the distance an airplane can travel on a unit of fuel. Here the inverse of SAR is used (1/SAR), which has the units of kilograms of fuel burned per kilometer of flight; therefore, a lower metric value represents a lower level of airplane CO_2 emissions (*i.e.,* better fuel efficiency). The SAR data are measured at three gross weight points used to represent a range of day-to-day airplane operations (at cruise).[67] For the ICAO CO_2 emissions metric, $(1/SAR)_{avg}$ [68] is calculated at 3 gross weight fractions of Maximum Takeoff Mass (MTOM): [69]

- *High gross mass:* 92% MTOM.
- *Mid gross mass:* Average of high gross mass and low gross mass.
- *Low gross mass:* (0.45 * MTOM) + (0.63 * (MTOM∧0.924)).

The Reference Geometric Factor (RGF) is a non-dimensional measure of the fuselage [70] size of an airplane

[64] Payload is the weight of passengers, baggage, and cargo. FAA Airplane Weight & Balance Handbook (Chapter 9, page 9–10, file page 82) *https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/media/FAA-H-8083-1.pdf* (x)(last accessed on March 16, 2020).

[65] ICF, 2018: *Aircraft CO_2 Cost and Technology Refresh and Industry Characterization,* Final Report, EPA Contract Number EP–C–16–020, September 30, 2018.

[66] Annex 16 Volume III Part II Chapter 2 sec. 2.2. ICAO, 2017: *Annex 16 Volume III—Environmental Protection—Aeroplane CO_2 Emissions, First Edition,* 40 pp. Available at: *http://www.icao.int/publications/Pages/catalogue.aspx* (last accessed July 15, 2020). The ICAO Annex 16 Volume III is found on page 16 of the English Edition of the 2020 catalog, and it is copyright protected; Order No. AN 16–3. Also see: ICAO, 2020, Supplement No. 6—July 2020, *Annex 16 Environmental Protection-Volume III-Aeroplane CO_2 Emissions, Amendment 1* (20/7/20). 22pp. Available at *https://www.icao.int/publications/catalogue/cat_2020_Sup06_en.pdf* (last accessed October 27, 2020). The ICAO Annex 16, Volume III, Amendment 1 is found on page 2 of Supplement No. 6—July 2020, English Edition, Order No. AN16–3/E/01.

[67] ICAO, 2016: *Tenth Meeting Committee on Aviation Environmental Protection Report,* Doc 10069, CAEP/10, 432 pp, AN/192, Available at: *https://www.icao.int/publications/Pages/catalogue.aspx* (last accessed March 16, 2020). The ICAO Report of the Tenth Meeting report is found on page 27 of the ICAO Products & Services English Edition 2020 catalog and is copyright protected; Order No. 10069.

[68] Avg means average.

[69] Annex 16 Vol. III Part II Chapter 2 sec. 2.3. ICAO, 2017: *Annex 16 Volume III—Environmental Protection—Aeroplane CO_2 Emissions, First Edition,* 40 pp. Available at: *http://www.icao.int/publications/Pages/catalogue.aspx* (last accessed July 15, 2020). The ICAO Annex 16 Volume III is found on page 16 of the English Edition of the 2020 catalog, and it is copyright protected; Order No. AN 16–3. Also see: ICAO, 2020, Supplement No. 6—July 2020, *Annex 16 Environmental Protection-Volume III-Aeroplane CO_2 Emissions, Amendment 1* (20/7/20). 22pp. Available at *https://www.icao.int/publications/catalogue/cat_2020_Sup06_en.pdf* (last accessed October 27, 2020). The ICAO Annex 16, Volume III, Amendment 1 is found on page 2 of Supplement No. 6—July 2020, English Edition, Order No. AN16–3/E/01.

[70] The fuselage is an aircraft's main body section. It holds crew, passengers, and cargo.

normalized by 1 square meter, generally considered to be the shadow area of the airplane's pressurized passenger compartment.[71]

When the ICAO CO_2 emissions metric is correlated against MTOM, it has a positive slope. The international Airplane CO_2 Emission Standards use the MTOM of the airplane as an already certificated reference point to compare airplanes. In this action, we are adopting MTOM as the correlating parameter as well.

We are adopting ICAO's airplane CO_2 emissions metric (shown in Equation IV–1) as the measure of airplane fuel efficiency as a surrogate for GHG emissions from covered airplanes (hereafter known as the ''fuel efficiency metric'' or ''fuel burn metric''). This is because the fuel efficiency metric controls emissions of both CO_2 and N_2O, the only two GHG emitted by airplane engines (see Section IV.H for further information). Consistent with ICAO, we are also adopting MTOM as the correlating parameter to be used when setting emissions limits.

B. Covered Airplane Types and Applicability

1. Maximum Takeoff Mass Thresholds

This GHG rule applies to civil subsonic jet airplanes (turbojet or turbofan airplanes) with certificated MTOM over 5,700 kg (12,566 lbs.) and propeller-driven civil airplanes (turboprop airplanes) over 8,618 kg (19,000 lbs.). These applicability criteria are the same as those in the ICAO Airplane CO_2 Emission Standards and correspond to the scope of the 2016 Findings. The applicability of this rule is limited to civil subsonic airplanes and does not extend to civil supersonic airplanes.[72] Through this action, as described earlier in Section II, the EPA is fully discharging its obligations under the CAA that were triggered by the 2016 Findings. Once the EPA and the FAA fully promulgate the airplane GHG emission standards and regulations for their implementation and enforcement domestically, the United States regulations will align with ICAO Annex 16 standards.

Examples of covered airplanes under this GHG rule include smaller civil jet airplanes such as the Cessna Citation CJ3+, up to and including the largest commercial jet airplanes—the Boeing 777 and the Boeing 747. Other examples of covered airplanes include larger civil turboprop airplanes, such as the ATR 72 and the Viking Q400.[73] [74] The GHG rule does not apply to smaller civil jet airplanes (*e.g.,* Cessna Citation M2), smaller civil turboprop airplanes (*e.g.,* Beechcraft King Air 350i), piston-engine airplanes, helicopters, and military airplanes.

2. Applicability

The rule applies to all covered airplanes, in-production, and new type designs produced after the respective effective dates of the standards except as provided in IV.B.3. There are different regulatory emissions levels and/or applicability dates depending on whether the covered airplane is in-production before the applicability date or is a new type design.

The in-production standards are only applicable to previously type certificated airplanes, newly-built on or after the applicability date (described in IV.D.1), and do not apply retroactively to airplanes that are already in-service. For example, converting a passenger airplane built prior to the 2028 in-production (and/or after 2023 if applicable) applicability date into a freight airplane would not trigger the change criteria described later in section IV.D.1.i (Changes for non-GHG Certificated Airplane Types), which apply only to newly produced airplanes (airplanes receiving their first airworthiness certificate) incorporating such modifications.

3. Exceptions

Consistent with the applicability of the ICAO standards, the EPA is adopting applicability language that excepts the following airplanes from the scope of the standards: Amphibious airplanes, airplanes initially designed or modified and used for specialized operational requirements, airplanes designed with an RGF of zero,[75] and those airplanes specifically designed or modified and used for fire-fighting purposes. Airplanes in these excepted categories are generally designed or modified in such a way that their designs are well outside of the design space of typical passenger or freight carrying airplanes. For example, amphibious airplanes are, by necessity, designed with fuselages that resemble boats as much as airplanes. As such, their aerodynamic efficiency characteristics fall well outside of the range of airplanes used in developing the ICAO Airplane CO_2 Emission Standards and our GHG rules.

Airplanes designed or modified for specialized operational requirements could include a wide range of activities, but many are outside the scope of the 2017 ICAO Airplane CO_2 standards. Airplanes that may be out of scope could include:

- Airplanes that require capacity to carry cargo that is not possible by using less specialized airplanes (*e.g.* civil variants of military transports); [76]
- Airplanes that require capacity for very short or vertical takeoffs and landings;
- Airplanes that require capacity to conduct scientific, [77] research, or humanitarian missions exclusive of commercial service; or
- Airplanes that require similar factors.

The EPA is finalizing the exceptions to the rule as proposed. Comments on this issue and our responses can be found in the RTC document included in the docket for this rulemaking.

4. New Airplane Types and In-Production Airplane Designations

The final rule recognizes differences between previously type certificated

[71] Annex 16 Vol. III Appendix 2. ICAO, 2017: *Annex 16 Volume III—Environmental Protection—Aeroplane CO_2 Emissions, First Edition,* 40 pp. Available at: *http://www.icao.int/publications/Pages/catalogue.aspx* (last accessed July 15, 2020). The ICAO Annex 16 Volume III is found on page 16 of the English Edition 2020 catalog, and it is copyright protected; Order No. AN 16–3. Also see: ICAO, 2020, Supplement No. 6—July 2020, *Annex 16 Environmental Protection-Volume III-Aeroplane CO_2 Emissions, Amendment 1* (20/7/20). 22pp. Available at *https://www.icao.int/publications/catalogue/cat_2020_Sup06_en.pdf* (last accessed October 27, 2020). The ICAO Annex 16, Volume III, Amendment 1 is found on page 2 of Supplement No. 6—July 2020, English Edition, Order No. AN16–3/E/01.

[72] Currently, civilian supersonic airplanes are not in operation. The international standard did not consider the inclusion of supersonic airplanes in the standard. More recently, there has been renewed interest in the development of civilian supersonic airplanes. This has caused ICAO to begin considering how existing emission standards should be revised for new supersonic airplanes. The US is involved in these discussions and at this point plans to work with ICAO to develop emission standards on the international stage prior to adopting them domestically.

[73] This was previously owned by Bombardier and was sold to Viking in 2018, November 8, 2018 (Forbes).

[74] It should be noted that there are no US domestic manufacturers that produce turboprops that meet the MTOM thresholds. These airplanes are given as examples but will be expected to be certificated by their national aviation certification authority.

[75] RGF refers to the pressurized compartment of an airplane, generally meant for passengers and/or cargo. If an airplane is unpressurized, the calculated RGF of the airplane is zero (0). These airplanes are very rare, and the few that are in service are used for special missions. An example is Boeing's Dreamlifter.

[76] This is not expected to include freight versions of passenger airplanes such as the Boeing 767F, Boeing 747–8F, or Airbus A330F. Rather, this is intended to except airplanes such as the Lockheed L–100 which is a civilian variant of the military C–130.

[77] For example, the NASA SOFIA airborne astronomical observatory.

airplanes that are in production and new type designs presented for original certification.

• *In-production airplanes:* Those airplane types which have already received a type certificate [78] from the FAA, and for which manufacturers either have existing undelivered sales orders or would be willing and able to accept new sales orders. The term can also apply to the individual airplane manufactured according to the approved design type certificate, and for which an Airworthiness Certificate is required before the airplane is permitted to operate.[79] [80]

• *New type designs:* Airplane types for which original certification is applied for on or after the compliance date of a rule, and which have never been manufactured prior to the compliance date of a rule.

Certificated designs may subsequently undergo design changes such as new wings, engines, or other modifications that would require changes to the type certificated design. These modifications happen more frequently than applications for a new type design. For example, a number of airplanes have undergone significant design changes (including the Boeing 747–8, Boeing 737 Max, Airbus 320 Neo, Airbus A330 Neo, and Boeing 777–X). As with a previous series of redesigns from 1996–2006, which included the Boeing 777–200LR in 2004, Boeing 777–300ER in 2006, Airbus 319 in 1996, and Airbus 330–200 in 1998, incremental improvements are expected to continue to be more frequent than major design changes over the next decade—following these more recent major programs (or more recent significant design changes).[81] [82]

New type designs are infrequent, and it is not unusual for new type designs to take 8–10 years to develop, from preliminary design to entry into service.[83] The most recent new type designs introduced in service were the Airbus A350 in 2015, [84] the Airbus A220 (formerly known as the Bombardier C-Series) in 2016, [85] and the Boeing 787 in 2011.[86, 87] However, it is unlikely more than one new type design will be presented for certification in the next ten years.[88] New type designs (and some redesigns) typically yield large fuel burn reductions—10 percent to 20 percent—over the prior generation they replace (considered a step-change in fuel burn improvement). As one might expect, these significant fuel burn reductions do not happen frequently. Also, airplane development programs are expensive.[89]

At ICAO, the difference between in-production airplanes and new type designs has been used to differentiate two different pathways by which fuel efficiency technologies can be introduced into civil airplane designs.

When a new requirement is applied to an in-production airplane, there may be a real and immediate effect on the manufacturer's ability to continue to build and deliver it in its certificated design configuration and to make business decisions regarding future production of that design configuration. Manufacturers need sufficient notice to make design modifications that allow for compliance to the new standards and to have those modifications certificated by their certification authorities. In the United States, applying a new requirement to an in-production airplane means that a newly produced airplane subject to this rule that does not meet the GHG standards would likely be denied an airworthiness certificate after January 1, 2028. As noted above in IV.B.2, in-service airplanes are not subject to the ICAO CO_2 standards and likewise are not subject to these GHG standards.

For new type designs, this rule has no immediate effect on airplane production or certification for the manufacturer. The standards that a new type design must meet are those in effect when the manufacturer applies for type certification. The applicable design standards at the time of application remain frozen over the typical 5-year time frame provided by certification authorities for completing the type certification process. Because of the investments and resources necessary to develop a new type design, manufacturers have indicated that it is important to have knowledge of the level of future standards at least 8 years in advance of any new type design entering service.[90] Because standards are known early in the design and certification process, there is more flexibility in how and what technology can be incorporated into a new type design. (See Section VI describing the Technology Response for more information on this).

To set standards at levels that appropriately reflect the feasibility to incorporate technology and lead time, the level and timing of the standards are different for in-production airplanes and new type designs. This is discussed further in Sections IV.C and IV.D below, describing standards for new type designs and in-production airplanes,

[78] A type certificate is a design approval whereby the FAA ensures that the manufacturer's designs meet the minimum requirements for airplane safety and environmental regulations. According to ICAO Cir 337, a type certificate is ''[a] document issued by a Contracting State to define the design of an airplane type and to certify that this design meets the appropriate airworthiness requirements of that State.'' A type certificate is issued once for each new type design airplane and modified as an airplane design is changed over the course of its production life.

[79] ICAO, 2016: *Tenth Meeting Committee on Aviation Environmental Protection Report,* Doc 10069, CAEP/10, 432 pp, AN/192, Available at: *http://www.icao.int/publications/Pages/catalogue.aspx* (last accessed March 16, 2020). The ICAO Report of the Tenth Meeting report is found on page 27 of the ICAO Products & Services English Edition 2020 catalog and is copyright protected; Order No. 10069.

[80] In existing U.S. aviation emissions regulations, in-production means newly-manufactured or built after the effective date of the regulations—and already certificated to pre-existing rules. This is similar to the current ICAO definition for in-production airplane types for purposes of the international CO_2 standard.

[81] ICF International, 2015: *CO_2 Analysis of CO_2-Reducing Technologies for Airplane,* Final Report, EPA Contract Number EP–C–12–011, March 17, 2015.

[82] Insofar as we are going through a wave of major redesign and service entry now, prospects for further step-function improvements will be low in the coming 10–15 years. (ICF International, *CO_2 Analysis of CO_2-Reducing Technologies for Airplane,* Final Report, EPA Contract Number EP–C–12–011, March 17, 2015.)

[83] ICF International, 2015: *CO2 Analysis of CO_2-Reducing Technologies for Airplane,* Final Report, EPA Contract Number EP–C–12–011, March 17, 2015.

[84] The Airbus A350 was announced in 2006 and received its type certification in 2014. The first model, the A350–900 entered service with Qatar Airways in 2015.

[85] The Bombardier C-series was announced in 2005 and received its type certification in 2015. The first model, the C100 entered service with Swiss Global Air Lines in 2016.

[86] Boeing, 2011: Boeing Unveils First 787 to Enter Service for Japan Airlines, December 14. Available at *http://boeing.mediaroom.com/2011-12-14-Boeing-Unveils-First-787-to-Enter-Service-for-Japan-Airlines* (last accessed March 16, 2020).

[87] ICF International, 2015: *CO_2 Analysis of CO_2-Reducing Technologies for Airplane,* Final Report, EPA Contract Number EP–C–12–011, March 17, 2015.

[88] Ibid.

[89] Analysts estimate a new single aisle airplane would have cost $10–12 billion to develop. The A380 and 787 are estimated to each have cost around $20 billion to develop; the A350 is estimated to have cost $15 billion, excluding engine development. Due to the large development cost of a totally new airplane design, manufacturers are opting to re-wing or re-engine their airplane. Boeing is said to have budgeted $5 billion for the re-wing of the 777, and Airbus and Boeing have budgeted $1–2 billion each for the re-engine of the A320 and the 737, respectively (excluding engine development costs). Embraer has publicly stated that it will need to spend $1–2 billion to re-wing the EMB–175 and variants. (ICF International, *CO_2 Analysis of CO_2-Reducing Technologies for Airplane,* Final Report, EPA Contract Number EP–C–12–011, March 17, 2015.)

[90] ICAO policy is that the compliance date of an emissions standard must be at least 3 years after it has been agreed to by CAEP. Adding in the 5-year certification window, this means that the level of the standard can be known 8 years prior to entry into service date for a new type design. Manufacturers also have significant involvement in the standard development process at ICAO, which begins at least 3 years before any new standard is agreed to.

and Section VI, discussing the technology response.

C. GHG Standard for New Type Designs

1. Applicability Dates for New Type Designs

The EPA is adopting GHG standards that apply to civil airplanes within the scope of the international standards adopted by ICAO in 2017 that meet maximum takeoff weight thresholds, passenger capacity, and dates of applications for original type certificates. In this way, EPA's standards align with ICAO's in defining those airplanes that are now subject to the standards finalized in this action. Consequently, for subsonic jet airplanes over 5,700 kg MTOM and certificated with more than 19 passenger seats, and for turboprop airplanes over 8,618 kg MTOM, the regulations apply to all airplanes for which application for an original type certificate is made to the FAA as the first certificating authority on or after January 11, 2021. For subsonic jet airplanes over 5,700 kg MTOM and less than 60,000 kg MTOM and a type certificated maximum passenger seating capacity of 19 seats or fewer, the regulations apply to all airplanes for which an original type certification application was made to the FAA as the first certificating authority on or after January 1, 2023.

Consistency with international standards is important for manufacturers, as they noted in comments to our ANPR in 2015 and in their comments to this rulemaking. Airplane manufacturers and engine manufacturers would have been surprised if the EPA had adopted criteria to identify airplanes covered by our GHG standards that resulted in different coverage than that of ICAO's standards—either in terms of maximum takeoff mass, passenger capacity, or dates of applications for new original type certificates. Additionally, if the EPA diverged from ICAO's criteria for CO_2 standards applicability, it would have introduced unnecessary uncertainty into the airplane type certification process. Also, as described earlier for the 2016 Findings, covered airplanes accounted for the majority (89 percent) of total U.S. aircraft GHG emissions.

In order to harmonize with the ICAO standards to the maximum extent possible, the EPA proposed the same effective date as ICAO, January 1, 2020, for defining those type certification applications subject to the standards, noting in the NPRM that it was a date that had already passed. However, to avoid potential concerns raised by commenters and because it does not affect harmonization with ICAO standards, we are adopting standards that are effective upon the effective date of this rule January 11, 2021. No airplane manufacturer has in fact yet submitted an application for a new type design certification since January 1, 2020, no manufacturer will currently need to amend any already submitted application to address the GHG standards. Further, neither the EPA nor the FAA is aware of any anticipated original new type design application to be submitted before the EPA's standards are promulgated and effective. Thus, there is no practical impact of changing the effective date for the new type design standards from January 1, 2020, as proposed, to the effective date of this rule January 11, 2021.

The EPA recognizes that new regulatory requirements have differing impacts on items that are already in production and those yet to be built. Airplane designs that have yet to undergo original type certification can more easily be adapted for new regulatory requirements, compared with airplanes already being produced subject to older, existing design standards. The agency has experience adopting regulations that acknowledge these differences, such as in issuing emission standards for stationary sources of hazardous air pollutants (which often impose more stringent standards for new sources, defined based on dates that precede dates of final rule promulgation, than for existing sources). See, *e.g.,* 42 U.S.C. 7412(a)(4), defining ''new source'' to mean a stationary source the construction or reconstruction of which is commenced after the EPA proposes regulations establishing an emission standard.

2. Regulatory limit for New Type Designs

The EPA is adopting the GHG emissions limit for new type designs that is a function of the airplane certificated MTOM and consists of three levels described below in Equation IV–2, Equation IV–3, and Equation IV–4.[91]

Equation IV-2: New Type Designs with a MTOM less than or equal to 60 000 kg

$$Maximum\ permitted\ value = 10^{\left(-2.73780 + (0.681310 * \log_{10}(MTOM)) + \left(-0.0277861 * (\log_{10}(MTOM))^2\right)\right)}$$

Equation IV-3: New Type Designs with a MTOM greater than 60 000 kg, and less than or equal to 70 395 kg:

$$Maximum\ permitted\ value = 0.764$$

Equation IV-4: New Type Designs with a MTOM greater than 70 395 kg

$$Maximum\ permitted\ value = 10^{\left(-1.412742 + (-0.020517 * \log_{10}(MTOM)) + \left(0.0593831 * (\log_{10}(MTOM))^2\right)\right)}$$

[91] Annex 16 Vol. III Part II Chapter 2 sec. 2.4.2 (a), (b), and (c). ICAO, 2017: *Annex 16 Volume III—Environmental Protection—Aeroplane CO_2 Emissions, First Edition,* 40 pp. Available at: *http://www.icao.int/publications/Pages/catalogue.aspx* (last accessed July 15, 2020). The ICAO Annex 16 Volume III is found on page 16 of the English Edition of the 2020 catalog and it is copyright protected; Order No. AN 16–3. Also see: ICAO, 2020, Supplement No.6—July 2020, *Annex 16 Environmental Protection-Volume III-Aeroplane CO_2 Emissions, Amendment 1* (20/7/20). 22pp. Available at *https://www.icao.int/publications/catalogue/cat_2020_Sup06_en.pdf* (last accessed October 27, 2020). The ICAO Annex 16, Volume III, Amendment 1 is found on page 2 of Supplement No. 6—July 2020, English Edition, Order No. AN16–3/E/01.

Figure IV–1 and Figure IV–2 show the numerical limits of the adopted new type design rules and how the airplane types analyzed in Sections V and VI relate to this limit. Figure IV–2 shows only the lower MTOM range of Figure IV–1 to better show the first two segments of the limit line. These plots below show the airplane fuel efficiency metric values as they were modeled. This includes all anticipated/modeled technology responses, improvements, and production assumptions in response to the market and this rule. (See Section V and VI for more information about this.) These final GHG emission limits are the same as the limits of the ICAO Airplane CO_2 Emission Standards.

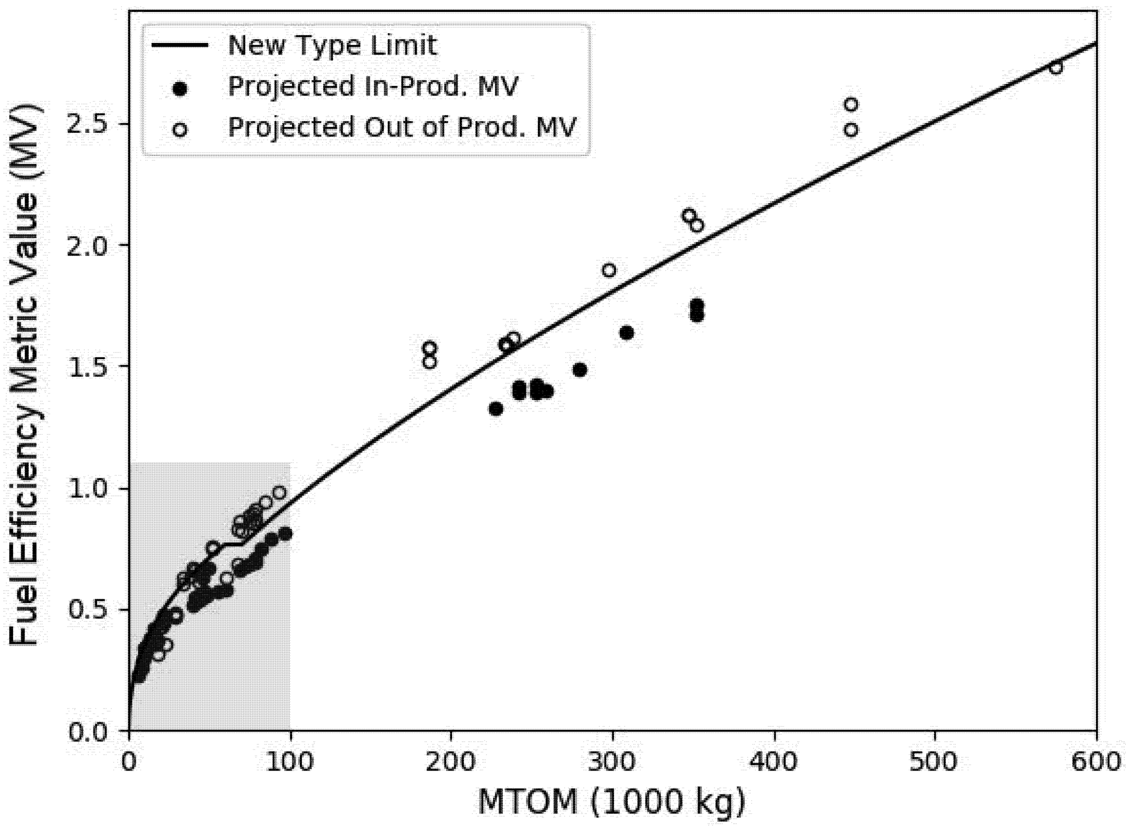

Figure IV-1 - Final New Type Design Rule

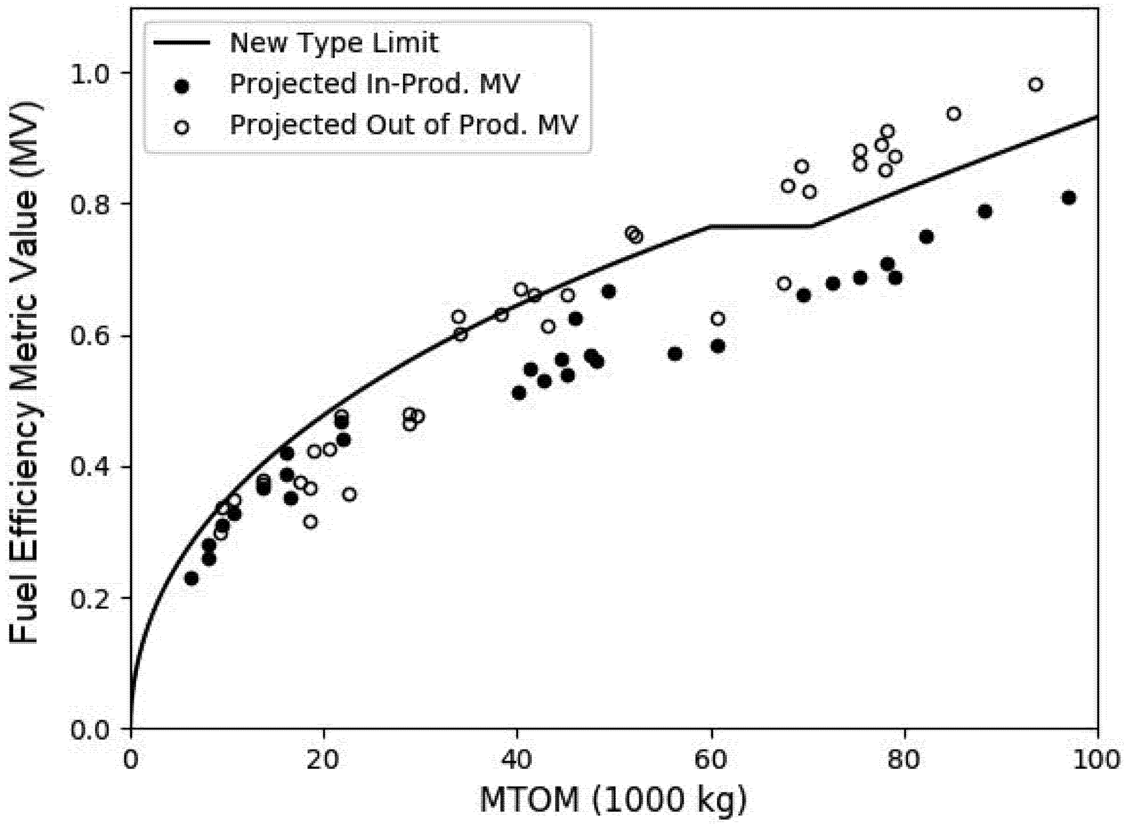

Figure IV-2 - Final New Type Design Rule - Zoomed in to highlights MTOM less than 100,000kg

After analyzing potential levels of the standard, ICAO determined, based on assessment of available data, that there were significant performance differences between large and small airplanes. Jet airplanes with an MTOM less than 60 tons [92] are either business jets or regional jets. The physical size of smaller airplanes presents scaling challenges that limit technology improvements that can readily be made on larger airplanes.[93] This leads to requiring higher capital costs to implement the technology relative to the sale price of the airplanes.[94] Business jets (generally less than 60 tons MTOM) tend to operate at higher altitudes and faster speeds than larger commercial traffic.

Based on these considerations, when developing potential levels for the international standards, ICAO further realized that curve shapes of the data differed for large and small airplanes (on MTOM versus metric value plots). Looking at the dataset, there was originally a gap in the data at 60 tons.[95] This natural gap allowed a ''kink'' point (*i.e.,* change in the slope of the standard) to be established between larger commercial airplanes and smaller business jets and regional jets. The identification of this kink point provided flexibility at ICAO to consider standards at appropriate levels for airplanes above and below 60 tons.

The level adopted for new type designs was set to reflect the performance for the latest generation of airplanes. The CO_2 emission standards agreed to at ICAO, and the GHG standards adopted here, are meant to be technology following standards. This means the rule reflects the performance and technology achieved by existing airplanes (in-production and in-development airplanes [96]).[97]

Airplanes of less than 60 tons with 19 or fewer passenger seats have additional economic challenges to technology development compared with similarly sized commercial airplanes. ICAO sought to reduce the burden on manufacturers of airplanes with 19 or fewer seats, and thus ICAO agreed to delay the applicability of the new type designs for 3 years. In maintaining consistency with the international decision, the applicability dates adopted in this rule reflect this difference determined by ICAO (see Section VI for further information).

As described earlier in Section II, consistency with the international standards will facilitate the acceptance of U.S. airplanes by member States and airlines around the world, and it will help to ensure that U.S. manufacturers

[92] In this rulemaking, 60 tons means 60 metric tons (or tonnes), which is equal to 60,000 kilograms (kg). 1 ton means 1 metric ton (or tonne), which is equal to 1,000 kg.

[93] ICF, 2018: *Aircraft CO_2 Cost and Technology Refresh and Industry Characterization*, Final Report, EPA Contract Number EP–C–16–020, September 30, 2018.

[94] U.S., *United States Position on the ICAO Aeroplane CO_2 Emissions Standard,* Montréal, Canada, CAEP10 Meeting, February 1–12, 2016, Presented by United States, CAEP/10–WP/59. Available in the docket for this rulemaking, Docket EPA–HQ–OAR–2018–0276.

[95] Initial data that were reviewed at ICAO did not include data on the Bombardier C-Series (now the Airbus A220) airplane. Once data were provided for this airplane, it was determined by ICAO that while the airplane did cross the 60 tons kink point, this did not pose a problem for analyzing stringency options, because the airplane passes all options considered.

[96] In-development airplanes are airplanes that were in-development when setting the standard at ICAO but will be in production by the applicability dates. These could be new type designs (*e.g.* Airbus A350) or redesigned airplanes (*e.g.* Boeing 737Max).

[97] Note: Figure IV–1 and Figure IV–2 show the metric values used in the EPA modeling for this action. These values differ from those used at ICAO. The rationale for this difference is discussed below in section VI of this rule, and in chapter 2 of the TSD.

will not be at a competitive disadvantage compared with their international competitors. Consistency with the international standards will also prevent backsliding by ensuring that all new type design airplanes are at least as efficient as today's airplanes.

D. GHG Standard for In-Production Airplane Types

1. Applicability Dates for In-Production Airplane Types

The EPA is adopting the same compliance dates for the GHG rule as those adopted by ICAO for its CO_2 emission standards. Section IV.D.2 below describes the rationale for these dates and the time provided to in-production types.

All airplanes type certificated prior to January 11, 2021, and receiving its first certificate of airworthiness after January 1, 2028, will be required to comply with the in-production standards. This GHG regulation will function as a production cutoff for airplanes that do not meet the fuel efficiency levels described below.

i. Changes for Non-GHG Certificated Airplane Types

After January 1, 2023, and until January 1, 2028, an applicant that submits a modification to the type design of a non-GHG certificated airplane that increases the Metric Value of the airplane type by greater than 1.5% [98] will be required to demonstrate that newly produced airplanes comply with the in-production standard. This earlier applicability date for in-production airplanes, January 1, 2023, is the same as that adopted by ICAO and is similarly designed to capture modifications to the type design of non-GHG certificated airplanes newly manufactured (initial airworthiness certificate) prior to the January 1, 2028, production cut-off date. The January 1, 2028 production cut-off date was introduced by ICAO as an anti-backsliding measure that gives notice to manufacturers that non-compliant airplanes will not receive airworthiness certification after this date.

An application for certification of a modified airplane type on or after January 1, 2023, will trigger compliance with the in-production GHG emissions limit provided that the airplane's GHG emissions metric value for the modified version to be produced thereafter increases by more than 1.5 percent from the prior version of the airplane type. As with changes to GHG certificated airplane types, introduction of a modification that does not adversely affect the airplane fuel efficiency Metric Value will not require demonstration of compliance with the in-production GHG standards at the time of that change. Manufacturers may seek to certificate any airplane type to this standard, even if the criteria do not require compliance.

As an example, if a manufacturer chooses to shorten the fuselage of a type certificated airplane, such action will not automatically trigger the requirement to certify to the in-production GHG rule. The fuselage shortening of a certificated type design would not be expected to adversely affect the metric value, nor would it be expected to increase the certificated MTOM. Manufacturers noted that ICAO included criteria that would require manufactures to recertify if they made ''significant'' changes to their airplane. ICAO did not define a ''significant change'' to a type design. The EPA did not include this requirement because ''significant change'' is not a defined term in the certification process. However, it is expected that manufacturers will likely volunteer to certify to the in-production rule when applying to the FAA for these types of changes, in order to maximize efficiencies in overall airworthiness certification processes (*i.e.,* avoid the need for iterative rounds of certification). This earlier effective date for in-production airplane types is expected to help encourage some earlier compliance for new airplanes.

2. Regulatory Limit for In-Production Type Designs

The EPA is adopting an emissions limit for in-production airplanes that is a function of airplane certificated MTOM and consists of three MTOM ranges as described below in Equation IV–5, Equation IV–6, and Equation IV–7.[99]

Equation IV-5: In-production airplanes with a MTOM less than or equal to 60 000 kg:

$$\mathit{Maximum\ permitted\ value} = 10^{-2.57535 + (0.609766 * log10(MTOM)) + \left(-0.0191302 * (log10(MTOM))^2\right)}$$

Equation IV-6: In-production airplanes with a MTOM greater than 60 000 kg, and less than or equal to 70 107 kg

$$\mathit{Maximum\ permitted\ value} = 0.797$$

Equation IV-7: In-production airplanes with a MTOM greater than 70 107 kg

$$\mathit{Maximum\ permitted\ value} = 10^{-1.39353 + (-0.020517 * log10(MTOM)) + \left(0.0593831 * (log10(MTOM))^2\right)}$$

[98] Note that IV.D.1.i, Changes for non-GHG certified Airplane Types, is different than the No GHG Change Threshold described in IV.F.1 below. IV.F.1 applies only to airplanes that *have previously been* certificated to a GHG rule. IV.D.1.i only applies only to airplane types that *have not been* certificated for GHG.

[99] Annex 16 Vol. III Part II Chapter 2 sec. 2.4.2(d), (e), and (f). ICAO, 2017: *Annex 16 Volume III—Environmental Protection—Aeroplane CO_2 Emissions, First Edition,* 40 pp. Available at: *http://www.icao.int/publications/Pages/catalogue.aspx* (last accessed July 15, 2020). The ICAO Annex 16 Volume III is found on page 16 of the English Edition of the 2020 catalog, and it is copyright protected; Order No. AN 16–3. Also see: ICAO, 2020, Supplement No. 6—July 2020, *Annex 16 Environmental Protection-Volume III-Aeroplane CO_2 Emissions, Amendment 1* (20/7/20). 22 pp. Available at *https://www.icao.int/publications/catalogue/cat_2020_Sup06_en.pdf* (last accessed October 27, 2020). The ICAO Annex 16, Volume III, Amendment 1 is found on page 2 of Supplement No. 6—July 2020, English Edition, Order No. AN16–3/E/01.

Figure IV–3 and Figure IV–4 show the numerical limits of the adopted in-production rules and the relationship of the airplane types analyzed in Sections V and VI to this limit. Figure IV–4 shows only the lower MTOM range of Figure IV–3 to better show the first two segments of the limit line. These plots below show the airplane CO_2 metric values as they were modeled. This includes all anticipated/modeled technology responses, improvements, and production assumptions in response to the market and the final rule. (See Sections V and VI for more information about this.) These GHG emission limits are the same as the limits of the ICAO Airplane CO_2 Emission Standards.

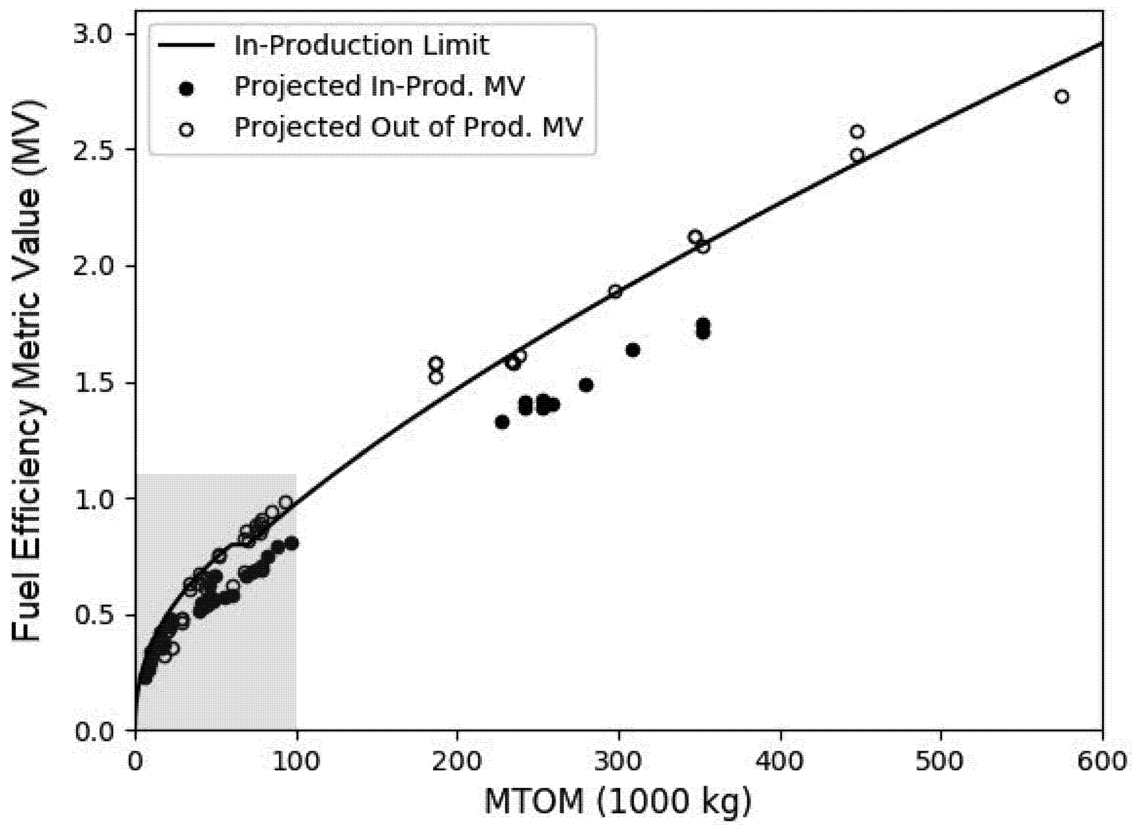

Figure IV-3 - Final In-Production Standard

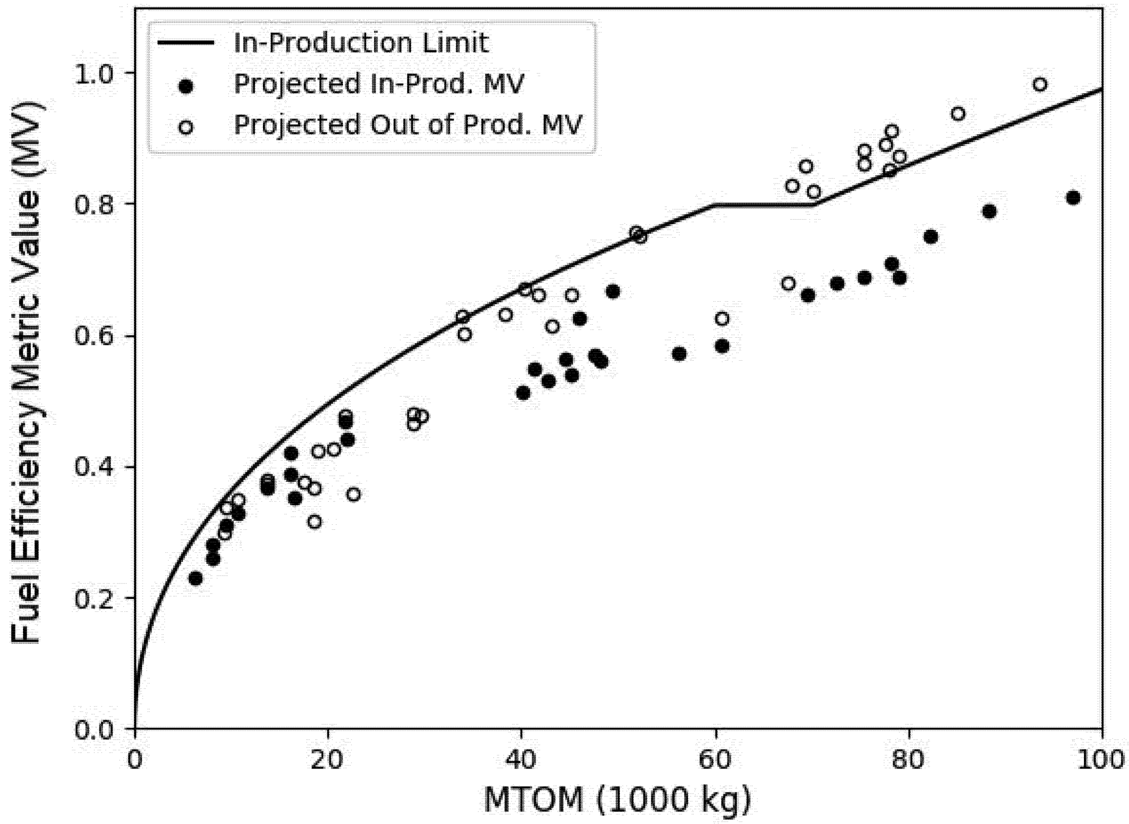

Figure IV-4 - Final In-Production Standard - zoomed in to highlights MTOM less than 100,000kg

As discussed in Section IV.C above, the kink point was included in the ICAO Aircraft CO_2 standards at 60 tons to account for a change in slope that is observed between large and small airplanes. The flat section starting at 60 tons is used as a transition to connect the curves for larger and smaller airplanes.

While the same technology is considered for both new type design and in-production airplanes, there will be a practical difference in compliance for in-production airplanes. Manufacturers will need to test and certify each type design to the GHG standard prior to January 1, 2028, or else newly produced airplanes will likely be denied an airworthiness certificate. In contrast, new type design airplanes have yet to go into production, but these airplanes will need to be designed to comply with the standards for new type designs (for an application for a new type design certificate on or after January 11, 2021). This poses a challenge for setting the level of the in-production standard because sufficient time needs to be provided to allow for the GHG certification process and the engineering and airworthiness certifications needed for improvements. The more stringent the in-production standard is, the more time that is necessary to provide manufacturers to modify production of their airplanes. ICAO determined that while the technology to meet the in-production level is available in 2020 (the ICAO standards new type design applicability date), additional time beyond the new type design applicability date was necessary to provide sufficient time for manufacturers to certify all of their products. The EPA agrees that additional time for in-production airplanes beyond the new type design applicability date is necessary to allow sufficient time to certify airplanes to the GHG standards.

Section VI describes the analysis that the EPA conducted to determine the cost and benefits of adopting this standard. Consistent with the ICAO standard, this rule applies to all in-production airplanes built on or after January 1, 2028, and to all in-production airplanes that have any modification that trigger the change criteria after January 1, 2023.

The levels of the in-production GHG standards are the same as ICAO's CO_2 standards, and they reflect the emission performance of current in-production and in-development airplanes. As discussed in Section IV.B.4 above and in Section VI, the regulations reflect differences in economic feasibility for introducing modifications to in-production airplanes and new type designs. The standards adopted by ICAO, and here, for in-production airplanes were developed to reflect these differences.

E. Exemptions From the GHG Standards

On occasion, manufacturers may need additional time to comply with a standard. The reasons for needing a temporary exemption from regulatory requirements vary and may include circumstances beyond the control of the manufacturer. The FAA is familiar with these actions, as it has handled the similar engine emission standards under its CAA authority to enforce the standards adopted by the EPA. The FAA has considerable authority under its authorizing legislation and its regulations to deal with these events.[100]

Since requests for exemptions are requests for relief from the enforcement

[100] Title 49 of the United States Code, sec. 44701(f), vests power in the FAA Administrator to issue exemptions as long as the public interest condition is met, and, pursuant to sec. 232(a) of the CAA, the Administrator may use that power ''in the execution of all powers and duties vested in him under this section'' ''to insure compliance'' with emission standards.

of these standards (as opposed to a request to comply with a different standard than set by the EPA), this rule will continue the relationship between the agencies by directing any request for exemption be filed with the FAA under its established regulatory paradigm. The instructions for submitting a petition for exemption to the FAA can be found in 14 CFR part 11, specifically § 11.63. Section 11.87 lists the information that must be filed in a petition, including a reason ''why granting your petition is in the public interest.'' Any request for exemption will need to cite the regulation that the FAA will adopt to carry out its duty of enforcing the standard set by the EPA. A list of requests for exemption received by the FAA is routinely published in the **Federal Register**.

The primary criterion for any exemption filed with the FAA is whether a grant of exemption will be in the public interest. The FAA will continue to consult with the EPA on all petitions for exemption that the FAA receives regarding the enforcement of aircraft engine and emission standards adopted under the CAA.

F. Application of Rules for New Version of an Existing GHG-Certificated Airplane

Under the international Airplane CO_2 Emission Standards, a new version of an existing CO_2-certificated airplane is one that incorporates modifications to the type design that increase the MTOM or increase its CO_2 Metric Value more than the No-CO_2-Change Threshold (described in IV.F.1 below). ICAO's standards provide that once an airplane is CO_2 certificated, all subsequent changes to that airplane must meet at least the CO_2 emissions regulatory level (or CO_2 emissions standard) of the parent airplane. For example, if the parent airplane is certificated to the in-production CO_2 emissions level, then all subsequent versions must also meet the in-production CO_2 emissions level. This would also apply to voluntary certifications under ICAO's standards. If a manufacturer seeks to certificate an in-production airplane type to the level applicable to a new type design, then future versions of that airplane must also meet the new type regulatory level. Once certificated, subsequent versions of the airplane may not fall back to a less stringent regulatory CO_2 level.

To comport with ICAO's approach, if the FAA finds that a new original type certificate is required for any reason, the airplane will need to comply with the regulatory level applicable to a new type design.

In this action, the EPA is adopting provisions for new versions of existing GHG-certificated airplanes that are the same as the ICAO requirements for the international Airplane CO_2 Emission Standards. These provisions will reduce the certification burden on manufacturers by clearly defining when a new GHG metric value must be established for the airplane.

1. No Fuel Efficiency Change Threshold for GHG-Certificated Airplanes

There are many types of modifications that could be introduced on an airplane design that could cause slight changes in GHG emissions (*e.g.* changing the fairing on a light,[101] adding or changing an external antenna, changing the emergency exit door configuration, etc.). To reduce burden on both certification authorities and manufacturers, a set of no CO_2 emissions change thresholds was developed for the ICAO Airplane CO_2 Emission Standards as to when new metric values will need to be certificated for changes. The EPA is adopting these same thresholds in its GHG rules.

Under this rule, an airplane is considered a modified version of an existing GHG certificated airplane, and therefore must recertify, if it incorporates a change in the type design that either (a) increases its maximum takeoff mass, or (b) increases its GHG emissions evaluation metric value by more than the no-fuel efficiency change threshold percentages described below and in Figure IV–5:[102]

- For airplanes with a MTOM greater than or equal to 5,700 kg, the threshold value decreases linearly from 1.35 to 0.75 percent for an airplane with a MTOM of 60,000 kg.
- For airplanes with a MTOM greater than or equal to 60,000 kg, the threshold value decreases linearly from 0.75 to 0.70 percent for airplanes with a MTOM of 600,000 kg.
- For airplanes with a MTOM greater than or equal to 600,000 kg, the threshold value is 0.70 percent.

[101] A fairing is ''*a structure on the exterior of an aircraft or boat, for reducing drag.*'' *https://www.dictionary.com/browse/fairing* (last accessed November 30, 2020).

[102] Annex 16, Volume III, Part 1, Chapter 1. ICAO, 2017: *Annex 16 Volume III—Environmental Protection—Aeroplane CO_2 Emissions, First Edition,* 40 pp. Available at: *http://www.icao.int/publications/Pages/catalogue.aspx* (last accessed July 15, 2020). The ICAO Annex 16 Volume III is found on page 16 of the English Edition of the 2020 catalog, and it is copyright protected; Order No. AN 16–3. Also see: ICAO, 2020. Supplement No. 6—July 2020, *Annex 16 Environmental Protection—Volume III—Aeroplane CO_2 Emissions, Amendment 1* (20/7/20). 22 pp. Available at *https://www.icao.int/publications/catalogue/CAT_2020_Sup06_en.pdf* (last accessed October 28, 2020). The ICAO Annex 16, Volume III, Amendment 1 is found on page 2 of Supplement No. 6—July 2020; English Edition, Order No. AN 16–3/E/01.

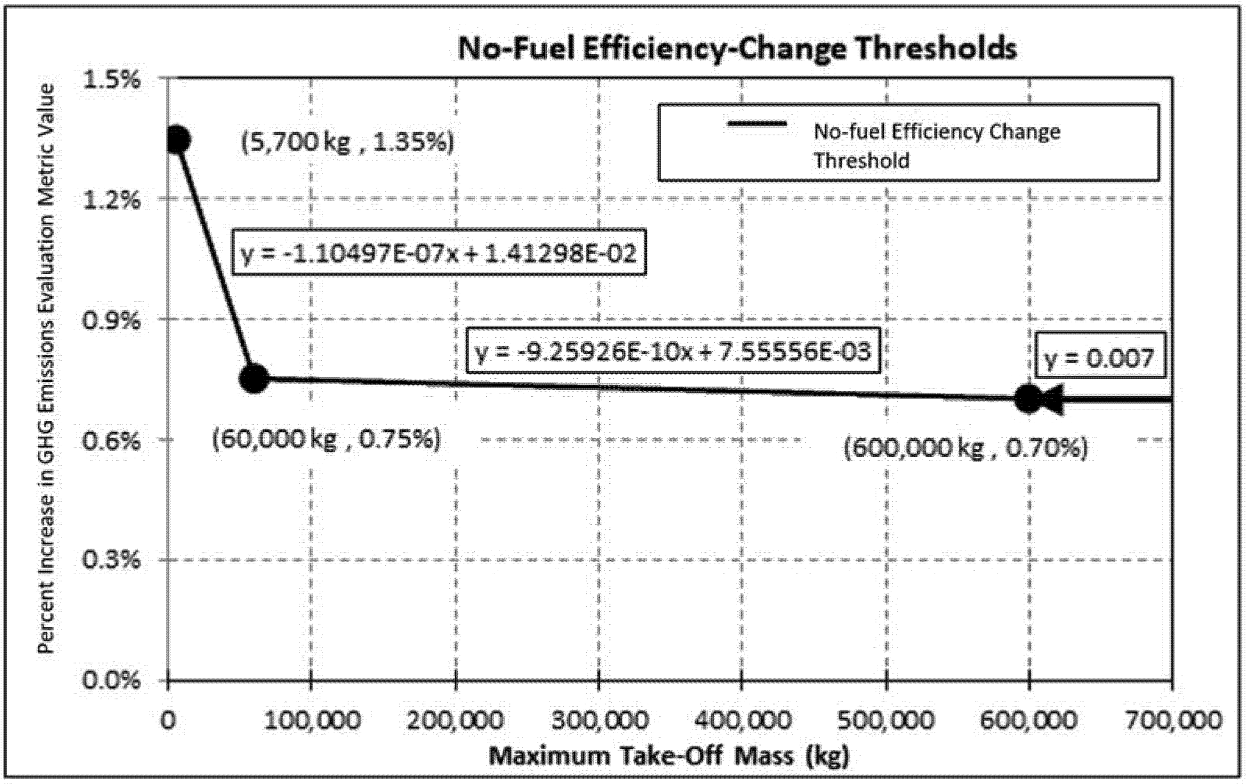

Figure IV-5: No Fuel Efficiency Change Thresholds for GHG Certificated Airplanes (ICAO Adopted No CO_2 Emissions Change Thresholds)

The threshold is dependent on airplane size because the potential fuel efficiency changes to an airplane are not constant across all airplanes. For example, a change to the fairing surrounding a wing light, or the addition of an antenna to a small business jet, may have greater impacts on the airplane's metric value than a similar change would on a large twin aisle airplane.

These GHG changes will be assessed on a before-change and after-change basis. If there is a flight test as part of the certification, the metric value (MV) change will be assessed based on the change in calculated metric value of flights with and without the change.

A modified version of an existing GHG certificated airplane will be subject to the same regulatory level as the airplane from which it was modified. A manufacturer may also choose to voluntarily comply with a later or more stringent standard.[103]

Under this rule, when a change is made to an airplane type that does not exceed the no-change threshold, the fuel efficiency metric value will not change. There will be no method to track these changes to airplane types over time. If an airplane type has, for example, a 10 percent compliance margin under the rule, then a small adverse change less than the threshold may not require the re-evaluation of the airplane metric value. However, if the compliance margin for a type design is less than the No Fuel Efficiency Change threshold and the proposed modification results in a change to the metric value that is less than the no fuel efficiency change threshold, then the airplane retains its original metric value, and the compliance margin to the regulatory limit remains the same. The proposal stated that if the margin to the standard was less than the No Fuel Efficiency Change Threshold that the plane would still be required to demonstrate compliance with the standard. Some commenters pointed out that this language was different than the description adopted by ICAO. To be consistent with ICAO, this language has been corrected.

Under this rule, a manufacturer that introduces modifications that reduce GHG emissions can request voluntary recertification from the FAA. There will be no required tracking or accounting of GHG emissions reductions made to an airplane unless it is voluntarily re-certificated.

The EPA is adopting, as part of the GHG rules, the no-change thresholds for modifications to airplanes discussed above, which are the same as the provisions in the international standard. We believe that these thresholds will maintain the effectiveness of the rule while limiting the burden on manufacturers to comply. The regulations reference specific test and other criteria that were adopted internationally in the ICAO standards setting process.

G. Test and Measurement Procedures

The international certification test procedures have been developed based upon industry's current best practices for establishing the cruise performance of their airplanes and on input from

[103] ETM Vol. III sec. 2.2.3. ICAO, 2018: *Environmental Technical Manual Volume III—Procedures for the CO_2 Emissions Certification of Aeroplanes, First Edition, Doc 9501,* 64 pp. Available at: *http://www.icao.int/publications/Pages/catalogue.aspx* (last accessed July 15, 2020). The ICAO Environmental Technical Manual Volume III is found on page 77 of the English Edition of the 2020 catalog, and it is copyright protected; Order No. 9501–3. Also see: ICAO, 2020: Doc 9501—*Environmental Technical Manual Volume III—Procedures for the CO_2 Emissions Certification of Aeroplanes, 2nd Edition, 2020.* 90 pp. Available at *https://www.icao.int/publications/catalogue/cat_2020_sup06_en.pdf* (last accessed October 28, 2020). The ICAO Environmental Technical Manual Volume III, 2nd Edition is found on page 3 of Supplement No. 6—July 2020, English Edition, Order No. 9501–3.

certification authorities. These procedures include specifications for airplane conformity, weighing, fuel specifications, test condition stability criteria, required confidence intervals, measurement instrumentation required, and corrections to reference conditions. In this action, we are incorporating by reference the test procedures for the ICAO Airplane CO_2 Emission Standards. Adoption of these test procedures will maintain consistency among all ICAO member States.

Airplane flight tests, or FAA approved performance models, will be used to determine SAR values that form the basis of the GHG metric value. Under the adopted rule, flight testing to determine SAR values shall be conducted within the approved normal operating envelope of the airplane, when the airplane is steady, straight, level, and trim, at manufacturer-selected speed and altitude.[104] The rule will provide that flight testing must be conducted at the ICAO-defined reference conditions where possible,[105] and that when testing does not align with the reference conditions, corrections for the differences between test and reference conditions shall be applied.[106]

We are incorporating by reference, in 40 CFR 1030.23(d), certain procedures found in ICAO Annex 16, Volume III.

H. Controlling Two of the Six Well-Mixed GHGs

As described earlier in Section IV.A and IV.G, we are adopting the ICAO test procedures and fuel efficiency metric.[107] The ICAO test procedures for the international Airplane CO_2 *Emission Standards measure fuel efficiency (or fuel burn), and ICAO uses fuel efficiency in the metric (or equation) for determining compliance.* As explained earlier in Section III and in the 2016 Findings,[108] only two of the six well-mixed GHGs—CO_2 and N_2O—are emitted from covered aircraft. Although there is not a standardized test procedure for directly measuring airplane CO_2 or N_2O emissions, the test procedure for fuel efficiency scales with the limiting of both CO_2 and N_2O emissions, as they both can be indexed on a per-unit-of-fuel-burn basis. Therefore, both CO_2 and N_2O emissions are controlled as airplane fuel burn is limited.[109] Since limiting fuel burn is the only means by which airplanes control their GHG emissions, the fuel-burn-based metric (or fuel-efficiency-based metric) reasonably serves as a means for controlling both CO_2 and N_2O.

Since CO_2 emissions represent nearly all GHG emissions from airplanes and ICAO's CO_2 test procedures measure fuel efficiency by using a fuel-efficiency-based metric, we are adopting rules that harmonize with the ICAO CO_2 standard—by adopting an aircraft engine GHG[110] standard that employs a fuel efficiency metric that will also scale with both CO_2 and N_2O emissions. The aircraft engine GHG standard will control both CO_2 and N_2O emissions, without the need for adoption of engine exhaust emissions rates for either CO_2 or N_2O. However, the air pollutant regulated by these standards will remain the aggregate of the six well-mixed GHGs.[111]

I. Response to Key Comments

The EPA received numerous comments on the proposed rulemaking which are presented in the Response to Comments document along with the EPA's responses to those comments. Below is a brief discussion of some of the key comments received.

1. Stringency of the Standards

Several commenters stated that the proposed rulemaking satisfies the requirements in the CAA, is consistent with the precedent for setting airplane emission standards in coordination with ICAO, and is supported by the administrative record for this rulemaking. The establishment of aircraft engine GHG standards that match the ICAO airplane CO_2 standards into U.S. law is consistent with the authority given to the EPA under section 231 of the CAA, and it clearly meets the criteria for adoption of aircraft engine standards specified in section 231. In addition, the proposed GHG standards align with the following CAEP terms of reference (described earlier in section II.D.1) that were assessed for the international airplane CO_2 standards: Technical feasibility, environmental benefit, economic reasonableness, and interdependencies of measures (*i.e.,* measures taken to minimize noise and emissions). These CAEP terms of reference are consistent with the criteria the EPA must adhere to under section 231(b) of the CAA that requires the EPA to allow enough lead time ''to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance within such period''—when adopting aircraft engine emission standards.

In addition, these commenters expressed that the EPA adopting

[104] It is expected that manufacturers will choose conditions that result in the highest SAR value for a given certification mass. Manufacturers may choose other than optimum conditions to determine SAR; however, doing so will be at their detriment.

[105] Annex 16, Vol. III, sec. 2.5. ICAO, 2017: *Annex 16 Volume III—Environmental Protection—Aeroplane CO_2 Emissions, First Edition,* 40 pp. Available at: *http://www.icao.int/publications/Pages/catalogue.aspx* (last accessed July 15, 2020). The ICAO Annex 16 Volume III is found on page 16 of English Edition 2020 catalog and is copyright protected; Order No. AN 16–3. Also see: ICAO, 2020, Supplement No. 6—July 2020, *Annex 16 Environmental Protection—Volume III—Aeroplane CO_2 Emissions, Amendment 1* (20/7/20) 22 pp. Available at *http://www.icao.int/publications/catalogue/cat_2020_sup06_en.pdf* (last accessed October 27, 2020). The ICAO Annex 16, Volume III, Amendment 1, is found on page 2 of Supplement No. 6—July 2020, English Edition, Order No. AN 16–3/E/01.

[106] Annex 16, Vol. III, Appendix 1. ICAO, 2017: *Annex 16 Volume III—Environmental Protection—Aeroplane CO_2 Emissions, First Edition,* 40 pp. Available at: *http://www.icao.int/publications/Pages/catalogue.aspx* (last accessed July 15, 2020). The ICAO Annex 16 Volume III is found on page 16 of English Edition 2020 catalog and is copyright protected; Order No. AN 16–3. Also see: ICAO, 2020, Supplement No. 6—July 2020, *Annex 16 Environmental Protection—Volume III—Aeroplane CO_2 Emissions, Amendment 1* (20/7/20) 22 pp. Available at *http://www.icao.int/publications/catalogue/cat_2020_sup06_en.pdf* (last accessed October 27, 2020). The ICAO Annex 16, Volume III, Amendment 1, is found on page 2 of Supplement No. 6—July 2020, English Edition, Order No. AN 16–3/E/01.

[107] ICAO's certification standards and procedures for airplane CO_2 emissions are based on the consumption of fuel (or fuel burn). ICAO uses the term CO_2 for its standards and procedures, but ICAO is actually regulating or measuring the rate of an airplane's fuel burn (or fuel efficiency). As described earlier, to convert an airplane's rate of fuel burn (for jet fuel) to a CO_2 emissions rate, a 3.16 kilograms of CO_2 per kilogram of fuel burn emission index needs to be applied.

[108] U.S. EPA, 2016: *Finding That Greenhouse Gas Emissions From Aircraft Cause or Contribute To Air Pollution That May Reasonably Be Anticipated To Endanger Public Health and Welfare; Final Rule,* 81 FR 54422 (August 15, 2016).

[109] For jet fuel, the emissions index or emissions factor for CO_2 is 3.16 kilograms of CO_2 per kilogram of fuel burn (or 3,160 grams of CO_2 per kilogram of fuel burn). For jet fuel, the emissions index for nitrous oxide is 0.1 grams of nitrous oxide per kilogram of fuel burn (which is significantly less than the emissions index for CO_2). Since CO_2 and nitrous oxide emissions are indexed to fuel burn, they are both directly tied to fuel burn. Controlling CO_2 emissions means controlling fuel burn, and in turn this leads to limiting nitrous oxide emissions. Thus, controlling CO_2 emissions scales with limiting nitrous oxide emissions.

SAE, 2009, *Procedure for the Calculation of Airplane Emissions,* Aerospace Information Report, AIR5715, 2009–07 (pages 45–46). The nitrous oxide emissions index is from this report.

ICAO, 2016: *ICAO Environmental Report 2016, Aviation and Climate Change,* 250 pp. The CO_2 emissions index is from this report. Available at *https://www.icao.int/environmental-protection/Documents/ICAO%20Environmental%20Report%202016.pdf* (last accessed March 16, 2020).

[110] See section II.E (*Consideration of Whole Airplane Characteristics*) of this rule for a discussion on regulating emissions from the whole airplane.

[111] Although compliance with the final GHG standard will be measured in terms of fuel efficiency, the EPA considers the six well-mixed GHGs to be the regulated pollutant for the purposes of the final standard.

standards that match ICAO standards is vital to competitiveness of the U.S. industry and certainty in the regulatory landscape. This approach provides international harmonization regulatory uniformity throughout the world. Adopting ICAO standards will protect U.S. jobs and strengthen the American aviation industry by ensuring the worldwide acceptance of U.S. manufactured airplanes. Adopting more stringent standards would place U.S. airplane manufacturers at a competitive disadvantage compared to their international competitors. Reciprocity and consistency are essential, specifically the worldwide mutual recognition of the sufficiency of ICAO's standards and the avoidance of any unnecessary difference from those standards in each Member State's law. Aviation is a global industry, and airplanes are assets that can fly anywhere in the world and cross international borders. Within this context, alignment of domestic and international standards levels the playing field for the aviation industry, and it makes sure that financial resources can be focused on improvement for the benefit of the environment (including investments creating CO_2 emissions reductions via carrying out the non-airplane-technology elements of ICAO's basket of measures). In addition, reciprocity and consistency of international standards decrease administrative complexity for airplane manufacturers and air carriers. Some commenters stated that aligning with ICAO standards ensures that U.S. manufacturers' airplanes are available to U.S. air carriers, while encouraging global competition and enabling U.S. air carriers to obtain airplanes and airplane engines at competitive prices.

In contrast, several commenters stated that the EPA's lack of consideration of feasible standards that result in GHG emission reductions is unlawful and arbitrary, and that the EPA should adopt more stringent standards. Under the authority that the EPA is provided in Clean Air Act section 231, the EPA is obligated to account for the danger to public health and welfare of the pollutant and the technological feasibility to control the pollutant. All in-production and new type design airplanes will meet the standards because existing non-compliant airplanes are anticipated to end production by 2028, the applicability date for in-production airplanes. More stringent standards are feasible for in-production and new type design airplanes, and the EPA should adopt technology-forcing instead of technology following standards to make sure the rulemaking will result in needed reductions in GHG emissions.

In response to these comments, we refer to Section II.B and the introductory paragraphs of Section IV which present our reasons for finalizing GHG standards that are aligned with the international CO_2 standards. Section 231(a)(2)(A) of the CAA directs the Administrator of the EPA to, from time to time, propose aircraft engine emission standards applicable to the emission of any air pollutant from classes of aircraft engines which in the Administrator's judgment causes or contributes to air pollution that may reasonably be anticipated to endanger public health or welfare. Section 231(a)(3) provides that after we propose standards, the Administrator shall issue such standards ''with such modifications as he deems appropriate.'' Section 231(b) requires that any emission standards ''take effect after such period as the Administrator finds necessary . . . to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance during such period.'' The U.S. Court of Appeals for the D.C. Circuit has held that these provisions confer an unusually broad degree of discretion on the EPA to adopt aircraft engine emission standards as the Agency determines are reasonable. *Nat'l Ass'n of Clean Air Agencies* v. *EPA,* 489 F.3d 1221, 1229–30 (D.C. Cir. 2007) (*NACAA*). As described in the 2005 EPA rule on aircraft engine NO_x standards,[112] while the statutory language of section 231 is not identical to other provisions in title II of the CAA that direct the EPA to establish technology-based standards for various types of engines, the EPA interprets its authority under section 231 to be somewhat similar to those provisions that require us to identify a reasonable balance of specified emissions reduction, cost, safety, noise, and other factors. *See, e.g., Husqvarna AB* v. *EPA,* 254 F.3d 195 (D.C. Cir. 2001) (upholding the EPA's promulgation of technology-based standards for small non-road engines under section 213(a)(3) of the CAA). However, we are not compelled under section 231 to obtain the ''greatest degree of emission reduction achievable'' as per sections 213 and 202(a)(3)(A) of the CAA, and so the EPA does not interpret the Act as requiring the agency to give subordinate status to factors such as cost, safety, and noise in determining what standards are reasonable for aircraft engines. Rather, the EPA has greater flexibility under section 231 in determining what standard is most reasonable for aircraft engines, and the EPA is not required to achieve a technology-forcing result. Moreover, in light of the United States' ratification of the Chicago Convention, EPA has historically given significant weight to uniformity with international requirements as a factor in setting aircraft engine standards. The fact that most airplanes already meet the standards does not in itself mean that the standards are inappropriate, provided the agency has a reasonable basis after considering all the relevant factors for setting the standards at a level that results in no actual emission reductions. By the same token, the EPA believes a technology-forcing standard would not be precluded by section 231, in light of section 231(b)'s forward-looking language. However, the EPA would, after consultation with the Secretary of Transportation, need to provide manufacturers sufficient lead time to develop and implement requisite technology. Also, there is an added emphasis on the consideration of safety in section 231 (*see, e.g.,* sections 231(a)(2)(B)(ii) (''The Administrator shall not change the aircraft engine emission standards if such change would [* * *] adversely affect safety''), 42 U.S.C. 7571(a)(2)(B)(ii), and 231(c) (''Any regulations in effect under this section [* * *] shall not apply if disapproved by the President, after notice and opportunity for public hearing, on the basis of a finding by the Secretary of Transportation that any such regulation would create a hazard to aircraft safety''), 42 U.S.C. 7571(c). Thus, it is reasonable for the EPA to give greater weight to considerations of safety in this context than it might in balancing emissions reduction, cost, and energy factors under other title II provisions.

In order to promote international cooperation on GHG emissions regulation and international harmonization of aviation standards and to avoid placing U.S. manufacturers at a competitive disadvantage that likely would result if the EPA were to adopt standards different from the standards adopted by ICAO, as discussed further above, the EPA is adopting standards for GHG emissions from certain classes of engines used on airplanes that match the stringency of the CO_2 standards adopted by ICAO. This rule will facilitate the acceptance of U.S. manufactured airplanes and airplane

[112] U.S. EPA, 2005: Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures; Final Rule, 70 FR 69664 (November 17, 2005). See page 69676 of this **Federal Register** notice.

engines by member States and airlines around the world. In addition, requiring U.S. manufacturers to certify to different or more stringent standards than have been adopted internationally could have disruptive effects on manufacturers' ability to market planes for international operation. Having invested significant effort and resources, working with the FAA and the Department of State, to gain international consensus within ICAO to adopt the first-ever international CO_2 standards for airplanes, the EPA believes that meeting the United States' obligations under the Chicago Convention by aligning domestic standards with the ICAO standards, rather than adopting more stringent standards, will have substantial benefits for future international cooperation on airplane emission standards, and such cooperation is the key for achieving worldwide emission reductions. This EPA rule to promulgate airplane GHG standards equivalent to international standards is consistent with U.S. obligations under ICAO. By issuing standards that meet or exceed the minimum stringency levels of ICAO standards, we satisfy these obligations.

Also, these final standards are the first-ever airplane GHG standards and test procedures for U.S. manufacturers, and international regulatory uniformity and certainty are key elements for these manufacturers as they become familiar with adhering to these standards and test procedures. Consistency with the international standards will prevent backsliding by ensuring that all new type design and in-production airplanes are at least as efficient as today's airplanes. CAEP meets triennially, and in the future, we anticipate ICAO/CAEP considering more stringent airplane CO_2 standards. The U.S. Interagency Group on International Aviation (IGIA) facilitates coordinated recommendations to the Secretary of State on issues pertaining to international aviation (and ICAO/CAEP), and the FAA is the chair of IGIA. Representatives of domestic states, NGOs, and industry can participate in IGIA to provide input into future standards for ICAO/CAEP. U.S. manufacturers will be prepared for any future standard change due to their experience with the first-ever standards. Moreover, the manufacturers anticipation of future ICAO standards will be another factor for them to consider in continually improving the fuel efficiency of their airplanes in addition to the business-as-usual market forces (*i.e.,* in addition to business-as-usual continually improving fuel efficiency for airplanes), as described later in section V.

2. Timing of the Standard—Extension of In Production Applicability Date for Some Freight Airplanes

Some commenters requested that the EPA deviate from the ICAO standards (and the EPA proposed implementation dates) and delay the 2028 in-production applicability date for a class of widebody purpose-built (or dedicated) freighters such as the Boeing 767F and Airbus A330–220F. These commenters requested that the in-production applicability date for purpose-built freight airplanes with MTOMs between 180,000 kg and 240,000 kg be extended by 10 years, from January 1, 2028 to January 1, 2038.

Boeing argued that significant unexpected economic factors arising after the ICAO CO_2 standard was established, including the COVID–19 pandemic, have affected and continue to severely affect Boeing, its supply chain, and its customers, and warrant additional time for Boeing to upgrade or replace the 767F in a practicable and economically feasible manner, consistent with the ICAO terms of reference and the mandatory factors in CAA section 231(b). Additional details on these comments can be found in the Response to Comments document under section 6.2.1.

The EPA recognizes the significant financial hardships the aviation industry is experiencing as a result of the COVID–19 pandemic. The challenges the industry now faces were not anticipated when the standards were agreed by ICAO in 2017. However, ICAO recognized that unexpected hardships may arise in the future and included language to allow certification authorities to grant exemptions when it may be appropriate to provide relief from the standards.

Consistent with ICAO, the EPA proposed to include exemption provisions (40 CFR 1030.10 of the regulations) by pointing to the FAA's existing exemption process to provide relief when unforeseen circumstances or hardships result in the need for additional time to comply with the GHG standards. These provisions are similar to those exemption provisions that have been in 40 CFR part 87 of the regulations for decades. Manufacturers will be able to apply to the FAA for exemptions in accordance with the regulations of 14 CFR part 11, and the FAA will consult with the EPA on each exemption application prior to granting relief from certification to the GHG standards.

Boeing provided a list of historical examples where they say the EPA delayed aircraft engine emission standards, adopted standards after ICAO implementation dates, or granted exemptions.[113] Boeing characterizes the examples of exemptions as the most relevant to their current situation with the 767F. However, neither Boeing nor other commenters provided any information or rationale to justify why the exemption provisions proposed in part 1030.10, which point to the FAA's existing exemption process, would be insufficient to resolve their concerns. Thus, there is not a sufficient basis for the EPA to conclude that the exemption provisions would not resolve this issue for the commenters.

As we noted at the beginning of Section IV and above in IV.J.1, there are significant benefits to industry and future international cooperation to adopting standards that to the highest practicable degree match ICAO standards, in terms of scope, timing, stringency, etc. If less stringent or delayed standards were adopted, it would have a disruptive impact on the manufacturers' ability to market their airplanes internationally. Boeing recognized this disruption in their proposed addition to the regulatory text, 1030.1(a)(8)(ii), where they stated the airworthiness certificate would be limited to U.S. domestic operation. Commenters did not provide any rationale, or make any statements, about this suggested revision to limit the operation of these freighters to the U.S., nor did they state why such an operational requirement would be in EPA's purview. To include limits as this on an airworthiness certificate would seem to impose operational restrictions on air carriers. Imposing a restriction such as that suggested by Boeing would be unprecedented for the EPA, and it is not clear how it could be accomplished. Further, such a significant change was not proposed for comment by interested parties. Operational restrictions would typically be the purview of the FAA under its enabling legislation.

Finally, although Boeing's request purported to also cover an Airbus airplane of the same weight class, the EPA received no comments from Airbus seconding the request, and therefore it does not appear that the problem identified by Boeing is universal to all airplanes of the same class that may be put into freighter service.

[113] Boeing stated that the EPA granted exemptions, but the FAA granted the exemptions after consultation with the EPA, as EPA is not authorized under the CAA to grant exemptions.

Given that no information was provided to show why the proposed exemptions would be insufficient, that the would-be affected airplane manufacturers do not seem to be universally in favor of or need a 10-year compliance extension, and that significant challenges and adverse impacts would arise if timely harmonization with international standards did not occur, the EPA is finalizing the standards and timing proposed in the NPRM. The EPA, in consultation with the FAA, believes that the exemption process should provide an appropriate avenue for manufacturers to seek relief.

V. Aggregate GHG and Fuel Burn Methods and Results

This section describes the EPA's emission impacts analysis for the final standards. This section also describes the assumptions and data sources used to develop the baseline GHG emissions inventories and the potential consequences of the final standards on aviation emissions. Consistent with Executive Order 12866, we analyzed the impacts of alternatives (using similar methodologies), and the results for these alternatives are described in chapters 4 and 5 of the Technical Support Document (TSD).

As described earlier in Section II, the manufacturers of affected airplanes and engines have already developed or are developing technologies that meet the 2017 ICAO Airplane CO_2 Emission Standards. The EPA expects that the manufacturers will comply with the ICAO Airplane CO_2 Emission Standards even in advance of member States' adoption into domestic regulations. Therefore, the EPA expects that the final GHG standards will not impose an additional burden on manufacturers. In keeping with the ICAO/CAEP need to consider technical feasibility in standard setting, the ICAO Airplane CO_2 Emission Standards reflect demonstrated technology that will be available in 2020.

As described below, the analysis for the final GHG standards considered individual airplane types and market forces. We have assessed GHG emission reductions needed for airplane types (or airplane models) to meet the final GHG standards compared to the improvements that are driven by market competition and are expected to occur in the absence of any standard (business as usual improvements). A summary of these results is described later in this section. Additional details can be found in chapter 5 of the accompanying TSD for the final standards.

A. What methodologies did the EPA use for the emissions inventory assessment?

The EPA participated in ICAO/CAEP's standard-setting process for the international Airplane CO_2 Emission Standards. CAEP provided a summary of the results from this analysis in the report of its tenth meeting,[114] which occurred in February 2016. However, due to the commercial sensitivity of the data used in the analysis, much of the underlying information is not available to the public. For the U.S. domestic GHG standards, however, we are making our analysis, data sources, and model assumptions transparent to the public so all stakeholders affected by the final standards can understand how the agency derives its decisions. Thus, the EPA has conducted an independent impact analysis based solely on publicly available information and data sources. An EPA report detailing the methodology and results of the emissions inventory analysis [115] was peer-reviewed by multiple independent subject matter experts, including experts from academia and other government agencies, as well as independent technical experts.[116]

The methodologies the EPA uses to assess the impacts of the final GHG standards are summarized in a flow chart shown in Figure V–1. This section describes the impacts of the final GHG standards. Essentially, the approach is to compare the GHG emissions of the business as usual baseline in the absence of standards with those emissions under the final GHG standards.

[114] ICAO, 2016: *Doc 10069—Report of the Tenth Meeting, Montreal,1–12 February 2016, Committee on Aviation Environmental Protection, CAEP 10,* 432 pp., pages 271 to 308, is found on page 27 of the ICAO Products & Services English Edition 2020 Catalog and is copyright protected. For purchase available at: *https://www.icao.int/publications/Pages/catalogue.aspx* (last accessed March 16, 2020). The summary of technological feasibility and cost information is located in Appendix C (starting on page 5C–1) of this report.

[115] U.S. EPA, 2020: Technical Report on Aircraft Emissions Inventory and Stringency Analysis, July 2020, 52 pp.

[116] RTI International and EnDyna, *EPA Technical Report on Aircraft Emissions Inventory and Stringency Analysis: Peer Review,* July 2019, 157 pp.

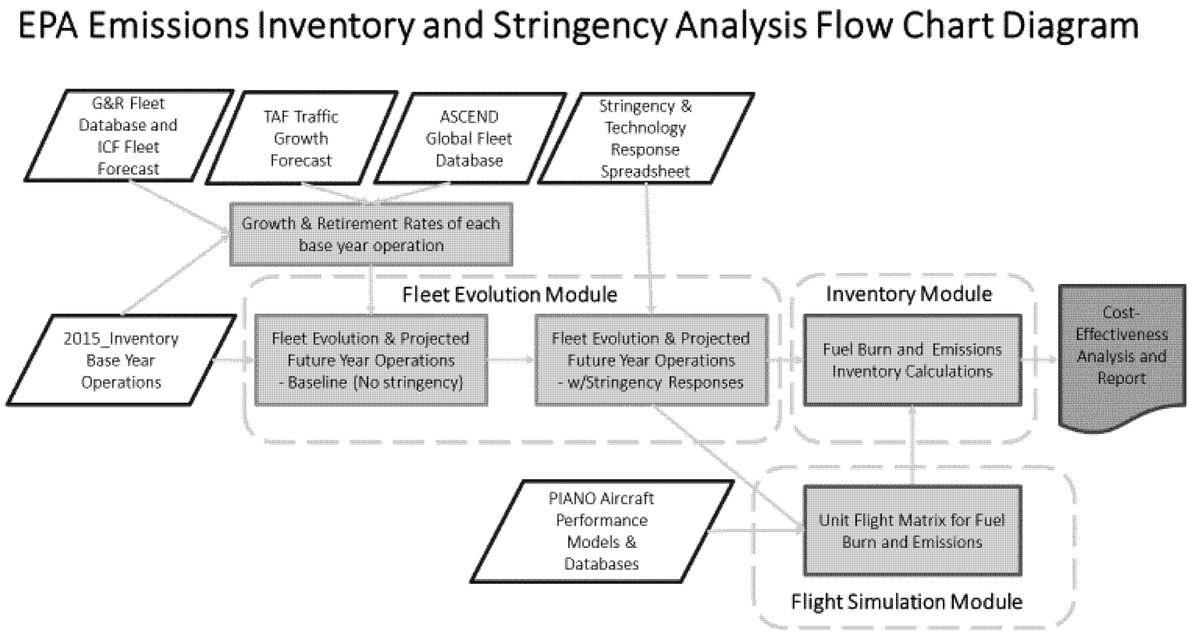

Figure V-1 EPA Regulatory Analysis Flow Chart

The first step of the EPA analysis is to create a baseline, which is constructed from the unique airport origin-destination (OD) pairs and airplane combinations in the 2015 base year. As described further in the next section, these base year operations are then evolved to future year operations, 2016–2040, by emulating the market driven fleet renewal process to define the baseline (without the final GHG regulatory requirements). The same method then is applied to define the fleet evolution under the final GHG standards, except that different potential technology responses are defined for the airplanes impacted by the final GHG standards. Specifically, they are either modified to meet the standards or removed from production. Once the flight activities for all analysis scenarios are defined by the fleet evolution module, then fuel burn and GHG [117] emissions are modelled for all the scenarios with a physics-based airplane performance model known as PIANO.[118] A brief account of the methods, assumptions, and data sources used is given below, and more details can be found in chapter 4 of the TSD.

1. Fleet Evolution Module

To develop the baseline, the EPA used FAA 2015 operations data as the basis from which to project future fleet operations out to 2040. The year-to-year activity growth rate was determined by the FAA 2015–2040 Terminal Area Forecast [119] (TAF) based on airport OD-pairs, route groups (domestic or international), and airplane types. The retirement rate of a specific airplane is determined by the age of the airplane and the retirement curve of its associated airplane type. Retirement curves of major airplane types are derived statistically based on data from the FlightGlobal Fleets Analyzer database [120] (also known as ASCEND Online Fleets Database—hereinafter ''ASCEND'').

The EPA then linked the 2015 FAA operations data to the TAF and ASCEND-based growth and retirement rates by matching the airport and airplane parameters. Where the OD-pair and airplane match between the operations data and the TAF, then the exact TAF year-on-year growth rates were applied to grow 2015 base year activities to future years. For cases without exact matches, growth rates from progressively more aggregated levels were used to grow the future year activities.[121]

The retirement rate was based on the exact age of the airplane from ASCEND for airplanes with a known tail number. When the airplane tail number was not known, the aggregated retirement rate of the next level matching fleet (*e.g.,* airplane type or category as defined by

[117] To convert fuel burn to CO_2 emissions, we used the conversion factor of 3.16 kg/kg fuel for CO_2 emissions, and to convert to the six well-mixed GHG emissions, we used 3.19 kg/kg fuel for CO_2 equivalent emissions. Our method for calculating CO_2 equivalent emissions is based on SAE AIR 5715, 2009: Procedures for the Calculation of Aircraft Emissions and the EPA publication: Emissions Factors for Greenhouse Gas Inventories, EPA, last modified 4, April 2014, *https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf* (last accessed March 16, 2020).

[118] PIANO is the Aircraft Design and Analysis Software by Dr. Dimitri Simos, Lissys Limited, UK, 1990–present; Available at *www.piano.aero* (last accessed March 16, 2020). PIANO is a commercially available airplane design and performance software suite used across the industry and academia.

[119] FAA 2015–2040 Terminal Area Forecast, the Terminal Area Forecast (TAF) is the official FAA forecast of aviation activity for U.S. airports. It contains active airports in the National Plan of Integrated Airport Systems (NPIAS) including FAA-towered airports, Federal contract-towered airports, non-Federal towered airports, and non-towered airports. Forecasts are prepared for major users of the National Airspace System including air carrier, air taxi/commuter, general aviation, and military. The forecasts are prepared to meet the budget and planning needs of the FAA and provide information for use by state and local authorities, the aviation industry, and the public.

[120] FlightGlobal Fleets Analyzer is a subscription based online data platform providing comprehensive and authoritative source of global airplane fleet data (also known as ASCEND database) for manufacturers, suppliers and Maintenance, Repair, Overhaul (MRO) providers. *https://signin.cirium.com* (last accessed December 16, 2019).

[121] For example, in the absence of exact airplane match, the aggregated growth rate of airplane category is used; in case of no exact OD-pair match, the growth rate of route group is used. Outside the U.S. the non-US flights were modelled with global average growth rates from ICAO for passenger and freighter operations and from the Bombardier forecast for business jets. See chapter 5 of the TSD for details.

ASCEND) was used to calculate the retirement rates for future years.

Combining the growth and retirement rates together, we calculate the future year growth and replacement (G&R) market demands. These future year G&R market demands are aligned to each base year flight, and the future year flights are allocated with available G&R airplanes [122] using an equal-product market-share selection process.[123] The market demand allocation is made based on ASK (Available Seat Kilometer) for passenger operations, ATK (Available Tonne Kilometer) for freighter operations, and number of operations for business jets.

For the 2015 base-year analysis, the baseline (no regulation) modelling includes continuous (2016–2040) annual fuel efficiency improvements. The modelling tracks the year airplanes enter the fleet and applies the type-specific fuel efficiency improvement [124] via an annual adjustment factor based on the makeup of the fleet in a particular year. Since there is uncertainty associated with the fuel-efficiency improvement assumption, the analysis also includes a sensitivity scenario without this assumption in the baseline. This sensitivity scenario applied the ICAO Constant Technology Assumption to the baseline, which meant that no technology improvements were projected beyond what was known in 2016. Specifically, current airplane types were assumed to have the same metric value in 2040 as they did in 2016. ICAO used this simplifying assumption because they conducted their stringency analysis on comparative basis and did not attempt to include future emission trends in their stringency analysis. ICAO stated that its analysis was ''. . .not suitable for application to any other purpose of any kind, and any attempt at such application would be in error.'' [125] In contrast to how ICAO used the Constant Technology Assumption, as a simplification, the EPA is using this as a worst case scenario in our sensitivity studies to provide an estimate of the range of uncertainty to our main analysis in extreme cases.

The EPA fleet evolution model focuses on U.S. aviation, including both domestic and international flights (with U.S. international flights defined as flights departing from the U.S. but landing outside the U.S.). This is the same scope of operations used for the EPA *Inventory of U.S. Greenhouse Gas Emissions and Sinks.*[126] However, because aviation is an international industry and manufacturers of covered airplanes sell their products globally, the analysis also covers the global fleet evolution and emissions inventories for reference (but at a much less detailed level for traffic growth and fleet evolution outside of the U.S.).

The fleet evolution modelling for the final regulatory scenarios defines available G&R airplanes for various market segments based on the technology responses identified by ICF, a contractor for the EPA, as described later in Section VI.[127]

2. Full Flight Simulation Module

PIANO version 5.4 was used for all the emissions modelling. PIANO v5.4 (2017 build) has 591 airplane models (including many project airplanes still under development, *e.g.,* the B777–9X) and 56 engine types in its airplane and engine databases. PIANO is a physics-based airplane performance model used widely by industry, research institutes, non-governmental organizations and government agencies to model airplane performance metrics such as fuel consumption and emissions characteristics based on specific airplane and engine types. We use it to model airplane performance for all phases of flight from gate to gate including taxi-out, takeoff, climb, cruise, descent, approach, landing, and taxi-in in this analysis.

To simplify the computation, we made the following modeling assumptions: (1) Assume airplanes fly great circle distance (which is the shortest distance along the surface of the earth between two airports) for each origin-destination (OD) pair. (2) Assume still air flights and ignore weather or jet stream effects. (3) Assume no delays in takeoff, landing, en route, and other flight-related operations. (4) Assume a load factor of 75 percent maximum payload capacity for all flights except for business jet where 50 percent is assumed. (5) Use the PIANO default reserve fuel rule [128] for a given airplane type. (6) Assume a one-to-one relationship between metric value improvement and fuel burn improvement for airplanes with better fuel-efficiency technology insertions (or technology responses).

Given the flight activities defined by the fleet evolution module in the previous section, we generated a unit flight matrix to summarize all the PIANO outputs of fuel burn, flight distance, flight time, emissions, etc. for all flights uniquely defined by a combination of departure and arrival airports (OD-pairs), airplane types, and engine types. This matrix includes millions of flights and forms the basis for our analysis (including the sensitivity studies).

3. Emissions Module

The GHG emissions calculation involves summing the outputs from the first two modules for every flight in the database. This is done globally, and then the U.S. portion is segregated from the global dataset. The same calculation is done for the baseline and the final GHG standard. When a surrogate airplane is used to model an airplane that is not in the PIANO database, or when a technology response is required for an airplane to pass a standard level, an adjustment factor is also applied to model the expected performance of the intended airplane and technology responses.

The differences between the final GHG standards and the baseline provide quantitative measures to assess the emissions impacts of the final GHG standards. A brief summary of these results is described in the next two sections. More details can be found in chapter 5 of the TSD.

[122] The airplane G&R database contains all the EPA-known in-production and in-development airplanes that are projected to grow and replace the global base-year fleet over the 2015–2040 analysis period. This airplane G&R database, the annual continuous improvements, and the technology responses are available in the 2018 ICF Report.

[123] The EPA uses equal product market share (for all airplane present in the G&R database), but attention has been paid to make sure that competing manufacturers have reasonable representative products in the G&R database.

[124] ICF, 2018: *Aircraft CO_2 Cost and Technology Refresh and Industry Characterization,* Final Report, EPA Contract Number EP–C–16–020, September 30, 2018.

[125] ICAO, 2016: *Doc 10069—Report of the Tenth Meeting, Montreal,1–12 February 2016, Committee on Aviation Environmental Protection, CAEP 10,* 432 pp., pages 271 to 308, is found on page 27 of the ICAO Products & Services English Edition 2020 Catalog and is copyright protected. For purchase available at: *https://www.icao.int/publications/Pages/catalogue.aspx* (last accessed March 16, 2020). The summary of technological feasibility and cost information is located in Appendix C (starting on page 5C–1) of this report. In particular, see paragraph 2.3 for the caveats, limitations and context of the ICAO analysis.

[126] U.S. EPA, 2018: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2016, 1,184 pp., U.S. EPA Office of Air and Radiation, EPA 430–R–18–003, April 2018. Available at: *https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2016* (last accessed March 16, 2020).

[127] ICF, 2018: *Aircraft CO_2 Cost and Technology Refresh and Industry Characterization,* Final Report, EPA Contract Number EP–C–16–020, September 30, 2018.

[128] For typical medium/long-haul airplanes, the default reserve settings are 200 NM diversion, 30 minutes hold, plus 5% contingency on mission fuel. Depending on airplane types, other reserve rules such as U.S. short-haul, European short-haul, National Business Aviation Association—Instrument Flight Rules (NBAA–IFR) or Douglas rules are used as well.

B. What are the baseline GHG emissions?

The commercial aviation marketplace is continually changing, with new origin-destination markets and new, more fuel-efficient airplanes growing in number and replacing existing airplanes in air carrier (or airline) fleets. This behavior introduces uncertainty to the future implications of this rulemaking. Since there is uncertainty, multiple baseline/scenarios may be analyzed to explore a possible range of implications of the rule.

For the analysis in this rulemaking and consistent with our regulatory impact analyses for many other mobile source sectors,[129,130] the EPA is analyzing additional baseline/scenarios that reflect a business-as-usual continually improving baseline with respect to fleet fuel efficiency. We also evaluated a baseline scenario that is fixed to reflect 2016 technology levels (*i.e.,* no continual improvement in fuel-efficient technology), and this baseline scenario is consistent with the approach used by ICAO.[131]

For the EPA analysis, the baseline GHG emissions are assessed for 2015, 2020, 2023, 2025, 2028, 2030, 2035, and 2040. The projected baseline GHG emissions for all U.S. flights (domestic and international) are shown in Figure V–2 and Figure V–3, both with and without the continuous (2016–2040) fuel-efficiency improvement assumption. More detailed breakdowns for the passenger, freighter, and business market segments can be found in chapter 5 of the TSD. It is worth noting that the U.S. domestic market is relatively mature, with a lower growth rate than those for most international markets. The forecasted growth rate for the U.S. domestic market combined with the Continuous Improvement Assumption results in a low GHG emissions growth rate in 2040 for the U.S. domestic market. However, it should be noted that this is one set of assumptions combined with a market forecast. Actual air traffic and emissions growth may vary as a result of a variety of factors.

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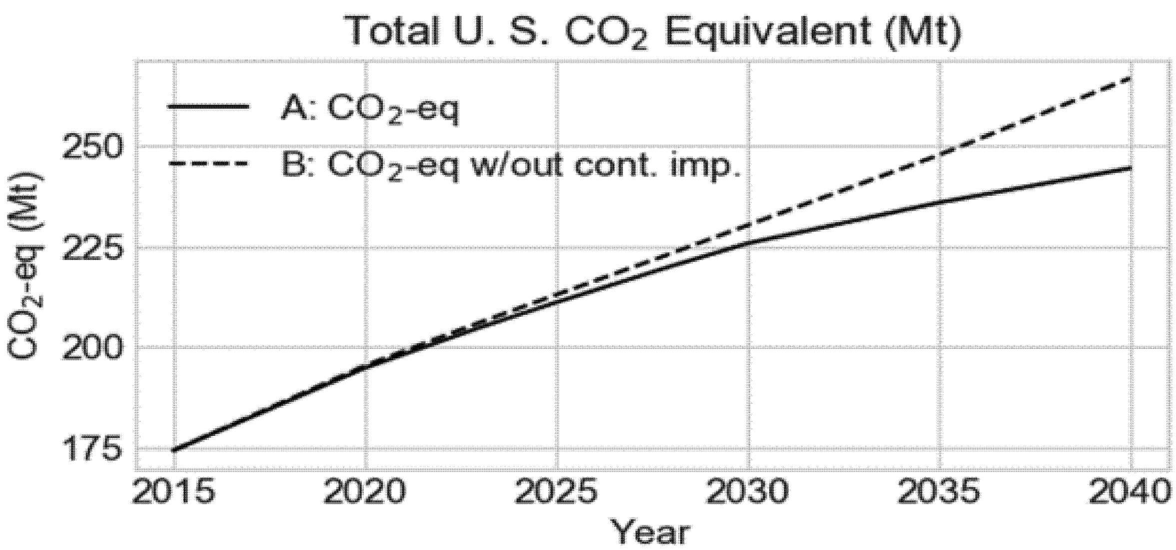


	2015	2020	2023	2025	2028	2030	2035	2040
A	174.16	194.74	204.83	211.1	220.13	225.83	236.0	244.6
B	174.16	195.3	206.08	213.0	223.31	230.33	247.86	267.02

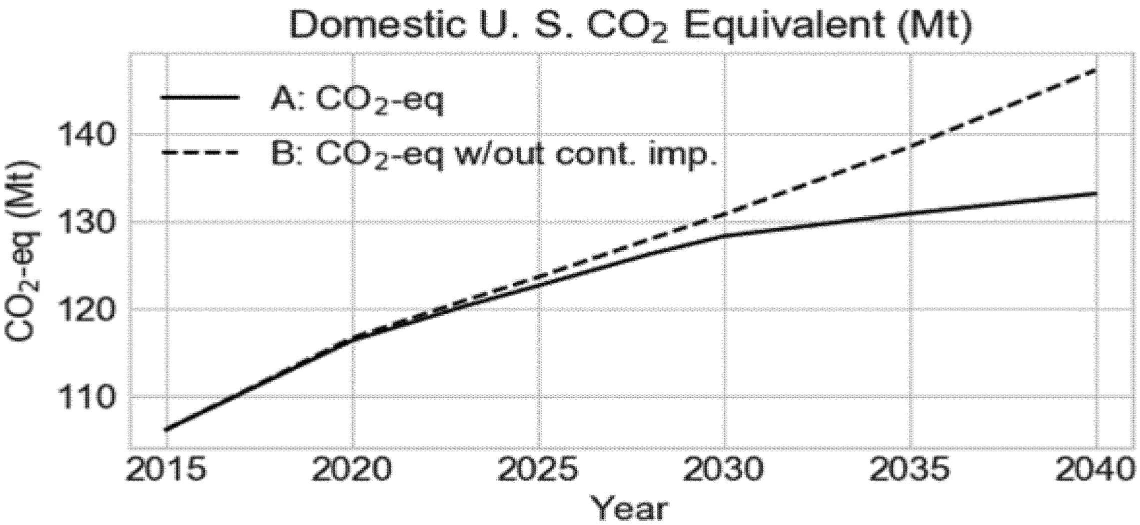
Figure V-2 - Main Analysis Baselines With and Without an Adjustment for Projected Continuous Improvement for the U.S. Total Aviation CO_2-eq Emissions in Megatonne (Mt)[132]

[129] U.S. EPA, 2016: *Regulatory Impact Analysis: Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles—Phase 2,* EPA–420–R–16–900, August 2016.

[130] U.S. EPA, 2009: *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Category 3 Marine Diesel Engines,* EPA–420–R–09–019, December 2009.

[131] A comparison of the EPA and ICAO modeling approaches and results is available in chapter 5 and 6 of the TSD.

[132] To convert fuel burn to CO_2 emissions, we used the conversion factor of 3.16 kg/kg fuel for CO_2 emissions, and to convert to the six well-mixed GHG emissions, we used 3.19 kg/kg fuel for CO_2 equivalent emissions. Our method for calculating CO_2 equivalent emissions is based on SAE AIR 5715, 2009: Procedures for the Calculation of Aircraft Emissions and the EPA publication: Emissions Factors for Greenhouse Gas Inventories, EPA, last modified 4, April 2014. *https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf* (last accessed March 16, 2020).



	2015	2020	2023	2025	2028	2030	2035	2040
A	106.15	116.35	120.25	122.62	126.24	128.31	130.9	133.17
B	106.15	116.64	120.88	123.6	127.94	130.79	138.52	147.31

Figure V-3 Main Analysis Baselines With and Without an Adjustment for Projected Continuous Improvement for the U.S. Domestic Aviation CO_2-eq Emissions in Megatonne (Mt)

Conceptually, the difference between the EPA and ICAO analysis baselines is illustrated in Figure V–4. The solid line represents the historical growth of emissions from the dawn of the jet age in 1960s to the present (2016). In this time, air traffic and operations have increased and offset the technology improvements. The long-dashed line (__ __) and dot-dash-dot (__ . __) lines represent different assumptions used by the EPA and ICAO to create baseline future inventories to compare the benefits of potential standards. The two baselines start in 2016, but their different assumptions lead to very different long-term forecasts. The EPA method (long dash) uses the input from an independent analysis conducted by ICF [133] to develop a Projected Continuous Improvement baseline to model future improvements similar to historical trends. The ICAO method creates a baseline using a Constant Technology Assumption that freezes the airplane technology going forward. This means that the in-production airplanes after that date will be built with no changes indefinitely into the future, *i.e.* the baseline assumes airplanes will have the same metric value in 2040 as they did in 2016. The dot-dot-dash (__ . __) line compares this Constant Technology Assumption to the solid historical emissions growth. ICAO used this simplifying assumption because they conducted their stringency analysis on comparative basis and did not attempt to include future emission trends in their stringency analysis. Comparative basis means ICAO looked at the difference in emission reductions between stringency options in isolation and did not attempt to factor in future business as usual improvements or fleet changes. The projected benefits of any standards will be different depending upon the baseline that is assumed. Note that ICAO stated that its analysis was ''. . . not suitable for application to any other purpose of any kind, and any attempt at such application would be in error.'' [134] To understand the true meaning of the analysis and make well-informed policy decisions, one must consider the underlying assumptions carefully. For example, if the EPA were to use the ICAO Constant Technology Assumption in our main analysis, the impact of the rulemaking would be overestimated, *i.e.,* these results would not be able to differentiate the effect of the standards from the expected business as usual improvements.

[133] ICF, 2018: *Aircraft CO_2 Cost and Technology Refresh and Industry Characterization,* Final Report, EPA Contract Number EP–C–16–020, September 30, 2018.

[134] ICAO, 2016: *Doc 10069—Report of the Tenth Meeting, Montreal,1–12 February 2016, Committee on Aviation Environmental Protection, CAEP 10,* 432pp., pages 271 to 308, is found on page 27 of the ICAO Products & Services English Edition 2020 Catalog and is copyright protected. For purchase available at: *https://www.icao.int/publications/Pages/catalogue.aspx* (last accessed March 16, 2020). The summary of technological feasibility and cost information is located in Appendix C (starting on page 5C–1) of this report. In particular, see paragraph 2.3 for the caveats, limitations and context of the ICAO analysis.

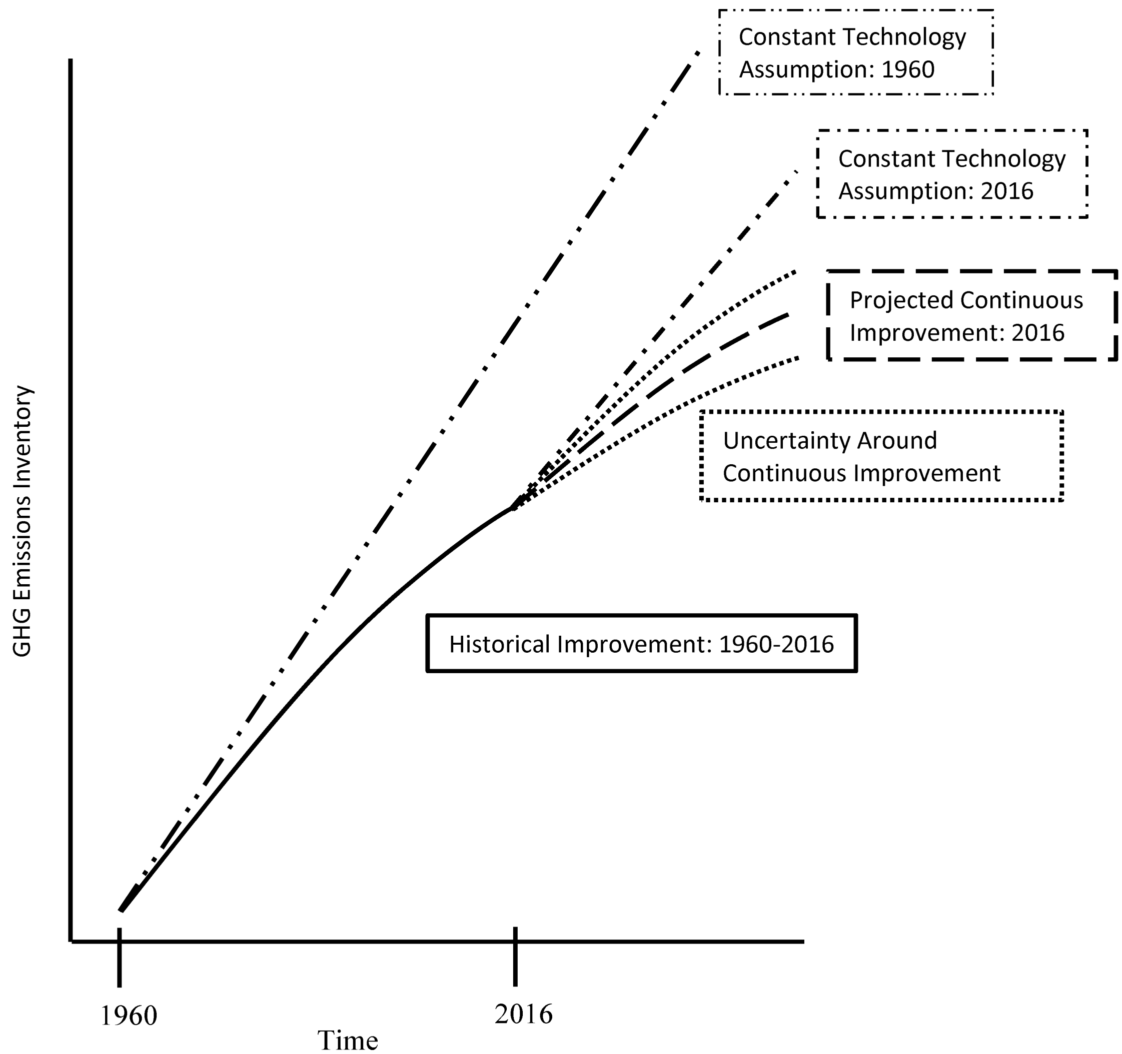


Figure V-4 Illustration of different baselines relative to historical GHG emissions inventory

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C. What are the projected effects in fuel burn and GHG emissions?

EPA's analysis projects that the final GHG standards will not result in reductions in fuel burn and GHG emissions beyond the baseline. This result makes sense because all of the airplanes in the G&R fleet either will meet the standard level associated with the final GHG standards or are expected to be out of production by the time the standards take effect, according to our technology responses.[135] In other words, the existing or expected fuel efficiency technologies from airplane and engine manufacturers that were the basis of the ICAO standards, which match the final standards, demonstrate technological feasibility. Thus, we do not project a cost or benefit for the final GHG standards (further discussion on the rationale for no expected reductions and no costs is provided later in this section and Section VI).

The EPA projected reduction in GHG emissions is different from the results of the ICAO analysis mentioned in V.A, which bounds the range of analysis exploration given the uncertainties involved with predicting the implications of this rule. The agency has conducted sensitivity studies around our main analysis to understand the differences[136] between our analysis and ICAO's (further detail on the differences in the analyses and the sensitivity studies is provided in the TSD). These sensitivity studies show that the no cost-no benefit conclusion is quite robust. For example, even if we assume no continuous improvement, the projected GHG emissions reductions for the final standards will still be zero since all the non-compliant airplanes (A380[137] and 767 freighters) are

[135] ICF, 2018: *Aircraft CO_2 Cost and Technology Refresh and Industry Characterization,* Final Report, EPA Contract Number EP–C–16–020, September 30, 2018.

[136] The differences in the analyses include different assumptions. Our analysis assumes continuous improvement and ICAO's analysis does not. Also, we make different projections about the end of production of the A380 and 767 compared to ICAO.

[137] On February 14, 2019, Airbus made an announcement to end A380 production by 2021 after Emirates airlines reduced its A380 order by 39 and replaced them with A330 and A350. (The Airbus press release is available at: *https://www.airbus.com/newsroom/press-releases/en/2019/02/airbus-and-emirates-reach-agreement-on-a380-fleet-sign-new-widebody-orders.html,* last accessed on February 10, 2020). EPA's analysis was conducted prior to Airbus's announcement, so the analysis does not consider the impact of the A380

projected to be out of production by 2028 (according to ICF analysis), the final standard effective year. We note that in their public comments on the proposal Boeing, along with Fedex, GE, and the Cargo Airline Association, expressed that there would continue to be a low volume demand for the B767 freighter beyond January 1, 2028. These commenters did not indicate the number of 767F's that would be produced after 2028. The EPA did not change the analysis to adjust the baseline to include continued production of the 767F beyond 2028 because insufficient information to characterize this scenario was provided.

Furthermore, we analyzed a sensitivity case where A380 and 767 freighters comply with the standards in 2028 and continue production until 2030 and not make any improvement between 2015 and 2027, the GHG emissions reductions will still be an order of magnitude lower than the ICAO results since all emissions reductions will come from just 3 years' worth of production (2028 to 2030) of A380 and 767 freighters. Considering that both airplanes are close to the end of their production life cycle by 2028 and low market demands for them, these limited emissions reductions may not be realized if the manufacturers are granted exemptions. Thus, the agency analysis results in a no cost-no benefit conclusion that is reasonable for the final GHG standards.

In summary, the ICAO Airplane CO_2 Emission Standards, which match the final EPA GHG standards, were predicated on technologies that manufacturers of affected airplanes and engines had already demonstrated to be safe and airworthy to the advanced technology readiness level 8 [138] when they were adopted in 2017. The EPA expects that the manufacturers will comply with the ICAO Airplane CO_2 Emission Standards even before member States' adoption into domestic regulations. Therefore, the EPA expects that the final airplane GHG standards will not impose an additional burden on manufacturers.

ending production in 2021. The early exit of A380, compared to the modeled scenarios, fits the general trend of reduced demands for large quad engine airplanes projected by the ICF technology responses and is consistent with our conclusion of no cost and no benefit for this rule.

[138] As described later in section VI.B for Technology Readiness Level 8 (TRL8), this refers to having been proven to be ''actual system completed and 'flight qualified' through test and demonstration.''

VI. Technological Feasibility and Economic Impacts

This section describes the technological feasibility and costs of the airplane GHG rule. This section describes the agency's methodologies for assessing technological feasibility and estimated costs of the final standards. Consistent with Executive Order 12866, we analyzed the technological feasibility and costs of alternatives (using similar methodologies), and the results for these alternatives are described in chapter 6 of the TSD.

The EPA and the FAA participated in the ICAO analysis that informed the adoption of the international Airplane CO_2 Emission Standards. A summary of that analysis was published in the report of ICAO/CAEP's tenth meeting,[139] which occurred in February 2016. However, due to the commercial sensitivity of much of the underlying data used in the ICAO analysis, the ICAO-published report (which is publicly available) provides only limited supporting data for the ICAO analysis. The EPA TSD for this rulemaking compares the ICAO analysis to the EPA analysis.

For the purposes of evaluating the final GHG regulations based on publicly available and independent data, the EPA had an analysis conducted of the technological feasibility and costs of the international Airplane CO_2 Emission Standards through a contractor (ICF) study.[140 141] The results, developed by the contractor, include estimates of technology responses and non-recurring costs for the domestic GHG standards, which are equivalent to the international Airplane CO_2 Emission Standards. Technologies and costs needed for airplane types to meet the final GHG regulations were analyzed and compared to the improvements that are anticipated to occur in the absence of regulation. The methods used in and the results from the analysis are described in the following paragraphs—and in further detail in chapter 2 of the TSD for this rulemaking.

[139] ICAO, 2016: *Report of Tenth Meeting, Montreal, 1–12 February 2016, Committee on Aviation Environmental Protection,* Document 10069, CAEP/10, 432pp, is found on page 27 of the English Edition of the ICAO Products & Services 2020 Catalog and is copyright protected; Order No. 10069. For purchase available at: *https://www.icao.int/publications/Pages/catalogue.aspx* (last accessed March 16, 2020). The summary of technological feasibility and cost information is located in Appendix C (starting on page 5C–1) of this report.

[140] ICF, 2018: *Aircraft CO_2 Cost and Technology Refresh and Industry Characterization,* Final Report, EPA Contract Number EP–C–16–020, September 30, 2018.

[141] ICF International, 2015: *CO_2 Analysis of CO_2-Reducing Technologies for Aircraft,* Final Report, EPA Contract Number EP–C–12–011, March 17, 2015.

A. Market Considerations

Prior to describing our technological feasibility and cost analysis, potential market impacts of the final GHG regulations are discussed in this section. As described earlier, airplanes and airplane engines are sold around the world, and international airplane emission standards help ensure the worldwide acceptability of these products. Airplane and airplane engine manufacturers make business decisions and respond to the international market by designing and building products that conform to ICAO's international standards. However, ICAO's standards need to be implemented domestically for products to prove such conformity. Domestic action through EPA rulemaking and subsequent FAA rulemaking enables U.S. manufacturers to obtain internationally recognized FAA certification, which for the adopted GHG standards will ensure type certification consistent with the requirements of the international Airplane CO_2 Emission Standards. This is important, as compliance with the international standards (via FAA type certification) is a critical consideration in airlines' purchasing decisions. By implementing the requirements that conform to ICAO requirements in the United States, we will remove any question regarding the compliance of airplanes certificated in the United States. The rule will facilitate the acceptance of U.S. airplanes and airplane engines by member States and airlines around the world. Conversely, U.S. manufacturers will be at a competitive disadvantage compared with their international competitors without this domestic action.

In considering the aviation market, it is important to understand that the international Airplane CO_2 Emission Standards were predicated on demonstrating technological feasibility; *i.e.,* that manufacturers have already developed or are developing improved technology that meets the 2017 ICAO CO_2 standards, and that the new technology will be integrated in airplanes throughout the fleet in the time frame provided before the implementation of the standards' effective date. Therefore, as described in Section V.C, the EPA projects that these final standards will impose no additional burden on manufacturers.

While recognizing that the international agreement was predicated on demonstrated technological feasibility, without access to the underlying ICAO/CAEP data it is informative to evaluate individual airplane models relative to the equivalent U.S. regulations. Therefore, the technologies and costs needed for airplane types to meet the rule were compared to the improvements that are expected to occur in the absence of standards (business as usual improvements). A summary of these results is described later in this section.

B. Conceptual Framework for Technology

As described in the 2015 ANPR, the EPA contracted with ICF to develop estimates of technology improvements and responses needed to modify in-production airplanes to comply with the international Airplane CO_2 Emission Standards. ICF conducted a detailed literature search, performed a number of interviews with industry leaders, and did its own modeling to estimate the cost of making modifications to in-production airplanes.[142] Subsequently, for this rulemaking, the EPA contracted with ICF to update its analysis (herein referred to as the ''2018 ICF updated analysis'').[143] It had been three years since the initial 2015 ICF analysis was completed, and the EPA had ICF update the assessment to ensure that the analysis included in this rulemaking reflects the current status of airplane GHG technology improvements. Therefore, ICF's assessment of technology improvements was updated since the 2015 ANPR was issued.[144]

The long-established ICAO/CAEP terms of reference were taken into account when deciding the international Airplane CO_2 Emission Standards, principal among these being technical feasibility. For the ICAO CO_2 certification standard setting, technical feasibility refers to any technology expected to be demonstrated to be safe and airworthy proven to Technology Readiness Level[145] (TRL) 8 by 2016 or shortly thereafter (per CAEP member guidance; approximately 2017), and expected to be available for application in the short term (approximately 2020) over a sufficient range of newly certificated airplanes.[146] This means that the analysis that informed the international standard considered the emissions performance of in-production and on-order or in-development[147] airplanes, including types that first enter into service by about 2020. (ICAO/CAEP's analysis was completed in 2015 for the February 2016 ICAO/CAEP meeting.)

In assessing the airplane GHG rule, the 2018 ICF updated analysis, which was completed a few years after the ICAO analysis, was able to use a different approach for technology responses. ICF based these responses on technology available at TRL8 by 2017 and projected continuous improvement of CO_2 metric values for in-production and in-development (or on-order) airplanes from 2010 to 2040 based on the incorporation of these technologies onto these airplanes over this same timeframe. Also, ICF considered the end of production of airplanes based on the expected business-as-usual status of airplanes (with the continuous improvement assumptions). This approach is described in further detail later in Section VI.C. The ICF approach differed from ICAO's analysis for years 2016 to 2020 and diverged even more for years 2021 and after. Since ICF was able to use the final effective dates in their analysis of the final airplane GHG standard (for new type design airplanes 2020, or 2023 for airplanes with less than 19 seats, and for in-production airplanes 2028), ICF was able to differentiate between airplane GHG technology improvements that would occur in the absence of the final standard (business as usual improvements) compared against technology improvements/responses needed to comply with the final standard. ICF's approach is appropriate for the EPA-final GHG standard because it is based on more up-to-date inputs and assumptions.

C. Technological Feasibility

1. Technology Principles and Application

i. Short- and Mid-Term Methodology

ICF analyzed the feasible technological improvements to new in-production airplanes and the potential GHG emission reductions they could generate. For this analysis, ICF created a methodological framework to assess the potential impact of technology introduction on airplane GHG emissions for the years 2015–2029 (upcoming short and mid-term). This framework included five steps to estimate annual metric value (baseline metric values were generated using PIANO data[148]) improvements for technologies that are being or will be applied to in-production airplanes. First, ICF identified the technologies that could reduce GHG emissions of new in-production airplanes. Second, ICF evaluated each technology for the amount of potential GHG reduction and the mechanisms by which this reduction could be achieved. These first two steps were analyzed by airplane category. Third and fourth, the technologies were passed through technical success probability and commercial success probability screenings, respectively. Finally, individual airplane differences were assessed within each airplane category to generate GHG emission reduction projections by technology by airplane model—at the airplane family level (*e.g.,* 737 family). ICF refers to their methodological framework for projection of the metric value improvement or reduction as the expected value methodology. The expected value methodology is a projection of the annual fuel efficiency metric value improvement[149] from

[142] ICF International, 2015: *CO_2 Analysis of CO_2-Reducing Technologies for Aircraft,* Final Report, EPA Contract Number EP–C–12–011, March 17, 2015.

[143] ICF, 2018: *Aircraft CO_2 Cost and Technology Refresh and Industry Characterization,* Final Report, EPA Contract Number EP–C–16–020, September 30, 2018.

[144] As described earlier in section IV, the ICAO test procedures for the international airplane CO_2 standards measure fuel efficiency (or fuel burn). Only two of the six well-mixed GHGs—CO_2 and N_2O are emitted from airplanes. The test procedures for fuel efficiency scale with the limiting of both CO_2 and N_2O emissions, as they both can be indexed on a per-unit-of-fuel-burn basis. Therefore, both CO_2 and N_2O emissions can be controlled as airplane fuel burn is limited. Since limiting fuel burn is the only means by which airplanes control their GHG emissions, the fuel burn (or fuel efficiency) reasonably serves as a surrogate for controlling both CO_2 and N_2O.

[145] TRL is a measure of Technology Readiness Level. CAEP has defined TRL8 as the ''actual system completed and 'flight qualified' through test and demonstration.'' TRL is a scale from 1 to 9, TRL1 is the conceptual principle, and TRL9 is the ''actual system 'flight proven' on operational flight.'' The TRL scale was originally developed by NASA. ICF International, *CO_2 Analysis of CO_2-Reducing Technologies for Aircraft,* Final Report, EPA Contract Number EP–C–12–011, see page 40, March 17, 2015.

[146] ICAO, 2016: *Report of the Tenth Meeting, Montreal, 1–12 February 2016, Committee on Aviation Environmental Protection,* Document 10069, CAEP10, 432pp, is found on page 27 of the English Edition of the ICAO Products & Services 2020 Catalog and is copyright protected: Order No. 10069. For purchase available at: *https://www.icao.int/publications/Pages/catalogue.aspx* (last accessed March 16, 2020). The statement on technological feasibility is located in Appendix C (page 5C–15, paragraph 6.2.1) of this report.

[147] Aircraft that are currently in-development but were anticipated to be in production by about 2020.

[148] To generate metric values, the 2015 ICF analysis and 2018 ICF updated analysis used PIANO (Project Interactive Analysis and Optimization) data so that their analyses results can be shared publicly. Metric values developed utilizing PIANO data are similar to ICAO metric values. PIANO is the Aircraft Design and Analysis Software by Dr. Dimitri Simos, Lissys Limited, UK, 1990-present; Available at *www.piano.aero* (last accessed March 16, 2020). PIANO is a commercially available aircraft design and performance software suite used across the industry and academia.

[149] Also referred to as the constant annual improvement in CO_2 metric value.

2015–2029 for all the technologies that would be applied to each airplane (or business as usual improvement in the absence of a standard).

As a modification to the 2015 ICF analysis, the 2018 ICF updated analysis extended the metric value improvements at the airplane family level (*e.g.,* 737 family) to the more specific airplane variant level (*e.g.,* 737–700, 737–800, etc.). Thus, to estimate whether each airplane variant complied with the final GHG standard, ICF projected airplane family metric value reductions to a baseline (or base year) metric value of each airplane variant. ICF used this approach to estimate metric values for 125 airplane models allowing for a comparison of the estimated metric value for each airplane model to the level of the final GHG standard at the time the standard goes into effect.

In addition, ICF projected which airplane models will end their production runs (or production cycle) prior to the effective date of the final GHG standard. These estimates of production status, at the time the standard will go into effect, further informed the projected response of airplane models to the final standard. Further details of the short- and mid-term methodology are provided in chapter 2 of the TSD.

ii. Long-Term Methodology

To project metric value improvements for the long-term, years 2030–2040, ICF generated a different methodology compared with the short- and mid-term methodology. The short- and mid-term methodology is based on forecasting metric value improvements contributed by specific existing technologies that are implemented, and ICF projects that about the 2030 timeframe a new round of technology implementation will begin that leads to developing a different method for predicting metric value improvements for the long term. For 2030 or later, ICF used a parametric approach to project annual metric value improvements. This approach included three steps. First, for each airplane type, technical factors were identified that drive fuel burn and metric value improvements in the long-term (*i.e.,* propulsive efficiency, friction drag reduction), and the fuel burn reduction prospect index [150] was estimated on a scale of 1 to 5 for each technical factor (chapter 2 of the TSD describes these technical factors in detail). Second, a long-term market prospect index was generated on a scale of 1 to 5 based on estimates of the amount of potential research and development (R&D) put into various technologies for each airplane type. Third, the long-term market prospect index for each airplane type was combined with its respective fuel burn reduction prospect index to generate an overall index score for its metric value improvements. A low overall index score indicates that the airplane type will have a reduced annual metric value reduction (the metric value decreases yearly at a slower rate relative to an extrapolated short- and mid-term annual metric value improvement), and a high overall index score indicates an accelerated annual metric value improvement (the metric value decreases yearly at a quicker rate relative to an extrapolated short- and mid-term annual metric value improvement). Further details of the long-term methodology are provided in chapter 2 of the TSD.

2. What technologies did the EPA consider to reduce GHG emissions?

ICF identified and analyzed seventy different aerodynamic, weight, and engine (or propulsion) technologies for fuel burn reductions. Although weight-reducing technologies affect fuel burn, they do not affect the metric value for the GHG rule.[151] Thus, ICF's assessment of weight-reducing technologies was not included in this rule, which excluded about one-third of the technologies evaluated by ICF for fuel burn reductions. In addition, based on the methodology described earlier in Section VI.C, ICF utilized a subset of the about fifty aerodynamic and engine technologies they evaluated to account for the improvements to the metric value for the final standard (for in-production and in-development airplanes [152]).

A short list of the aerodynamic and engine technologies that were considered to improve the metric value of the rule is provided below. Chapter 2 of the TSD provides a more detailed description of these technologies.

- *Aerodynamic technologies:* The airframe technologies that accounted for the improvements to the metric values from airplanes included aerodynamic technologies that reduce drag. These technologies included advance wingtip devices, adaptive trailing edge, laminar flow control, and riblet coatings.
- *Engine technologies:* The engine technologies that accounted for reductions to the metric values from airplanes included architecture and cooling technologies. Architecture technologies included ultra-high bypass engines and the fan drive gear, and cooling technologies included compressor airfoil coating and turbine air cooling.

3. Technology Response and Implications of the Final Standard

The EPA does not project that the GHG rule will cause manufacturers to make technical improvements to their airplanes that would not have occurred in the absence of the rule. The EPA projects that the manufacturers will meet the standards independent of the EPA standards, for the following reasons (as was described earlier in Section VI.A):

- Manufacturers have already developed or are developing improved technology in response to the ICAO standards that match the final GHG regulations;
- ICAO decided on the international Airplane CO_2 Emission Standards, which are equivalent to the final GHG standards, based on proven technology by 2016/2017 that was expected to be available over a sufficient range of in-production and on-order airplanes by approximately 2020. Thus, most or nearly all in-production and on-order airplanes already meet the levels of the final standards;
- Those few in-production airplane models that do not meet the levels of the final GHG standards are at the end of their production life and are expected to go out of production in the near term or

[150] The fuel burn reduction prospect index is a projected ranking of the feasibility and readiness of technologies (for reducing fuel burn) to be implemented for 2030 and later. There are three main steps to determine the fuel burn reduction prospect index. First, the technology factors that mainly contribute to fuel burn were identified. These factors included the following engine and airframe technologies as described below: (Engine) sealing, propulsive efficiency, thermal efficiency, reduced cooling, and reduced power extraction and (Airframe) induced drag reduction and friction drag reduction. Second, each of the technology factors were scored on the following three scoring dimensions that will drive the overall fuel burn reduction effectiveness in the outbound forecast years: Effectiveness of technology in reducing fuel burn, likelihood of technology implementation, and level of research effort required. Third, the scoring of each of the technical factors on the three dimensions were averaged to derive an overall fuel burn reduction prospect index.

[151] The metric value does not directly reward weight reduction technologies because such technologies are also used to allow for increases in payload, equipage and fuel load. Thus, reductions in empty weight can be canceled out or diminished by increases in payload, fuel, or both; and, this varies by operation. Empty weight refers to operating empty weight. It is the basic weight of an airplane including the crew, all fluids necessary for operation such as engine oil, engine coolant, water, unusable fuel and all operator items and equipment required for flight, but excluding usable fuel and the payload.

[152] Airplanes that are currently in-development but will be in production by the applicability dates. These could be new type designs or redesigned airplanes.

seek an exemption from the final standards; and

• These few in-production airplane models anticipated to go out of production are being replaced or are expected to be replaced by in-development airplane models (airplane models that have recently entered service or will in the next few years) in the near term—and these in-development models have much improved metric values compared to the in-production airplane model they are replacing.

Based on the approach described above in Sections VI.C.1 and VI.C.2, ICF assessed the need for manufacturers to develop technology responses for in-production and in-development airplane models to meet the final GHG standards (for airplane models that were projected to be in production by the effective dates of the final standards and would be modified to meet these standards, instead of going out of production). After analyzing the results of the approach/methodology, ICF estimated that all airplane models (in-production and in-development airplane models) will meet the levels of the final standard or be out of production by the time the standard became effective. Thus, a technology response is not necessary for airplane models to meet the final rule. This result confirms that the international Airplane CO_2 Emission Standards are technology following standards, and that the EPA's final GHG standards as they will apply to in-production and in-development airplane models will also be technology following.[153]

For the same reasons, a technology response is not necessary for new type design airplanes to meet the GHG rule. The EPA is currently not aware of a specific model of a new type design airplane that is expected to enter service after 2020. Additionally, any new type design airplanes introduced in the future will have an economic incentive to improve their fuel burn or metric value at the level of or less than the rule.

D. Costs Associated With the Program

This section provides the elements of the cost analysis for technology improvements, including certification costs, and recurring costs. As described, above, the EPA does not anticipate new technology costs due to the GHG rule. While recognizing that the GHG rule does not have non-recurring costs (NRC), certification costs, or recurring costs, it is informative to describe the elements of these costs.

1. Non-Recurring Costs

Non-recurring cost (NRC) consists of the cost of engineering and integration,[154] testing (flight and ground testing) and tooling, capital equipment, and infrastructure. As described earlier for the technology improvements and responses, ICF conducted a detailed literature search, conducted a number of interviews with industry leaders, and did its own modeling to estimate the NRC of making modifications to in-production airplanes. The EPA used the information gathered by ICF for assessing the cost of individual technologies, which were used to build up NRC for incremental improvements (a bottom-up approach). These improvements are for 0 to 10 percent improvements in the airplane CO_2 metric value, and this magnitude of improvements is typical for in-production airplanes (the focus of our analysis). In the initial 2015 ICF analysis, ICF developed NRC estimates for technology improvements to in-production airplanes, and in the 2018 ICF updated analysis these estimates have been brought up to date. The technologies available to make improvements to airplanes are briefly listed earlier in Section VI.C.2.

The methodology for the development of the NRC for in-production airplanes consisted of six steps. First, technologies were categorized either as minor performance improvement packages (PIPs) with 0 to 2 percent (or less than 2 percent) fuel burn improvements or as larger incremental updates with 2 to 10 percent improvements. Second, the elements of non-recurring cost were identified (*e.g.,* engineering and integration costs), as described earlier. Third, these elements of non-recurring cost are apportioned by incremental technology category for single-aisle airplanes (*e.g.,* for the category of an airframe minor PIP, 85 percent of NRC is for engineering of integration costs, 10 percent is for testing, and 5 percent is for tooling, capital equipment, and infrastructure).[155] Fourth, the NRC elements were scaled to the other airplane size categories (from the baseline single-aisle airplane category). Fifth, we estimated the NRC costs for single-aisle airplane and applied the scaled costs to the other airplane size categories.[156] Sixth, we compiled technology supply curves by airplane model, which enabled us to rank incremental technologies from most cost effective to the least cost effective. For determining technical responses by these supply curves, it was assumed that the manufacturer invests in and incorporates the most cost-effective technologies first and go on to the next most cost-effective technology to attain the metric value improvements needed to meet the standard. Chapter 2 of the TSD provides a more detailed description of this NRC methodology for technology improvements and results.

2. Certification Costs

Following this final rulemaking for the GHG standards, the FAA will issue a rulemaking to enforce compliance to these standards, and any potential certification costs for the GHG standards will be estimated by FAA and attributed to the FAA rulemaking. However, it is informative to discuss certification costs.

As described earlier, manufacturers have already developed or are developing technologies to respond to ICAO standards that are equivalent to the final standards, and they will comply with the ICAO standards in the absence of U.S. regulations. Also, this rulemaking will potentially provide for a cost savings to U.S. manufacturers since it will enable them to domestically certify their airplane (via subsequent FAA rulemaking) instead of having to certify with foreign certification authorities (which will occur without this EPA rulemaking). If the final GHG standards, which match the ICAO standards, are not adopted in the U.S., the U.S. civil airplane manufacturers will have to certify to the ICAO standards at higher costs because they will have to move their entire certification program(s) to a non-U.S. certification authority.[157] Thus, there are no new certification costs for the rule. However, it is informative to

[153] As described earlier, this result is different from the ICAO analysis, which did not use continuous improvement CO_2 metric values nor production end dates for products.

[154] Engineering and Integration includes the engineering and Research & Development (R&D) needed to progress a technology from its current level to a level where it can be integrated onto a production airframe. It also includes all airframe and technology integration costs.

[155] For the incremental technology category of an engine minor PIP, 35 percent of NRC is for engineering of integration costs, 50 percent is for testing, and 15 percent is for tooling, capital equipment, and infrastructure. For the category of a large incremental upgrade, 55 percent of NRC is for engineering of integration costs, 40 percent is for testing, and 5 percent is for tooling, capital equipment, and infrastructure.

[156] Engineering and integration costs and tooling, capital equipment, and infrastructure costs were scaled by airplane realized sale price from the single-aisle airplane category to the other airplane categories. Testing costs were scaled by average airplane operating costs.

[157] In addition, European authorities charge fees to airplane manufacturers for the certification of their airplanes, but FAA does not charge fees for certification.

describe the elements of the certification cost, which include obtaining an airplane, preparing an airplane, performing the flight tests, and processing the data to generate a certification test report (*i.e.,* test instrumentation, infrastructure, and program management).

The ICAO certification test procedures to demonstrate compliance with the international Airplane CO_2 Emission Standards—incorporated by reference in this rulemaking—were based on the existing practices of airplane manufacturers to measure airplane fuel burn (and to measure high-speed cruise performance).[158] Therefore, some manufacturers already have or will have airplane test data (or data from high-speed cruise performance modelling) to certify their airplane to the standard, and they will not need to conduct flight testing for certification to the standard. Also, these data will already be part of the manufacturers' fuel burn or high-speed performance models, which they can use to demonstrate compliance with the international Airplane CO_2 Emission Standards. In the absence of the standard, the relevant CO_2 or fuel burn data will be gathered during the typical or usual airplane testing that the manufacturer regularly conducts for non-GHG standard purposes (*e.g.,* for the overall development of the airplane and to demonstrate its airworthiness). In addition, such data for new type design airplanes (where data has not been collected yet) will be gathered in the absence of a standard. Also, the EPA is not making any attempt to quantify the costs associated with certification by the FAA.

3. Recurring Operating Costs

For the same reasons there are no NRC and certification costs for the rule as discussed earlier, there will be no recurring costs (recurring operating and maintenance costs) for the rule; however, it is informative to describe elements of recurring costs. The elements of recurring costs for incorporating fuel saving technologies will include additional maintenance, material, labor, and tooling costs. Our analysis shows that airplane fuel efficiency improvements typically result in net cost savings through the reduction in the amount of fuel consumed. If technologies add significant recurring costs to an airplane, operators (*e.g.,* airlines) will likely reject these technologies.

E. Summary of Benefits and Costs

ICAO intentionally established its standards, which match the final standards, at a level which is technology following to adhere to its definition of technical feasibility that is meant to consider the emissions performance of in-production and in-development airplanes, including types that would first enter into service by about 2020. Independent of the ICAO standards nearly all airplanes produced by U.S. manufacturers will meet the ICAO in-production standards in 2028 due to business-as-usual market forces on continually improving fuel efficiency. The cumulative fuel efficiency improvement of the global airplane fleet was 54 percent between 1990 and 2019, and over 21 percent from 2009 to 2019, which was an average annual rate of 2 percent.[159] Business-as-usual improvements are expected to continue in the future. The manufacturers anticipation of future ICAO standards will be another factor for them to consider in continually improving the fuel efficiency of their airplanes. Thus, all airplanes either meet the stringency levels, are expected to go out of production by the effective dates or will seek exemptions from the GHG standard. Therefore, there will be no costs and no additional benefits from complying with these final standards—beyond the benefits from maintaining consistency or harmonizing with the international standards and preventing backsliding by ensuring that all new type design and in-production airplanes are at least as fuel efficient as today's airplanes.

VII. Aircraft Engine Technical Amendments

The EPA, through the incorporation by reference of ICAO Annex 16, Volume II, Third Edition (July 2008), requires the same test and measurement procedures as ICAO for emissions from aircraft engines. See our regulations at 40 CFR 87.8(b)(1). At the CAEP/10 meeting in February 2016, several minor technical updates and corrections to the test and measurement procedures were approved and ultimately included in a Fourth Edition of ICAO Annex 16, Volume II (July 2017). Further technical updates and corrections were approved at the CAEP/11 meeting in February 2019 and included in Amendment 10 (July 20, 2020). The EPA played an active role in the CAEP process during the development of these revisions and concurred with their adoption. Thus, we are updating the incorporation by reference in § 87.8(b) of our regulations to refer to the new Fourth Edition of ICAO Annex 16, Volume II (July 2017), Amendment 10 (July 20, 2020), replacing the older Third Edition.

Most of these ICAO Annex 16 updates and corrections to the test and measurement procedures were editorial in nature and merely served to clarify the procedures rather than change them in any substantive manner. Additionally, some updates served to correct typographical errors and incorrect formula formatting. However, there is one change contained in these ICAO Annex 16 updates that warrants additional discussion here: a change to the certification test fuel specifications.

Fuel specification bodies establish limits on jet fuels properties for commercial use so that aircraft are safe and environmentally acceptable in operation. For engine emissions certification testing, the ICAO fuel specification prior to CAEP10 was a minimum 1 percent volume of naphthalene content and a maximum content of 3.5 percent (1.0–3.5%). However, the ASTM International specification is 0.0–3.0 percent naphthalene, and an investigation found that it is challenging to source fuels for engine emissions certification testing that meet the minimum 1% naphthalene level. In many cases, engine manufacturers were forced to have fuels custom blended for certification testing purposes at a cost premium well above that of commercial jet fuel. Additionally, such custom blended fuels needed to be ordered well in advance and shipped by rail or truck to the testing facility. In order to potentially alleviate the cost and logistical burden that the naphthalene specification of certification fuel presented, CAEP undertook an effort to analyze and consider whether it would be appropriate to align the ICAO Annex 16 naphthalene specification for certification fuel with that of in-use commercial fuel.

Prior to the CAEP10 meeting, technical experts (including the EPA) reviewed potential consequences of a test fuel specification change and concluded that there would be no effect on gaseous emissions levels and a negligible effect on the 'Smoke Number' (SN) level as long as the aromatic and

[158] ICAO, 2016: *Report of Tenth Meeting, Montreal, 1–12 February 2016, Committee on Aviation Environmental Protection,* Document 10069, CAEP/10, 432pp, is found on page 27 of the English Edition of the ICAO Products & Services 2020 Catalog and is copyright protected; Order No. 10069. See Appendix C of this report. For purchase available at: *https://www.icao.int/publications/Pages/catalogue.aspx* (last accessed March 16, 2020).

[159] ATAG, 2020: *Tracking Aviation Efficiency, How is the aviation sector performing in its drive to improve fuel efficiency, in line with its short-term goal?* Fact Sheet #3, January 2020. Available at *https://aviationbenefits.org/downloads/fact-sheet-3-tracking-aviation-efficiency/* .

hydrogen content remains within the current emissions test fuel specification limits. ICAO subsequently adopted the ASTM International specification of 0.0–3.0 percent naphthalene for the engine emissions test fuel specification and no change to the aromatic and hydrogen limits, which was incorporated into the Fourth Edition of ICAO Annex 16, Volume II, (July 2017).

The EPA is adopting, through the incorporation of the Annex revisions in 40 CFR 87.8(b), the new naphthalene specification for certification testing into U.S. regulations. This change will have the benefit of more closely aligning the certification fuel specification for naphthalene with actual in-use commercial fuel properties while reducing the cost and logistical burden associated with certification fuel procurement for engine manufacturers. As previously mentioned, all the other changes associated with updating the incorporation by reference of ICAO Annex 16, Volume II, are editorial or typographical in nature and merely intended to clarify the requirements or correct mistakes and typographical errors in the Annex.

VIII. Statutory Authority and Executive Order Reviews

Additional information about these statutes and Executive orders can be found at *http://www2.epa.gov/laws-regulations/laws-and-executive-orders.*

A. Executive Order 12866: Regulatory Planning and Review and Executive Order 13563: Improving Regulation and Regulatory Review

This action is a significant regulatory action that was submitted to the Office of Management and Budget (OMB) for review. The OMB has determined that this action raises ''. . . novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in this Executive Order.'' This action addresses novel policy issues due to it being the first ever GHG standards promulgated for airplanes and airplane engines. Accordingly, the EPA submitted this action to the OMB for review under E.O. 12866 and E.O. 13563. Any changes made in response to OMB recommendations have been documented in the docket. Sections I.C.3 and VI.E of this preamble summarize the cost and benefits of this action. The supporting information is available in the docket.

B. Executive Order 13771: Reducing Regulation and Controlling Regulatory Costs

This action is expected to be an Executive Order 13771 regulatory action. Sections I.C.3. and VI.E. of this preamble summarize the cost and benefits of this action. The supporting information is available in the Final Technical Support Document and the docket.

C. Paperwork Reduction Act (PRA)

The EPA proposed a reporting requirement, along with an associated Information Collection Request (ICR), in the NPRM. However, the EPA is not adopting the proposed reporting requirement, and therefore not submitting a final ICR to OMB for approval. Thus, this action does not impose any new information collection burden under the PRA.

D. Regulatory Flexibility Act (RFA)

I certify that this action will not have a significant economic impact on a substantial number of small entities under the RFA. In making this determination, the impact of concern is any significant adverse economic impact on small entities. An agency may certify that a rule will not have a significant economic impact on a substantial number of small entities if the rule relieves regulatory burden, has no net burden or otherwise has a positive economic effect on the small entities subject to the rule. Among the potentially affected entities (manufacturers of covered airplanes and engines for those airplanes), there is one small business potentially affected by this action. This one small business is a manufacturer of aircraft engines. However, we did not project any costs associated with this action. We have therefore concluded that this action will have no net regulatory burden for all directly regulated small entities.

E. Unfunded Mandates Reform Act (UMRA)

This action does not contain an unfunded mandate of $100 million or more as described in UMRA, 2 U.S.C. 1531–1538, and does not significantly or uniquely affect small governments. The action imposes no enforceable duty on any state, local or tribal governments or the private sector.

F. Executive Order 13132: Federalism

This action does not have federalism implications. It will not have substantial direct effects on the states, on the relationship between the National Government and the states, or on the distribution of power and responsibilities among the various levels of government.

G. Executive Order 13175: Consultation and Coordination With Indian Tribal Governments

This action does not have tribal implications as specified in Executive Order 13175. This action regulates the manufacturers of airplanes and aircraft engines and will not have substantial direct effects on one or more Indian tribes, on the relationship between the Federal Government and Indian tribes, or on the distribution of power and responsibilities between the Federal Government and Indian tribes. Thus, Executive Order 13175 does not apply to this action.

H. Executive Order 13045: Protection of Children From Environmental Health Risks and Safety Risks

This action is not subject to Executive Order 13045 because it is not economically significant as defined in Executive Order 12866, and because the EPA does not believe the environmental health or safety risks addressed by this action present a disproportionate risk to children.

I. Executive Order 13211: Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution or Use

This action is not a ''significant energy action'' because it is not likely to have a significant adverse effect on the supply, distribution or use of energy and has not otherwise been designated by OIRA as a significant energy action. These airplane GHG regulations are not expected to result in any changes to airplane fuel consumption beyond what would have otherwise occurred in the absence of this rule, as discussed in Section V.C.

J. National Technology Transfer and Advancement Act (NTTAA) and 1 CFR Part 51

Section 12(d) of the National Technology Transfer and Advancement Act of 1995 (''NTTAA''), Public Law 104–113, 12(d) (15 U.S.C. 272 note) directs EPA to use voluntary consensus standards in its regulatory activities unless to do so would be inconsistent with applicable law or otherwise impractical. Voluntary consensus standards are technical standards (*e.g.,* materials specifications, test methods, sampling procedures, and business practices) that are developed or adopted by voluntary consensus standards bodies. NTTAA directs agencies to provide Congress, through OMB, explanations when the Agency decides not to use available and applicable voluntary consensus standards. This action involves technical standards.

In accordance with the requirements of 1 CFR 51.5, we are incorporating by reference the use of test procedures contained in ICAO's International Standards and Recommended Practices Environmental Protection, Annex 16, Volumes II and III, along with the modifications contained in this rulemaking. This includes the following standards and test methods:

Standard or test method	Regulation	Summary
ICAO 2017, *Aircraft Engine Emissions,* Annex 16, Volume II, Fourth Edition, July 2017, as amended by Amendment 10, July 20, 2020.	40 CFR 87.1, 40 CFR 87.42(c), and 40 CFR 87.60(a) and (b).	Test method describes how to measure gaseous and smoke emissions from airplane engines.
ICAO 2017, *Aeroplane CO_2 Emissions,* Annex 16, Volume III, First Edition, July 2017, as amended by Amendment 1, July 20, 2020.	40 CFR 1030.23(d), 40 CFR 1030.25(d), 40 CFR 1030.90(d), and 40 CFR 1030.105.	Test method describes how to measure the fuel efficiency of airplanes.

The material from the ICAO Annex 16, Volume II is an updated version of the document that is already incorporated by reference in 40 CFR 87.1, 40 CFR 87.42(c), and 40 CFR 87.60(a) and (b).

The referenced standards and test methods may be obtained through the International Civil Aviation Organization, Document Sales Unit, 999 University Street, Montreal, Quebec, Canada H3C 5H7, (514) 954–8022, *www.icao.int,* or *sales@icao.int.*

K. Executive Order 12898: Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations

The EPA believes that this action does not have disproportionately high and adverse human health or environmental effects on minority populations, low-income populations and/or indigenous peoples, as specified in Executive Order 12898 (59 FR 7629, February 16, 1994). It provides similar levels of environmental protection for all affected populations without having any disproportionately high and adverse human health or environmental effects on any population, including any minority or low-income population.

L. Congressional Review Act

This action is subject to the CRA, and the EPA will submit a rule report to each House of the Congress and to the Comptroller General of the United States. This action is not a ''major rule'' as defined by 5 U.S.C. 804(2).

List of Subjects

40 CFR Part 87

Environmental protection, Air pollution control, Aircraft, Incorporation by reference.

40 CFR Part 1030

Environmental protection, Air pollution control, Aircraft, Greenhouse gases, Incorporation by reference.

Andrew Wheeler,

Administrator.

For the reasons set forth in the preamble, EPA amends 40 CFR chapter I as follows:

PART 87—CONTROL OF AIR POLLUTION FROM AIRCRAFT AND AIRCRAFT ENGINES

■ 1. The authority citation for part 87 continues to read as follows:

Authority: 42 U.S.C. 7401 *et seq.*

■ 2. Section 87.8 is amended by revising paragraphs (a) and (b)(1) to read as follows:

§ 87.8 Incorporation by reference.

(a) Certain material is incorporated by reference into this part with the approval of the Director of the Federal Register under 5 U.S.C. 552(a) and 1 CFR part 51. To enforce any edition other than that specified in this section, the Environmental Protection Agency must publish a document in the **Federal Register** and the material must be available to the public. All approved material is available for inspection at U.S. EPA, Air and Radiation Docket Center, WJC West Building, Room 3334, 1301 Constitution Ave. NW, Washington, DC 20004, *www.epa.gov/dockets,* (202) 202–1744, and is available from the sources listed in this section. It is also available for inspection at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, email *fedreg.legal@nara.gov* or go to *www.archives.gov/federal-register/cfr/ibr-locations.html.*

(b) * * *

(1) Annex 16 to the Convention on International Civil Aviation, Environmental Protection, as follows:

(i) Volume II—Aircraft Engine Emissions, Fourth Edition, July 2017. IBR approved for §§ 87.1, 87.42(c), and 87.60(a) and (b).

(ii) Amendment 10 to Annex 16, Volume II, to the Convention on International Civil Aviation, effective July 20, 2020 (ICAO Annex 16, Volume II). IBR approved for §§ 87.1, 87.42(c), and 87.60(a) and (b).

* * * * *

■ 3. Add part 1030 to read as follows:

PART 1030—CONTROL OF GREENHOUSE GAS EMISSIONS FROM ENGINES INSTALLED ON AIRPLANES

Scope and Applicability

Subsonic Airplane Emission Standards and Measurement Procedures

Reference Information

Authority: 42 U.S.C. 7401–7671q.

Scope and Applicability

§ 1030.1 Applicability.

(a) Except as provided in paragraph (c) of this section, when an aircraft engine subject to 40 CFR part 87 is installed on an airplane that is described in this section and subject to title 14 of the Code of Federal Regulations, the airplane may not exceed the Greenhouse Gas (GHG) standards of this part when original civil certification under title 14 is sought.

(1) A subsonic jet airplane that has—

(i) A type certificated maximum passenger seating capacity of 20 seats or more;

(ii) A maximum takeoff mass (MTOM) greater than 5,700 kg; and

(iii) An application for original type certification that is submitted on or after January 11, 2021.

(2) A subsonic jet airplane that has—

(i) A type certificated maximum passenger seating capacity of 19 seats or fewer;

(ii) A MTOM greater than 5,700 kg, but not greater than 60,000 kg; and

(iii) An application for original type certification that is submitted on or after January 1, 2023.

(3) A propeller-driven airplane that has—

(i) A MTOM greater than 8,618 kg; and

(ii) An application for original type certification that is submitted on or after January 1, 2020.

(4) A subsonic jet airplane—

(i) That is a modified version of an airplane whose original type certificated version was not required to have GHG emissions certification under this part;

(ii) That has a MTOM greater than 5,700 kg;

(iii) For which an application for the modification in type design is submitted on or after January 1, 2023; and

(iv) For which the first certificate of airworthiness is issued for an airplane built with the modified design.

(5) A propeller-driven airplane—

(i) That is a modified version of an airplane whose original type certificated version was not required to have GHG emissions certification under this part;

(ii) That has a MTOM greater than 8,618 kg;

(iii) For which an application for certification that is submitted on or after January 1, 2023; and

(iv) For which the first certificate of airworthiness is issued for an airplane built with the modified design.

(6) A subsonic jet airplane that has—

(i) A MTOM greater than 5,700 kg; and

(ii) Its first certificate of airworthiness issued on or after January 1, 2028.

(7) A propeller-driven airplane that has—

(i) A MTOM greater than 8,618 kg; and

(ii) Its first certificate of airworthiness issued on or after January 1, 2028.

(b) An airplane that incorporates modifications that change the fuel efficiency metric value of a prior version of airplane may not exceed the GHG standards of this part when certification under 14 CFR is sought. The criteria for modified airplanes are described in § 1030.35. A modified airplane may not exceed the metric value limit of the prior version under § 1030.30.

(c) The requirements of this part do not apply to:

(1) Subsonic jet airplanes having a MTOM at or below 5,700 kg.

(2) Propeller-driven airplanes having a MTOM at or below 8,618 kg.

(3) Amphibious airplanes.

(4) Airplanes initially designed, or modified and used, for specialized operations. These airplane designs may include characteristics or configurations necessary to conduct specialized operations that the EPA and the FAA have determined may cause a significant increase in the fuel efficiency metric value.

(5) Airplanes designed with a reference geometric factor of zero.

(6) Airplanes designed for, or modified and used for, firefighting.

(7) Airplanes powered by piston engines

§ 1030.5 State standards and controls.

No State or political subdivision of a State may adopt or attempt to enforce any airplane or aircraft engine standard with respect to emissions unless the standard is identical to a standard that applies to airplanes under this part.

§ 1030.10 Exemptions.

Each person seeking relief from compliance with this part at the time of certification must submit an application for exemption to the FAA in accordance with the regulations of 14 CFR parts 11 and 38. The FAA will consult with the EPA on each exemption application request before the FAA takes action.

Subsonic Airplane Emission Standards and Measurement Procedures

§ 1030.20 Fuel efficiency metric.

For each airplane subject to this part, including an airplane subject to the change criteria of § 1030.35, a fuel efficiency metric value must be calculated in units of kilograms of fuel consumed per kilometer using the following equation, rounded to three decimal places:

$$Fuel\ Efficiency\ metric\ value = \frac{\left(\frac{1}{SAR}\right)_{avg}}{RGF^{0.24}}$$

Where:

SAR = specific air range, determined in accordance with § 1030.23.

RGF = reference geometric factor, determined in accordance with § 1030.25.

§ 1030.23 Specific air range (SAR).

(a) For each airplane subject to this part the SAR of an airplane must be determined by either:

(1) Direct flight test measurements; or

(2) Using a performance model that is:

(i) Validated by actual SAR flight test data; and

(ii) Approved by the FAA before any SAR calculations are made.

(b) For each airplane model, establish a 1/SAR value at each of the following reference airplane masses:

(1) High gross mass: 92 percent maximum takeoff mass (MTOM).

(2) Low gross mass: (0.45 * MTOM) + (0.63 * (MTOM − 0.924)).

(3) Mid gross mass: Simple arithmetic average of high gross mass and low gross mass.

(c) Calculate the average of the three 1/SAR values described in paragraph (b) of this section to calculate the fuel efficiency metric value in § 1030.20. Do not include auxiliary power units in any 1/SAR calculation.

(d) All determinations under this section must be made according to the procedures applicable to SAR in Paragraphs 2.5 and 2.6 of ICAO Annex 16, Volume III and Appendix 1 of ICAO Annex 16, Volume III (incorporated by reference in § 1030.110).

§ 1030.25 Reference geometric factor (RGF).

For each airplane subject to this part, determine the airplane's nondimensional reference geometric factor (RGF) for the fuselage size of each airplane model, calculated as follows:

(a) For an airplane with a single deck, determine the area of a surface (expressed in m∧2) bounded by the maximum width of the fuselage outer mold line projected to a flat plane parallel with the main deck floor and the forward and aft pressure bulkheads except for the crew cockpit zone.

(b) For an airplane with more than one deck, determine the sum of the areas (expressed in m∧2) as follows:

(1) The maximum width of the fuselage outer mold line, projected to a flat plane parallel with the main deck

floor by the forward and aft pressure bulkheads except for any crew cockpit zone.

(2) The maximum width of the fuselage outer mold line at or above each other deck floor, projected to a flat plane parallel with the additional deck floor by the forward and aft pressure bulkheads except for any crew cockpit zone.

(c) Determine the non-dimensional RGF by dividing the area defined in paragraph (a) or (b) of this section by 1 m^2.

(d) All measurements and calculations used to determine the RGF of an airplane must be made according to the procedures for determining RGF in Appendix 2 of ICAO Annex 16, Volume III (incorporated by reference in § 1030.110).

§ 1030.30 GHG emission standards.

(a) The greenhouse gas emission standards in this section are expressed as maximum permitted values fuel efficiency metric values, as calculated under § 1030.20.

(b) The fuel efficiency metric value may not exceed the following, rounded to three decimal places:

For airplanes defined in . . .	with MTOM . . .	the standard is . . .
(1) Section 1030.1(a)(1) and (2)	5,700 < MTOM < 60,000 kg	$10^{(-2.73780 + (0.681310 * \text{log10(MTOM)}) + (-0.0277861 * (\text{log10(MTOM)})^{2}))}$
(2) Section 1030.1(a)(3)	8,618 < MTOM < 60,000 kg	$10^{(-2.73780 + (0.681310 * \text{log10(MTOM)}) + (-0.0277861 * (\text{log10(MTOM)})^{2}))}$
(3) Section 1030.1(a)(1) and (3)	60,000 < MTOM < 70,395 kg	0.764
(4) Section 1030.1(a)(1) and (3)	MTOM > 70,395 kg	$10^{(-1.412742 + (-0.020517 * \text{log10(MTOM)}) + (0.0593831 * (\text{log10(MTOM)})^{2}))}$
(5) Section 1030.1(a)(4) and (6)	5,700 < MTOM < 60,000 kg	$10^{(-2.57535 + (0.609766 * \text{log10(MTOM)}) + (-0.0191302 * (\text{log10(MTOM)})^{2}))}$
(6) Section 1030.1(a)(5) and (7)	8,618 < MTOM < 60,000 kg	$10^{(-2.57535 + (0.609766 * \text{log10(MTOM)}) + (-0.0191302 * (\text{log10(MTOM)})^{2}))}$
(7) Section 1030.1(a)(4) through (7)	60,000 < MTOM < 70,107 kg	0.797
(8) Section 1030.1(a)(4) through (7)	MTOM > 70,107 kg	$10^{(-1.39353 + (-0.020517 * \text{log10(MTOM)}) + (0.0593831 * (\text{log10(MTOM)})^{2}))}$

§ 1030.35 Change criteria.

(a) For an airplane that has demonstrated compliance with § 1030.30, any subsequent version of that airplane must demonstrate compliance with § 1030.30 if the subsequent version incorporates a modification that either increases—

(1) The maximum takeoff mass; or

(2) The fuel efficiency metric value by more than:

(i) For airplanes with a MTOM greater than or equal to 5,700 kg, the value decreases linearly from 1.35 to 0.75 percent for an airplane with a MTOM of 60,000 kg.

(ii) For airplanes with a MTOM greater than or equal to 60,000 kg, the value decreases linearly from 0.75 to 0.70 percent for airplanes with a MTOM of 600,000 kg.

(iii) For airplanes with a MTOM greater than or equal to 600,000 kg, the value is 0.70 percent.

(b) For an airplane that has demonstrated compliance with § 1030.30, any subsequent version of that airplane that incorporates modifications that do not increase the MTOM or the fuel efficiency metric value in excess of the levels shown in paragraph (a) of this section, the fuel efficiency metric value of the modified airplane may be reported to be the same as the value of the prior version.

(c) For an airplane that meets the criteria of § 1030.1(a)(4) or (5), after January 1, 2023 and until January 1, 2028, the airplane must demonstrate compliance with § 1030.30 if it incorporates any modification that increases the fuel efficiency metric value by more than 1.5 per cent from the prior version of the airplane.

§ 1030.98 Confidential business information.

The provisions of 40 CFR 1068.10 apply for information you consider confidential.

Reference Information

§ 1030.100 Abbreviations.

The abbreviations used in this part have the following meanings:

TABLE 1 TO § 1030.100

EPA	U.S. Environmental Protection Agency.
FAA	U.S. Federal Aviation Administration.
GHG	greenhouse gas.
IBR	incorporation by reference.
ICAO	International Civil Aviation Organization.
MTOM	maximum takeoff mass.
RGF	reference geometric factor.
SAR	specific air range.

§ 1030.105 Definitions.

The following definitions in this section apply to this part. Any terms not defined in this section have the meaning given in the Clean Air Act. The definitions follow:

Aircraft has the meaning given in 14 CFR 1.1, a device that is used or intended to be used for flight in the air.

Aircraft engine means a propulsion engine that is installed on or that is manufactured for installation on an airplane for which certification under 14 CFR is sought.

Airplane has the meaning given in 14 CFR 1.1, an engine-driven fixed-wing aircraft heavier than air, that is supported in flight by the dynamic reaction of the air against its wings.

Exempt means to allow, through a formal case-by-case process, an airplane to be certificated and operated that does not meet the applicable standards of this part.

Greenhouse Gas (GHG) means an air pollutant that is the aggregate group of six greenhouse gases: carbon dioxide, nitrous oxide, methane, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

ICAO Annex 16, Volume III means Volume III of Annex 16 to the Convention on International Civil Aviation (see § 1030.110).

Maximum takeoff mass (MTOM) is the maximum allowable takeoff mass as stated in the approved certification basis for an airplane type design. Maximum takeoff mass is expressed in kilograms.

Performance model is an analytical tool (or a method) validated using corrected flight test data that can be used to determine the specific air range values for calculating the fuel efficiency metric value.

Reference geometric factor is a non-dimensional number derived from a two-dimensional projection of the fuselage.

Round has the meaning given in 40 CFR 1065.1001.

Specific air range is the distance an airplane travels per unit of fuel consumed. Specific air range is expressed in kilometers per kilogram of fuel.

Subsonic means an airplane that has not been certificated under 14 CFR to exceed Mach 1 in normal operation.

Type certificated maximum passenger seating capacity means the maximum number of passenger seats that may be installed on an airplane as listed on its type certificate data sheet, regardless of the actual number of seats installed on an individual airplane.

§ 1030.110 Incorporation by reference.

(a) Certain material is incorporated by reference into this part with the approval of the Director of the Federal Register under 5 U.S.C. 552(a) and 1 CFR part 51. To enforce any edition other than that specified in this section, the Environmental Protection Agency must publish a document in the **Federal Register** and the material must be available to the public. All approved material is available for inspection at EPA Docket Center, WJC West Building, Room 3334, 1301 Constitution Ave. NW, Washington, DC 20004, *www.epa.gov/dockets,* (202) 202–1744, and is available from the sources listed in this section. It is also available for inspection at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, email *fedreg.legal@nara.gov* or go to: *www.archives.gov/federal-register/cfr/ibr-locations.html.*

(b) International Civil Aviation Organization, Document Sales Unit, 999 University Street, Montreal, Quebec, Canada H3C 5H7, (514) 954–8022, *www.icao.int,* or *sales@icao.int.*

(1) ICAO Annex 16, Volume III, Annex 16 to the Convention on International Civil Aviation, Environmental Protection, Volume III—Aeroplane CO_2 Emissions, as follows:

(i) First Edition, July 2017. IBR approved for §§ 1030.23(d) and 1030.25(d).

(ii) Amendment 1, July 20, 2020. IBR approved for §§ 1030.23(d) and 1030.25(d).

(2) [Reserved]

[FR Doc. 2020–28882 Filed 1–8–21; 8:45 am]

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