ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 87 and 1068

[EPA–HQ–OAR–2014–0828; FRL 9924–06–OAR]

RIN 2060–AS31

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

AGENCY: Environmental Protection Agency (EPA).

ACTION: Proposed rule and advance notice of proposed rulemaking.

SUMMARY: In this action, the Administrator is proposing to determine that greenhouse gas concentrations in the atmosphere endanger the public health and welfare of current and future generations within the meaning of section 231(a) of the Clean Air Act. She proposes to make this finding specifically with respect to the same six well-mixed greenhouse gases (GHGs)—carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride—that together were defined as the air pollution in the 2009 Endangerment Finding under section 202(a) of the Clean Air Act and that together constitute the primary cause of the climate change problem. The Administrator is also proposing to find that greenhouse gas emissions from certain classes of engines used in aircraft are contributing to air pollution—the mix of greenhouse gases in the atmosphere—that endangers public health and welfare under section 231(a) of the Clean Air Act. Concurrent with these proposed findings, the EPA is issuing an Advance Notice of Proposed Rulemaking to provide an overview of and seek input on a variety of issues related to setting an international CO_2 standard for aircraft at the International Civil Aviation Organization (ICAO), ICAO's progress in establishing global aircraft standards that achieve meaningful reductions in CO_2 emissions, and (provided the EPA promulgates final endangerment and cause and contribute findings for aircraft engine GHG emissions) the potential use of section 231 of the Clean Air Act to adopt and implement corresponding aircraft engine GHG emission standards domestically, ensuring transparency and the opportunity for public comment.

DATES: *Comments.* Comments must be received on or before August 31, 2015.

Public Hearing. The EPA will hold a public hearing on August 11, 2015 in Washington, DC, at the William Jefferson Clinton East Building, Room 1153, 101 Constitution Avenue NW., Washington, DC 20004. If no one contacts the EPA requesting to speak at the hearing for this proposal by July 13, 2015 the public hearing will not take place and will be cancelled with no further notice. Speakers should contact Ms. JoNell Iffland (see **FOR FURTHER INFORMATION CONTACT**) to request to speak at the hearing. The last day to pre-register in advance to speak at the hearing will be August 6, 2015. The hearing will start at 10:00 a.m. local time and continue until everyone has had a chance to speak. Requests to speak will be taken the day of the hearing at the hearing registration desk, although preferences on speaking times may not be able to be fulfilled. If you require the service of a translator or special accommodations such as audio description, please let us know at the time of registration. For further information on the public hearing or to register to speak at the hearing, *please see* section I.B below or go to *http://www.epa.gov/otaq/aviation.htm*.

ADDRESSES: *Comments.* Submit your comments, identified by Docket ID No. EPA–HQ–OAR–2014–0828, by one of the following methods:

- *Online: www.regulations.gov* Follow the on-line instructions for submitting comments.
- *Email: A-and-R-Docket@epamail.epa.gov* Attention Docket ID No. EPA–HQ–OAR–2014–0828.
- *Fax:* (202) 566–9744, Attention Docket ID No. EPA–HQ–OAR–2014–0828.
- *Mail:* U.S. Postal Service, send comments to Air and Radiation Docket and Information Center, Environmental Protection Agency, Mail Code: 28221T, 1200 Pennsylvania Ave. NW., Washington, DC 20460. Attention Docket ID No. EPA–HQ–OAR–2014–0828.
- *Hand Delivery:* U.S. Environmental Protection Agency, EPA West, EPA Docket Center, EPA West Building, Room 3334, 1301 Constitution Ave. NW., Washington, DC 20004. Attention Docket ID No. EPA–HQ–OAR–2014–0828. Such deliveries are only accepted during the Docket's normal hours of operation, and special arrangements should be made for deliveries of boxed information.

Instructions: Direct your comments to Docket ID No. EPA–HQ–OAR–2014–0828. See section I.B on ''Public Participation'' for more information about submitting written comments. The EPA's policy is that all comments received will be included in the public docket without change and may be made available online at *http://www.regulations.gov*, including any personal information provided, unless the comment includes information claimed to be confidential business information (CBI) or other information whose disclosure is restricted by statute. Do not submit information that you consider to be CBI or otherwise protected through *http://www.regulations.gov* or email. The *http://www.regulations.gov* Web site is an ''anonymous access'' system, which means the EPA will not know your identity or contact information unless you provide it in the body of your comment. If you send an email comment directly to the EPA without going through *http://www.regulations.gov,* your email address will be automatically captured and included as part of the comment that is placed in the public docket and made available on the Internet. If you submit an electronic comment, the EPA recommends that you include your name and other contact information in the body of your comment and with any disk or CD–ROM you submit. If the EPA cannot read your comment due to technical difficulties and cannot contact you for clarification, the EPA may not be able to consider your comment. Electronic files should avoid the use of special characters, or any form of encryption, and be free of any defects or viruses. For additional information about the EPA's public docket visit the EPA Docket Center homepage at: *http://www.epa.gov/dockets*. For additional instructions on submitting comments, go to section I.B of this document.

Docket. The EPA has established a docket for this rulemaking under Docket ID No. EPA–HQ–OAR–2014–0828. All documents in the docket are listed in the *www.regulations.gov* index. Although listed in the index, some information is not publicly available, *e.g.,* 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 in the EPA's docket. Publicly available docket materials are available either electronically in *www.regulations.gov* or in hard copy at the Air and Radiation Docket and Information Center, EPA/DC, EPA WJC West, Room 3334, 1301 Constitution Ave. NW., Washington, DC. The Public Reading Room is open from 8:30 a.m. to 4:30 p.m., Monday through Friday, excluding legal holidays. 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 CONTACT: JoNell Iffland, Office of Transportation and Air Quality, Assessment and Standards Division (ASD), Environmental Protection Agency, 2000 Traverwood Drive, Ann Arbor, MI 48105; Telephone number: (734) 214–4454; Fax number: (734) 214–4816; Email address: *iffland.jonell@epa.gov*. Please use this contact information for general questions about this rulemaking, to request a hearing, to determine if a hearing will be held, and to register to speak at the hearing, if one is held.

SUPPLEMENTARY INFORMATION:

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I. General Information

A. Does this action apply to me?

These proposed findings, if finalized, would trigger new duties that would apply to the EPA, but would not themselves apply new requirements to other entities outside the federal government. Specifically, if the EPA issues final findings that greenhouse gas emissions from certain classes of engines—those used in certain aircraft—cause or contribute to air pollution which endangers public health or welfare, then the EPA would have a duty under section 231 of the Clean Air Act to promulgate aircraft engine emission standards applicable to emissions of that air pollutant from those classes of engines. Only those standards would apply to and have an effect on other entities outside the federal government. Entities potentially interested in this proposed action are those that manufacture and sell aircraft engines and aircraft in the United States. Categories that may be regulated in a future regulatory action include:

Category	NAICS [a] Code	SIC [b] Code	Examples of potentially affected entities
Industry	3364412	3724	Manufacturers of new aircraft engines.
Industry	336411	3721	Manufacturers of new aircraft.

[a] North American Industry Classification System (NAICS).
[b] Standard Industrial Classification (SIC) code.

This table is not intended to be exhaustive, but rather provides a guide for readers regarding entities likely to be interested in this proposed action. This table lists the types of entities that the EPA is now aware could potentially have an interest in this proposed action. If the EPA issues final affirmative findings under section 231(a) regarding greenhouse gases, the EPA would then be required to undertake a separate notice and comment rulemaking to issue emission standards applicable to greenhouse gas emissions from the classes of aircraft engines that the EPA finds cause or contribute in such a finding, and the FAA would be required to Prescribe regulations to insure compliance with these emissions standards pursuant to section 232 of the Clean Air Act. Other types of entities not listed in the table could also be interested and potentially affected by subsequent actions at some future time. If you have any questions regarding the scope of this proposed action, consult the person listed in the preceding **FOR FURTHER INFORMATION CONTACT** section.

B. Public Participation

The EPA requests comment on all aspects of the proposed aircraft endangerment and cause or contribute findings and the Advance Notice of Proposed Rulemaking (ANPR). This section describes how you can participate in this process.

If you submitted comments on the issues raised by this proposal in dockets for other, earlier Agency efforts (*e.g.,* the 2009 Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202 of the Clean Air Act or the Advance Notice of Proposed Rulemaking on Regulating Greenhouse Gases under the Clean Air Act), you must still submit your comments to the docket for this action (EPA–HQ–OAR–2014–0828) by the deadline if you want them to be considered.

1. What should I consider as I prepare my comments for the EPA?

We are opening a formal comment period by publishing this document. We will accept comments during the period indicated in the **DATES** section. If you have an interest in the proposed aircraft endangerment and cause or contribute findings and/or the ANPR described in this document, we encourage you to comment on any aspect of this rulemaking.

Tips for Preparing Your Comments

When submitting comments, remember to:

- Identify the rulemaking by docket number and other identifying information (subject heading, **Federal Register** date and page number).
- Follow directions—The agency may ask you to respond to specific questions or organize comments by referencing a Code of Federal Regulations (CFR) part or section number.
- Explain why you agree or disagree, suggest alternatives, and substitute language for your requested changes.
- Describe any assumptions and provide any technical information and/or data that you used.
- If you estimate potential costs or burdens, explain how you arrived at your estimate in sufficient detail to allow for it to be reproduced.
- Provide specific examples to illustrate your concerns, and suggest alternatives.
- Explain your views as clearly as possible, avoiding the use of profanity or personal threats.
- Make sure to submit your comments by the comment period deadline identified.

Do not submit information to the EPA containing CBI through *http://www.regulations.gov* or email. Clearly mark the part or all of the information that you claim to be CBI. For CBI information on a disk or CD–ROM that you mail to the EPA, mark the outside of the disk or CD–ROM as CBI and then identify electronically within the disk or CD–ROM the specific information that is claimed as CBI. In addition to one complete version of the comment that includes information claimed as CBI, you must submit a copy of the comment that does not contain the information claimed as CBI for inclusion in the public docket. Information so marked will not be disclosed except in accordance with procedures set forth in 40 CFR part 2.

2. Public Hearing

If a hearing is held, it will provide interested parties the opportunity to present data, views or arguments concerning the proposed action. The EPA will make every effort to accommodate all speakers who arrive and register. Because this hearing, if held, will be at a U.S. government facility, individuals planning to attend the hearing should be prepared to show valid picture identification to the security staff in order to gain access to the meeting room. Please note that the REAL ID Act, passed by Congress in 2005, established new requirements for entering federal facilities. These requirements took effect July 21, 2014. If your driver's license is issued by Alaska, American Samoa, Arizona, Kentucky, Louisiana, Maine, Massachusetts, Minnesota, Montana, New York, Oklahoma, or the state of Washington, you must present an additional form of identification to enter the federal buildings where the public hearings will be held. Acceptable alternative forms of identification include: Federal employee badges, passports, enhanced driver's licenses and military identification cards. In addition, you will need to obtain a property pass for any personal belongings you bring with you. Upon leaving the building, you will be required to return this property pass to the security desk. No large signs will be allowed in the building, cameras may only be used outside of the building and demonstrations will not be allowed on federal property for security reasons. The EPA may ask clarifying questions during the oral presentations but will not respond to the presentations at that time. Written statements and supporting information submitted during the comment period will be considered with the same weight as oral comments and supporting information presented at the public hearings.

Speakers should contact Ms. JoNell Iffland (see **FOR FURTHER INFORMATION CONTACT**) if they will need specific equipment, or if there are other special needs related to providing comments at the hearing. Oral testimony will be limited to no more than 10 minutes for each commenter, although we may need to adjust the time for each speaker if there is a large turnout. The EPA requests that commenters provide the EPA with three copies of their oral testimony in hard copy form the day of the hearing or an electronic copy in advance of the hearing date. Verbatim transcripts of the hearings and written statements will be included in the docket for the rulemaking. The EPA will make every effort to follow the schedule as closely as possible on the day of the hearing; however, please plan for the hearing to run either ahead of schedule or behind schedule.

Information regarding the hearing (including information as to whether or not one will be held) will be available at *http://www.epa.gov/otaq/aviation.htm*. Again, if we do not receive a request to speak at the August 11, 2015 public hearing by July 13, 2015 the hearing will be cancelled.

C. Did the EPA conduct a peer review before issuing this notice?

As outlined in section IV.A of this action, the EPA's approach to providing the technical and scientific information to inform the Administrator's judgment regarding the question of whether greenhouse gases endanger public health and welfare was to rely primarily upon the recent, major assessments by the U.S. Global Change Research Program (USGCRP), the Intergovernmental Panel on Climate Change (IPCC), and the National Research Council (NRC) of the National Academies. These assessments draw synthesis conclusions across thousands of individual peer-reviewed studies that appear in scientific journals, and the reports themselves undergo additional peer review. The EPA has considered the processes and procedures employed by the USGCRP, IPCC, and the NRC, and has determined that these assessments have been adequately peer reviewed in a manner commensurate with the EPA's Peer Review Policy [1] and the guidelines in Office of Management and Budget's (OMB) Final Information Quality Bulletin for Peer Review (''OMB Bulletin'') for highly influential scientific assessments. According to guidelines in the EPA's Peer Review Handbook, if the Agency has determined that information has already been subject to adequate peer review, then it is not necessary to have further peer review of that information.[2]

The EPA also cites data from its annual Inventory of U.S. Greenhouse Gas Emissions and Sinks report,[3] which the Agency has determined to have been adequately reviewed in accordance with the OMB Bulletin and the EPA's Peer Review Handbook. For the presentation of emissions inventory information to support the cause or contribute finding, the EPA disaggregated the existing data in one area of the GHG Inventory (for the General Aviation Jet Fuel Category) and had the disaggregation methodology and results peer reviewed in accordance with the EPA's Peer Review Handbook. The EPA Science Advisory Board reviewed this approach to the underlying technical and scientific information supporting this action, and concluded that the approach had precedent and the action will be based on well-reviewed information. All relevant peer review documentation is located in the docket for today's action (EPA–HQ–OAR–2014–0828).

D. Children's Environmental Health

As described in detail in section IV of this preamble, the scientific evidence and conclusions in the USGCRP, IPCC, and the NRC assessment reports cited in the 2009 Endangerment Finding [4] indicate that children are uniquely vulnerable to climate change related health effects given behavioral, developmental, and physiological factors. The new assessment literature published since 2009 strengthens these conclusions by providing more detailed findings regarding children's vulnerabilities and projected impacts they may experience.

These assessments describe that children will be disproportionately impacted by climate change given the unique physiological and developmental factors that occur during this lifestage. Impacts to children are expected from heat waves, air pollution, infectious and waterborne illnesses, and mental health effects resulting from extreme weather events. In addition, the assessments find that climate change will influence production of pollen that affects asthma and other allergic respiratory diseases, to which children are among those especially susceptible.

E. Environmental Justice

As described in detail in section IV below, the scientific evidence and conclusions in the USGCRP, IPCC, and the NRC assessment reports cited in the 2009 Endangerment Finding indicate that certain populations are most vulnerable to the health and welfare effects of climate change, including the elderly, the poor, and indigenous peoples in the United States, particularly Alaska Natives. The more recent assessment reports strengthen these conclusions by providing more detail regarding these populations' vulnerabilities and projected impacts they may experience.

In addition, the most recent assessment reports provide new analysis about how low-income populations and some populations defined jointly by ethnic/racial characteristics and geographic location are vulnerable to certain climate change health impacts, raising environmental justice concerns. Factors that contribute to increased vulnerability to the health effects of climate change include limited resources to adapt to and recover from climate impacts, as well as existing health disparities (*e.g.,* higher prevalence of chronic health conditions such as diabetes).

II. Introduction: Overview and Context for This Proposal

A. Summary

Pursuant to section 231(a)(2)(A) of the Clean Air Act (CAA or Act), the Administrator proposes to find that greenhouse gas (GHG) emissions from aircraft engines used in certain types of aircraft (referred to as ''covered aircraft'' throughout this notice) contribute to air pollution that endangers public health and welfare. Covered aircraft would be those aircraft to which ICAO has agreed the international CO_2 standard would apply: [5] 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. Examples of covered aircraft would include smaller jet aircraft such as the Cessna Citation CJ2+ and the Embraer E170, up to and including the largest commercial jet aircraft—the Airbus A380 and the Boeing 747. Other examples of covered aircraft would include larger turboprop aircraft, such as the ATR 72 and the Bombardier Q400.

In this proposed action, the EPA relies primarily on the extensive scientific and technical evidence in the record supporting the 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) (collectively

[1] U.S. EPA, 2006: *EPA Peer Review Policy.* Available at *http://www.epa.gov/peerreview/* (Last accessed May 12, 2015).

[2] U.S. EPA, 2012: *EPA Peer Review Handbook, Third Edition.* Available at *http://www.epa.gov/peerreview/pdfs/peer_review_handbook_2012.pdf* (Last accessed May 12, 2015).

[3] U.S. EPA, 2015: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013,* 564 pp. Available at *http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html#fullreport*, (Last accessed May 12, 2015).

[4] 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) (''2009 Endangerment Finding''); 74 FR 18886 (April 24, 2009) (''Proposed 2009 Endangerment Finding'').

[5] ICAO, 2013: *CAEP/9 Agreed Certification Requirement for the Aeroplane CO2 Emissions Standards,* Circular (Cir) 337, AN/192, Available at: *http://www.icao.int/publications/catalogue/cat_2015_en.pdf.* The ICAO Circular 337 is found on page 85 of the catalog and is copyright protected; Order No. CIR337 (last accessed May 12, 2015.

referred to as the 2009 Endangerment Finding in this action). This includes the major, peer-reviewed scientific assessments that were used to address the question of whether GHGs in the atmosphere endanger public health and welfare, and on the analytical framework and conclusions upon which the EPA relied in making that finding. The Administrator's view is that the body of scientific evidence amassed in the record for the 2009 Endangerment Finding also compellingly supports an endangerment finding under CAA section 231(a). Furthermore, this proposed finding under section 231 reflects the EPA's careful consideration not only of the scientific and technical record for the 2009 Endangerment Finding, but also of science assessments released since 2009, which, as illustrated below, strengthen and further support the judgment that GHGs in the atmosphere may reasonably be anticipated to endanger public health and welfare. No information or analyses published since late 2009 suggest that it would be reasonable for the EPA to now reach a different or contrary conclusion for purposes of CAA section 231(a)(2)(A) than the Agency reached for purposes of section 202(a). However, as explained below, in proposing this finding for purposes of section 231, we are not reopening or revising our prior findings under CAA section 202.

The Administrator is proposing to define the ''air pollution'' referred to in section 231(a)(2)(A) of the CAA to be the mix of six well-mixed GHGs: CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. This is the same definition that was used for the finding for purposes of section 202(a). It is the Administrator's judgment that the total body of scientific evidence compellingly supports a positive endangerment finding that elevated concentrations of the six well-mixed GHGs constitute air pollution that endangers both the public health and the public welfare of current and future generations within the meaning of section 231(a) of the Clean Air Act.

Under section 231 of the CAA, the Administrator must also determine whether emissions of any air pollutant from a class or classes of aircraft engines cause or contribute to the air pollution that may reasonably be anticipated to endanger public health or welfare. Following the rationale outlined in the 2009 Endangerment Finding, the Administrator in this action is proposing to use the same definition of the air pollutant as was used for purposes of section 202(a) for purposes of making the cause or contribute determination under section 231(a)—that is, the aggregate group of the same six well-mixed GHGs. Based on the data summarized in section V, the Administrator is proposing to find that GHG emissions from aircraft engines used in covered aircraft, contribute to the air pollution that endangers public health and welfare under section 231(a).

The Administrator's proposed findings come in response to a citizen petition submitted by Friends of the Earth, Oceana, the Center for Biological Diversity, and Earthjustice (Petitioners) requesting that the EPA issue an endangerment finding and standards under section 231(a)(2)(A) of the Act for the GHG emissions from aircraft. The EPA is not proposing or taking action under any other provision of the CAA. Further, the EPA anticipates that ICAO will adopt a final CO_2 emissions standard in February 2016. This proposal, and any final endangerment and cause or contribute findings for aircraft engine GHG emissions, are also part of preparing for a possible subsequent domestic rulemaking process to adopt standards that are of at least equivalent stringency as the anticipated ICAO CO_2 standards. Once an international standard is finalized by ICAO, member states are then required to adopt standards that are of at least equivalent stringency to those set by ICAO. Section II. D provides additional discussion of the international aircraft standard-setting process.

B. Background Information Helpful to Understanding This Proposal

1. Greenhouse Gases and Their Effects

GHGs in the atmosphere effectively trap some of the Earth's heat that would otherwise escape to space. GHGs are both naturally occurring and anthropogenic. The primary GHGs directly emitted by human activities include CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Of these six gases, two (CO_2 and nitrous oxide) are emitted by aircraft engines.

These six gases, once emitted, remain in the atmosphere for decades to centuries. Thus, they become well mixed globally in the atmosphere and their concentrations accumulate when emissions exceed the rate at which natural processes remove them from the atmosphere. Observations of the Earth's globally averaged combined land and ocean surface temperature over the period 1880 to 2012 show a warming of 0.85 [0.65 to 1.06] degrees Celsius or 1.53 [1.17 to 1.91] degrees Fahrenheit.[6] The heating effect caused by the human-induced buildup of these and other GHGs in the atmosphere, plus other human activities (*e.g.,* land use change and aerosol emissions), is extremely likely (>95 percent likelihood) to be the cause of most of the observed global warming since the mid-20th century.[7] A detailed explanation of climate change and its impact on health, society, and the environment is included in the record for the 2009 Endangerment Finding. The relevant scientific information from that record has also been included in the docket for this proposed determination under CAA section 231 (EPA–HQ–OAR–02914–0828). Section IV of this preamble discusses this information, as well as information from the most recent scientific assessments, in the context of the Administrator's proposed endangerment finding under CAA section 231.

The U.S. transportation sector constitutes a meaningful part of total U.S. and global anthropogenic GHG emissions. In 2013, aircraft remained the single largest GHG-emitting transportation source not yet subject to any GHG regulations. Aircraft clearly contribute to U.S. transportation emissions, accounting for 11 percent of all U.S transportation GHG emissions and representing more than 3 percent of total U.S. GHG emissions in 2013.[8] Globally, U.S. aircraft GHG emissions represent 29 percent of all global aircraft emissions and 0.5 percent of total global GHG emissions. Section V of this preamble provides detailed information on aircraft GHG emissions in the context of the Administrator's proposed cause or contribute finding under CAA section 231.

2. Statutory Basis for This Proposal

Section 231(a)(2)(A) of the CAA states that ''The Administrator shall, from time to time, issue proposed emission standards applicable to the emission of any air pollutant from any class or classes of aircraft engines which in [her] judgment causes, or contributes to, air pollution which may reasonably be anticipated to endanger public health or welfare.''

[6] ''IPCC, 2013: *Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis.* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, 29 pp.

[7] Ibid.

[8] U.S. EPA, 2015: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013,* 564 pp. Available at *http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html#fullreport,* (last accessed May 12, 2015).

Before the Administrator may issue standards addressing emissions of GHGs under section 231, the Administrator must satisfy a two-step test. First, the Administrator must decide whether, in her judgment, the air pollution under consideration may reasonably be anticipated to endanger public health or welfare. Second, the Administrator must decide whether, in her judgment, emissions of an air pollutant from certain classes of aircraft engines cause or contribute to this air pollution.[9] If the Administrator answers both questions in the affirmative, she must issue standards under section 231. *See Massachusetts* v. *EPA,* 549 U.S. 497,533 (2007) (interpreting analogous provision in CAA section 202). Section III of this preamble summarizes the legal framework for this proposed action under CAA section 231. Typically, past endangerment and cause or contribute findings have been proposed concurrently with proposed standards under various sections of the CAA, including section 231. Comment has been taken on these proposed findings as part of the notice and comment process for the emission standards. *See, e.g.,* Rulemaking for non-road compression-ignition engines under section 213(a)(4) of the CAA, Proposed Rule at 58 FR 28809, 28813–14 (May 17, 1993), Final Rule at 59 FR 31306, 31318 (June 17, 1994); Rulemaking for highway heavy-duty diesel engines and diesel sulfur fuel under sections 202(a) and 211(c) of the CAA, Proposed Rule at 65 FR 35430 (June 2, 2000), and Final Rule 66 FR 5002 (January 18, 2001). However, there is no requirement that the Administrator propose the endangerment and cause or contribute findings concurrently with proposed standards. See 74 FR 66502 (December 26, 2001), (explaining that nothing in section 202(a) requires the EPA to propose or issue endangerment and cause or contribute findings in the same rulemaking, and that Congress left the EPA discretion to choose an approach that satisfied the requirements of section 202(a)). The same analysis applies to section 231(a)(2)(A), which is analogous to section 202(a). The EPA is choosing to propose these findings at this time for a number of reasons, including its previous commitment to issue such proposed findings in response to a 2007 citizens' petition.[10]

The Administrator is applying the rulemaking provisions of CAA section 307(d) to this action, pursuant to CAA section 307(d)(1)(V), which provides that the provisions of 307(d) apply to ''such other actions as the Administrator may determine.''[11] Any standard setting rulemaking under section 231 will also be subject to the notice and comment rulemaking procedures under 307(d), as provided in CAA section 307(d)(1)(F) (applying the provisions of 307(d) to the promulgation or revision of any aircraft emission standard under section 231). Thus, these proposed findings will be subject to the same rulemaking requirements that would apply if the proposed findings were part of a standard-setting rulemaking.

C. The EPA's Responsibilities Under the Clean Air Act

The CAA provides broad authority to combat air pollution to protect public health and welfare. Cars, trucks, construction equipment, airplanes, and ships, as well as a broad range of electric generation, industrial, commercial and other facilities, are subject to various CAA programs. Implementation of the Act over the past four decades has resulted in significant reductions in air pollution while the nation's economy has continued to grow.

1. The EPA's Regulation of Greenhouse Gases

In *Massachusetts* v. *EPA,* 549 U.S. 497 (2007), the Supreme Court found that GHGs are air pollutants that can be regulated under the CAA. The Court held that the Administrator must determine whether emissions of GHGs from new motor vehicles cause or contribute to air pollution which may reasonably be anticipated to endanger public health and/or welfare, or whether the science is too uncertain to make a reasoned decision. In making these decisions, the Administrator was bound by the provisions of section 202(a) of the CAA. The Supreme Court decision resulted from a petition for rulemaking under section 202(a) filed by more than a dozen environmental, renewable energy, and other organizations.

Following the Supreme Court decision, the EPA proposed (74 FR 18886, April 24, 2009) and then finalized (74 FR 66496, December 15, 2009) the 2009 Endangerment Finding, which can be summarized as follows:

- Endangerment Finding: The Administrator found that the then-current and projected concentrations of the six key well-mixed GHGs—CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride—in the atmosphere threaten the public health and welfare of current and future generations.
- Cause or Contribute Finding: The Administrator found that the combined emissions of these well-mixed GHGs from new motor vehicles and new motor vehicle engines contribute to the GHG pollution which threatens public health and welfare.

The findings did not themselves impose any requirements on industry or other entities. However, these findings compelled the EPA to promulgate GHG emission standards for new motor vehicles under section 202(a). Subsequently, in May 2010 the EPA, in collaboration with the National Highway Traffic Safety Administration (NHTSA), finalized Phase 1 GHG emission standards for light-duty vehicles (2012–2016 model years).[12] This was followed in August 2011 by adoption of the first-ever GHG emission standards for heavy-duty engines and vehicles (2014–2018 model years).[13] On August 29, 2012, the second phase of the GHG emission standards for light-duty vehicles (2017–2025 model years) was finalized further reducing GHG emissions from light-duty vehicles.[14] In 2014, the President directed the EPA and the Department of Transportation to set standards by March 2016 that further increase fuel efficiency and reduce GHG emissions from medium- and heavy-duty vehicles.[15]

[9] To clarify the distinction between air pollution and air pollutant, the air pollution is the atmospheric concentrations and can be thought of as the total, cumulative stock of GHGs in the atmosphere. The air pollutants, on the other hand, are the emissions of GHGs and can be thought of as the flow that changes the size of the total stock.

[10] Center for Biological Diversity, Center for Food Safety, Friends of the Earth, International Center for Technology Assessment, and Oceana, 2007: Petition for Rulemaking Under the Clean Air Act to Reduce the Emissions of Air Pollutants from Aircraft the Contribute to Global Climate Change, December 5. Available at *http://www.epa.gov/otaq/aviation.htm* (last accessed May 12, 2015).

[11] As the Administrator is applying the provisions of section 307(d) to this rulemaking under section 307(d)(1)(V), we need not determine whether those provisions would apply to this action under section 307(d)(1)(F).

[12] U.S. EPA, 2010: *Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule,* 75 FR 25324 (May 7, 2010).

[13] US EPA, 2011: *Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Final Rule,* 76 **Federal Register** 57106 (September 15, 2011).

[14] U.S. EPA, 2012: *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule,* 77 FR 62623 (October 15, 2012).

[15] Executive Office of the President, 2014: *Remarks by the President on Fuel Efficiency Standards of Medium and Heavy-Duty Vehicles,* Office of the Press Secretary, February 18. Available at: *http://www.whitehouse.gov/the-press-office/*

Continued

The GHG rules for cars and trucks have been supported by a broad range of stakeholders, including states, major automobile and truck manufacturers, and environmental and labor organizations. Together these new standards for cars and trucks are resulting in significant reductions in GHG emissions, and over the lifetime of these vehicles GHG emissions will have been reduced by 6 billion metric tons.[16 17]

On June 25, 2013, President Obama announced a Climate Action Plan that set forth a series of executive actions to further reduce GHGs, prepare the U.S. for the impacts of climate change, and lead international efforts to address global climate change.[18] As part of the Climate Action Plan, the President issued a Presidential Memorandum directing the EPA to work expeditiously to complete carbon pollution standards for the power sector.[19] In response, in January 2014, the EPA proposed carbon pollution standards for new electric utility generating units.[20] This was followed in June 2014, by proposed standards to address carbon pollution from modified and reconstructed power plants [21] and from existing power plants.[22]

In the Climate Action Plan, the President also indicated that the U.S. was working internationally to make progress in a variety of areas and specifically noted the progress being made by ICAO to develop global CO_2 emission standards for aircraft.[23] The proposed endangerment and cause or contribute findings for aircraft GHG emissions under section 231(a)(2)(A) of the CAA are a preliminary but necessary first step to begin to address GHG emissions from the aviation sector, the highest-emitting category of transportation sources that the EPA has not yet addressed. As presented in more detail in Section V of this preamble, total U.S. aircraft GHG emissions in 2013 represented 11 percent of GHG emissions from the U.S. transportation sector,[24] and in 2010, the latest year with complete global emissions data, U.S. aircraft GHG emissions represented 29 percent of global aircraft GHG emissions.[25 26] U.S. aircraft GHG emissions are projected to increase by almost 50 percent over the next two decades.[27] See section V of this preamble for more information about the data sources that compose the aircraft GHG emissions inventory.

2. Background on the Aircraft Petition, 2008 ANPR, and D.C. District Court Decision

Section 231(a)(2)(A) of the CAA directs the Administrator of the EPA to, from time to time, propose aircraft engine emissions standards applicable to the emission of any air pollutant from any classes of aircraft engines which in her judgment causes or contributes to air pollution which may reasonably be anticipated to endanger public health or welfare.

On December 5, 2007, Friends of the Earth, Oceana, the Center for Biological Diversity, Earthjustice, and others (Petitioners) sent a letter to the EPA petitioning the Agency to undertake rulemaking regarding GHG emissions from aircraft.[28] Specifically, Petitioners requested that the EPA make a finding that GHG emissions from aircraft engines ''may reasonably be anticipated to endanger public health and welfare'' and that the EPA promulgate standards for GHG emissions from aircraft.

Following the Supreme Court's decision in *Massachusetts* v. *EPA* in 2007, the EPA issued an ANPR in 2008 presenting information relevant to potentially regulating GHGs under the Act, and soliciting public comment on how to respond to the Court's ruling and the potential ramifications of the Agency's decision to regulate GHGs under the CAA. This ANPR described and solicited comment on numerous petitions the Agency had received to regulate GHG emissions from both stationary and mobile sources, including aircraft. 73 FR 44354, 44468–44473 (July 30, 2008). With regard to aircraft, the Agency sought comment on the impact of aircraft operations on GHG emissions and the potential for reductions in GHG emissions from these operations.

In response to the ANPR, the EPA received comments from a wide range of aviation sector stakeholders including industry trade groups, individual manufacturers, states and local governments, and nongovernmental organizations (NGOs). Industry groups and individual manufacturers stressed that fuel costs (and market forces) created an economic incentive to reduce fuel consumption and thus GHG emissions. One industry association indicated its commitment to achieve an additional 30 percent fuel efficiency improvement by 2025. Another commenter identified engine technologies that were improving fuel efficiency by more than 15 percent in the next generation of aircraft. With regard to CO_2 engine emissions standards, these commenters felt that

2014/02/18/remarks-president-fuel-efficiency-standards-medium-and-heavy-duty-vehicl (last accessed May 12, 2015).

[16] U.S. EPA. ''EPA and NHTSA Set Standards to Reduce Greenhouse Gases and *Improve Fuel Economy for Model Years 2017–2025 Cars and Light Trucks.*'' Office of Transportation and Air Quality Document No. EPA–420–F–12–051, August 2012. Available at *http://www.epa.gov/otaq/climate/documents/420f12051.pdf* (last accessed May 26, 2015). See also US EPA, 2012: *Regulatory Impact Analysis: Final Rulemaking for 2017–2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards and Corporation Average Fuel Economy Standards,* August, Document No. EPA–420–R–12–016, Table 7.4–2. Available at: *http://www.epa.gov/oms/climate/documents/420r12016.pdf* (last accessed May 12, 2015).

[17] 76 FR 57106 (September 15, 2011).

[18] Executive Office of the President, 2013: *The President's Climate Action Plan,* June 25. Available at: *http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf* (last accessed May 26, 2015).

[19] Executive Office of the President, 2013: *Presidential Memorandum—Power Sector Carbon Pollution Standards,* Office of the Press Secretary, June 25. Available at: *http://www.whitehouse.gov/the-press-office/2013/06/25/presidential-memorandum-power-sector-carbon-pollution-standards* (last accessed May 12, 2015).

[20] U.S. EPA, 2014: *Standards of Performance for Greenhouse Gas Emissions From New Stationary Sources: Electric Utility Generating Units; Proposed Rule,* 79 FR 1430 (January 8, 2014).

[21] U.S. EPA, 2014: *Carbon Pollution Standards for Modified and Reconstructed Stationary Sources: Electric Utility Generating Units; Proposed Rules,* 79 FR 34960 (June 18, 2014).

[22] U.S. EPA, 2014: *Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Proposed Rule,* 79 FR 34830 (June 18, 2014).

[23] Executive Office of the President, 2013: *The President's Climate Action Plan* at 21, June. Available at: *http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf* (last accessed May 12, 2015).

[24] U.S. EPA, 2015: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013,* 564 pp. Available at *http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html#fullreport* (last accessed May 12, 2015).

[25] Ibid.

[26] 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, pp. 599–670.

[27] As discussed in section V.B.2.c., fuel burn growth rates for air carriers and general aviation aircraft operating on jet fuel are projected to grow by 49 percent from 2010 to 2035, and this provides a scaling factor for growth in GHG emissions which would increase at a similar rate as the fuel burn by 2030, 2035, and 2040. FAA, 2015: *FAA Aerospace Forecast Fiscal Years 2015–2035,* 134 pp. Available at *https://www.faa.gov/about/office_org/headquarters_offices/apl/aviation_forecasts/aerospace_forecasts/2015–2035/media/2015_National_Forecast_Report.pdf* (last accessed May 12, 2015).

[28] Center for Biological Diversity, Center for Food Safety, Friends of the Earth, International Center for Technology Assessment, and Oceana, 2007: *Petition for Rulemaking Under the Clean air Act to Reduce the Emissions of Air Pollutants from Aircraft the Contribute to Global Climate Change,* December 5. Available at *http://www.epa.gov/otaq/aviation.htm* (last accessed May 12, 2015).

international CO_2 standards for aircraft engines were not necessary and that, if pursued, such standards would burden the industry and necessitate the development of new test procedures if CO_2 emissions standards were based on aircraft cruise conditions instead of landing and takeoff operations (LTO). Industry commenters also argued that other potential approaches to reducing aircraft related emissions, such as averaging of GHGs among existing aircraft fleets and cap-and-trade schemes as existed in the European Union, were beyond the scope of the EPA's authority under section 231 of the CAA. Finally, industry commenters noted that any program developed by the EPA should incentivize market forces and provide for flexibility.

State/local governments and NGO commenters felt strongly that the EPA had clear authority to find endangerment under section 231 and that there were multiple options to reduce aircraft emissions, so that the Agency must set a GHG emissions standard for aircraft engines as states were preempted from doing so under CAA section 233. These commenters also argued that GHG standards for aircraft engines could provide aircraft manufacturers the incentive to renew or redesign aircraft and to adopt advanced engines brought to market. In addition these commenters suggested that an engine GHG standard could be set as a function of thrust similar to ICAO's standard for oxides of nitrogen (NO_X) [29] and should also include provisions for an averaging, banking, and trading (ABT) program.[30] Some commenters also stated their support for fleet-wide (in-use fleet) emission reductions through a cap-and-trade system. Finally, these stakeholders stated that, absent the EPA rulemaking, quick international actions were unlikely and that the EPA should engage internationally to push for action on reducing CO_2 emissions from aircraft.

On July 31, 2008, Earthjustice, on behalf of Petitioners, notified the EPA of its intent to file suit under CAA section 304(a) against the EPA for the Agency's alleged unreasonable delay in responding to its aircraft petition and in making an endangerment finding under section 231. On June 11, 2010, Petitioners filed a complaint against the EPA in the U.S. District Court for the District of Columbia claiming that, among other things, the EPA had unreasonably delayed because it had failed to answer the 2007 Petition and to determine whether or not GHG emissions from aircraft cause or contribute to air pollution which may reasonably be anticipated to endanger public health and/or welfare.

The District Court found that while CAA section 231 generally confers broad discretion to the EPA in determining what standards to promulgate, section 231(a)(2)(A) imposed a nondiscretionary duty on the EPA to make a finding with respect to endangerment from aircraft GHG emissions. *Center for Biological Diversity, et al.* v. *EPA,* 794 F. Supp. 2d 151 (D.D.C. 2011). This ruling was issued in response to EPA's motion to dismiss the case on jurisdictional grounds and did not address the merits of the Plaintiffs' claims regarding the Agency's alleged unreasonable delay. Therefore, it did not include an order for the EPA to make such a finding by a certain date. In a subsequent ruling on the merits, the Court found that the Plaintiffs had not shown that EPA had unreasonably delayed in making an endangerment determination regarding GHG emissions from aircraft. *Center for Biological Diversity, et al.* v. *EPA,* No. 1:10–985 (D.D.C. March, 20, 2012). Thus, the Court did not find the EPA to be liable based on the Plaintiffs' claims and did not place the Agency under a remedial order to make an endangerment finding or to issue standards. The Plaintiffs did not appeal this ruling to the U.S. Court of Appeals for the D.C. Circuit.

The EPA issued a Response to the Aircraft Petition [31] on June 27, 2012 stating our intention to move forward with a proposed endangerment finding for aircraft GHG emissions under section 231, while explaining that it would take the Agency significant time to complete this action. The EPA explained that the Agency would not begin this effort until after the U.S. Court of Appeals completed its then-pending review of the previous section 202 Endangerment Finding, since the then-awaited ruling might provide important guidance for the EPA in conducting future GHG endangerment findings. The EPA further explained that after receiving the Court of Appeal's ruling, it would take at least 22 months from that point for the Agency to conduct an additional finding regarding aircraft GHG emissions.

Meanwhile, the Court upheld EPA's section 202 findings in a decision of a three-judge panel on June 26, 2012, and denied petitions for rehearing of that decision on December 20, 2012. *Coalition for Responsible Regulation, Inc.,* v. *EPA,* 684 F.3d 102 (D.C. Cir. 2012), reh'g denied 2012 U.S. App. LEXIS 26315, 25997 (D.C. Cir. 2012).[32] Given these rulings, we are proceeding with this proposed findings regarding aircraft engine GHG emissions as a further step toward responding to the Petition for Rulemaking.

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

The EPA and the Federal Aviation Administration (FAA) traditionally work within the standard-setting process of ICAO's Committee on Aviation Environmental Protection (CAEP) to establish international emission standards and related requirements. 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 equivalent to ICAO's standards where appropriate. This approach has been affirmed as reasonable by the U.S. Court of Appeals for the D.C. Circuit. *NACAA* v. *EPA,* 489 F.3d 1221, 1230–32 (D.C. Cir. 2007). After EPA promulgates aircraft engine emissions standards, CAA section 232 requires the FAA to issue subsequent regulations to ensure compliance with these standards when issuing certificates under its United States Code Title 49 authority. In exercising the EPA's standard-setting and FAA's enforcement authorities, we expect to proceed using a similar approach for the future CAA section 231 aircraft engine

[29] Sections II.D.1 and II.E provide an overview of the history ICAO's regulation of aircraft engine NO_X emissions from 1981 through 2012 and the EPA's adoption of equivalent aircraft engine NO_X standards under the CAA.

[30] ABT programs have been utilized in a number of Clean Air Act programs to provide greater flexibilities that lower overall costs by allowing a manufacturer to comply with performance standards through averaging emissions among the vehicles it manufactures. Companies that achieve extra pollution reductions can bank these as 'credits'' and then 'trade or sell' emission credits to other companies, typically those that face higher costs to control pollution. Well-designed ABT programs can sometimes achieve greater emissions reductions at less cost and provide incentives for technology innovation.

[31] U.S. EPA, 2012: *Memorandum in Response to Petition Regarding Greenhouse Gas Emissions from Aircraft,* June 14. Available at *http://www.epa.gov/otaq/aviation.htm* (last accessed May 12, 2015) and Docket EPA–HQ–OAR–2014–0828.

[32] Petitions for *certiorari* were filed in the Supreme Court, and the Supreme Court granted six of those petitions but ''agreed to decide only one question: ''Whether EPA permissibly determined that its regulation of greenhouse gas emissions from new motor vehicles triggered permitting requirements under the Clean Air Act for stationary sources that emit greenhouse gases''. *Utility Air Reg. Group* v. *EPA,* 134 S. Ct. 2427, 2438 (2014); *see also Virginia* v. *EPA,* 134 S. Ct. 418 (2013), *Pac. Legal Found.* v. *EPA,* 134 S. Ct. 418 (2013), and *CRR,* 134 S. Ct. 468 (2013) (all denying cert.). Thus, the Supreme Court did not disturb the D.C. Circuit's holding that affirmed the 2009 Endangerment Finding.

GHG standard (which may take the form of a CO_2 standard), provided the EPA issues final positive endangerment and cause or contribute findings under CAA section 231. This approach is contingent on ICAO's adoption of an international aircraft CO_2 standard that is consistent with CAA section 231 and is appropriate for domestic needs in the United States.

1. International Regulations and U.S. Obligations

As noted above, we have 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. ICAO is a United Nations (UN) specialized agency, established in 1944 by the Convention on International Civil Aviation (Chicago Convention), ''in order 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.'' [33] ICAO sets standards and regulations necessary 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 legally-enforceable national civil aviation regulations. The U.S. is currently one of 191 participating ICAO member States.[34] [35]

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. The Chicago Convention also recognizes that member States may adopt standards that are more stringent than those agreed upon by ICAO. Any member State which finds it impracticable to comply in all respects with any international standard or procedure, or which deems it necessary to adopt regulations or practices differing in any particular respect from those established by an international standard, is required to give immediate notification to ICAO of the differences between its own practice and that established by the international standard.[36]

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. Standards and Recommended Practices (SARPs) for the certification of aircraft noise and aircraft engine emissions are covered by Annex 16 of 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 greenhouse gas emissions on the global climate.

The Convention has a number of other features that govern international commerce. First, member States that wish to use aircraft in international transportation must adopt emissions standards and other recommended practices that are at least as stringent as ICAO's standards. Member States may ban the use of any aircraft within their airspace that does not meet ICAO standards.[37] Second, member States are required to recognize the airworthiness certificates of any State whose standards are at least as stringent as ICAO's standards, thereby assuring that aircraft of any member State will be permitted to operate in any other member State.[38] Third, to ensure that international commerce is not unreasonably constrained, a member State which elects to adopt more stringent domestic emission standards is obligated to notify ICAO of the differences between its standards and ICAO standards.[39]

ICAO's CAEP, which consists of Members and Observers from States, intergovernmental and non-governmental organizations representing 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.'' [40] CAEP is composed of various task groups, work groups, and other committees whose contributing members include atmospheric, economic, aviation, environmental, and other professionals interested in and knowledgeable about aviation and environmental protection. 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.

At CAEP meetings, the U.S. is represented by the FAA and plays an active role.[41] The EPA has historically been a principal participant in various ICAO/CAEP working groups and other international venues, assisting and advising FAA on aviation emissions, technology, and policy matters. In turn, the FAA assists and advises the EPA on

[33] ICAO, 2006: *Convention on International Civil Aviation, Ninth Edition,* Document 7300/9. Available at: *http://www.icao.int/publications/catalogue/cat_2015_en.pdf* (last accessed May 12, 2015).

The ICAO Document 7300 is found on page 1 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. 7300.

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

[35] There are currently 191 Contracting States according to ICAO's Web site: *www.icao.int* (last accessed May 12, 2015).

[36] ICAO, 2006: *Doc 7300-Convention on International Civil Aviation, Ninth edition,* Document 7300/9. Available at *http://www.icao.int/publications/catalogue/cat_2015_en.pdf* (last accessed May 12, 2015). The ICAO Document 7300 is found on page 1 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. 7300.

[37] ICAO, 2006: *Convention on International Civil Aviation, Article 87, Ninth Edition,* Document 7300/9. Available *at http://www.icao.int/publications/catalogue/cat_2015_en.pdf* (last accessed May 12, 2015). The ICAO Circular 337 is found on page 85 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. CIR337.

[38] ICAO, 2006: *Convention on International Civil Aviation, Article 33, Ninth Edition,* Document 7300/9. Available at *http://www.icao.int/publications/catalogue/cat_2015_en.pdf* (last accessed May 12, 2015). The ICAO Circular 337 is found on page 85 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. CIR337.

[39] ICAO, 2006: *Convention on International Civil Aviation, Article 38, Ninth Edition,* Document 7300/9. Available at *http://www.icao.int/publications/catalogue/cat_2015_en.pdf* (last accessed May 12, 2015). The ICAO Document 7300 is found on page 1 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. 7300.

[40] CAEP's terms of reference are available at *http://www.icao.int/environmental-protection/Pages/Caep.aspx#ToR* (last accessed May 12, 2015).

[41] Pursuant to the President's memorandum of August 11, 1960 (and related Executive Order No. 10883 from 1960), the Interagency Group on International Aviation (IGIA) was established to facilitate coordinated recommendations to the Secretary of State on issues pertaining to international aviation. The DOT/FAA is the chair of IGIA, and as such, the FAA represents the U.S. on environmental matters at CAEP.

aviation technology and certification matters. 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).[42 43]

The first international standards and recommended practices for aircraft engine emissions were recommended by CAEP's predecessor, the Committee on Aircraft Engine Emissions (CAEE), and adopted by ICAO in 1981.[44] These standards limited aircraft engine emissions of hydrocarbons, carbon monoxide, and 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.[45] These 1993 standards applied both to newly-certified turbofan engines, which are those engine models that received their initial type certificate after the effective date of the regulations—also referred to as newly-certified engines or new engine designs—and to in-production engines, but with different effective dates for newly-certified 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. The CAEP/4 standards applied only to new engine designs certified (or newly-certified engines) after December 31, 2003 (*i.e.,* unlike the CAEP/2 standards, the CAEP/4 requirements did not apply to in-production engines). In 2004, CAEP/6 recommended a 12 percent NO_X reduction, which ICAO approved in 2005.[46 47] The CAEP/6 standards applied to new engine designs certified after December 31, 2007. In 2010, CAEP/8 recommended a further tightening of the NO_X standards by 15 percent for new engine designs certified after December 31, 2013.[48 49] The Committee also recommended that the CAEP/6 standards be applied to in-production engines (eliminating the production of CAEP/4 compliant engines with the exception of spare engines). ICAO approved these recommendations in 2011, then equivalent standards (to CAEP/6 and CAEP/8 standards) were promulgated domestically in 2012 by the EPA in consultation with FAA.[50]

2. The International Community's Reasons for Addressing Aircraft GHG Emissions

In October 2010, the 37th Assembly (Resolution A37–19) of ICAO requested the development of an ICAO CO_2 emissions standard.[51] Also, Resolution A37–19 provided a framework towards the achievement of an environmentally sustainable future for international aviation. With this Resolution, the ICAO Assembly agreed to a global aspirational goal for international aviation of improving annual fuel efficiency by two percent and stabilizing CO_2 emissions at 2020 levels.[52] The Resolution included the following statements regarding ICAO policies and practices related to climate change.

—. . . ICAO and its member States recognize the importance of providing continuous leadership to international civil aviation in limiting or reducing its emissions that contribute to global climate change;
—Reemphasizing the vital role which international aviation plays in global economic and social development and the need to ensure that international aviation continues to develop in a sustainable manner;
—. . . the ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to achieve stabilization of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system; and
—Acknowledging that international aviation emissions, currently accounting for less than 2 per cent of total global CO_2 emissions, are projected to grow as a result of the continued development of the sector.

As the above statements indicate, reducing climate impacts of international aviation is a critical element of ICAO's strategic objective of achieving environmental protection and sustainable development of air transport. ICAO is currently pursuing a comprehensive set of measures to reduce aviation's climate impact, including alternative fuels, CO_2 emissions technology-based standards, operational improvements, and market based measures. The development and adoption of a CO_2 emissions standard is an important part of ICAO's comprehensive set of measures.

3. Relationship of the EPA's Proposed Endangerment and Cause or Contribute Findings to International Aircraft Standards

As described earlier, the EPA and the FAA work within the ICAO/CAEP standard setting process to establish international emission standards and related requirements. Under this approach international emission standards have first been adopted by

[42] ICAO, 2008: *Aircraft Engine Emissions,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Third Edition, July. Available at *http://www.icao.int/publications/catalogue/cat_2015_en.pdf* (last accessed May 12, 2015). The ICAO Circular 337 is found on page 85 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. CIR337.

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

[44] ICAO, 2008: *Aircraft Engine Emissions: Foreword,* International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Third Edition, July. Available at *http://www.icao.int/publications/catalogue/cat_2015_en.pdf* (last accessed May 12, 2015). The ICAO Annex 16 Volume II is found on page 19 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. AN16–2.

[45] CAEP conducts its work over a period of years. Each work cycle is numbered sequentially and that identifier is used to differentiate the results from one CAEP to another by convention. The first technical meeting on aircraft emission standards was CAEP's successor, *i.e.,* CAEE. The first meeting of CAEP, therefore, is referred to as CAEP/2.

[46] CAEP/5 did not address new aircraft engine emission standards.

[47] ICAO, 2008: *Aircraft Engine Emissions,* Annex 16, Volume II, Third Edition, July 2008, Amendment 5 effective on July 11, 2005. Available at *http://www.icao.int/publications/catalogue/cat_2015_en.pdf* (last accessed May 12, 2015). The ICAO Annex 16 Volume II is found on page 19 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. AN16–2.

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

[49] 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.

[50] ICAO, 2011: *Aircraft Engine Emissions,* Annex 16, Volume II, Third Edition, July 2008, Amendment 7 effective on July 18, 2011. Available at *http://www.icao.int/publications/catalogue/cat_2015_en.pdf* (last accessed May 12, 2015). The ICAO Annex 16 Volume II is found on page 19 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. AN16–2/E/10 (last accessed February 5, 2015). 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).

[51] A consolidated statement of continuing policies and practices related to environmental protection (known as Assembly Resolutions) is revised and updated by the Council every three years for adoption by the ICAO Assembly. ICAO, 2010: *Resolutions Adopted by the Assembly, 37th Session, Montreal, September 29–October 8, 2010,* Provisional Edition, November.

[52] The global aspirational goal for international aviation of improving annual fuel efficiency by 2 percent is for the annual international civil aviation in-service fleet. Fuel efficiency is measured on the basis of the volume of fuel used per revenue tonne kilometer performed. (ICAO, CAEP, *Aspirational Goals and Implementation Options,* HLM–ENV/09–WP/5, High-Level Meeting on International Aviation and Climate Change, Presented by the Secretariat, Montreal, October 7 to 9, 2009. Available at *http://www.icao.int/Meetings/AMC/MA/High%20Level%202009/hlmenv_wp005_en.pdf* (last accessed May 12, 2015).

ICAO (with U.S. participation and agreement), and subsequently the EPA has initiated rulemakings under CAA section 231 to establish domestic aircraft engine emission standards that are of at least equivalent stringency as ICAO's standards. This approach has been affirmed as reasonable by the U.S. Court of Appeals for the D.C. Circuit. *NACAA* v. *EPA,* 489 F.3d 1221, 1230–32 (D.C. Cir. 2007). In exercising the EPA's standard-setting authority, provided the EPA makes positive endangerment and cause or contribute findings under CAA section 231 and ICAO adopts an international aircraft CO_2 standard that is consistent with CAA section 231 and is appropriate for domestic needs in the United States, the EPA expects to proceed along a similar approach for the future CAA section 231 aircraft GHG standard (or aircraft CO_2 standard).

We anticipate that ICAO/CAEP will adopt a final aircraft CO_2 emissions standard in February 2016. This proposal, and any final endangerment and cause or contribute finding for aircraft GHG emissions, are part of preparing for the possible subsequent domestic rulemaking process to adopt standards that are of at least equivalent stringency as the anticipated ICAO CO_2 standards. These findings, which are factual and science-based, encompass a determination of whether GHG emissions from aircraft cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare. If positive findings are made, the EPA will be obligated under section 231 of the CAA to set emission standards applicable to GHG emissions from the classes of aircraft engines for which the EPA makes the cause or contribute finding. If positive findings are not made, the EPA will not have triggered its obligation to set GHG emission standards under CAA section 231.

The EPA has worked diligently over the past four years within the ICAO/CAEP process on a range of technical issues regarding aircraft CO_2 emission standards. The ANPR that accompanies this proposal, in Section VI, discusses the issues arising in the ongoing international proceedings and U.S. input to CAEP regarding the international CO_2 standard to help ensure transparency about this process. In addition, in the ANPR the EPA requests public comments on a variety of issues to assist the Agency in developing its position with regard to these issues and the aircraft engine GHG emission standards that it may potentially adopt under the CAA.

E. The EPA's Regulation of Aircraft Emissions

As required by the CAA, the EPA has been engaged in reducing harmful air pollution from aircraft engines for over 40 years. In 1973, the EPA began to regulate gaseous exhaust emissions, smoke, and fuel venting from aircraft engines.[53] We have occasionally 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. These ICAO requirements are generally referred to as CAEP/2 standards.[54] That action included new NO_X emission standards for newly manufactured commercial turbofan engines (as described earlier, those engines built after the effective date of the regulations that were already certified to pre-existing standards—also referred to as in-production engines)[55] and for newly-certified commercial turbofan engines (as described earlier, those engine models that received their initial type certificate after the effective date of the regulations—also referred to as new engine designs).[56] It also included a carbon monoxide emission standard for in-production commercial turbofan engines.[57] In 2005, we promulgated more stringent NO_X emission standards for newly-certified commercial turbofan engines.[58] 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-certified and in-production commercial and non-commercial turbofan aircraft engines, and these NO_X standards align with ICAO's CAEP/6 and CAEP/8 requirements that became effective in 2013 and 2014, respectively.[59 60]

The EPA's actions to regulate certain pollutants emitted from aircraft engines come directly from its authority in section 231 of the CAA, and we have aligned the U.S. emissions requirements with those promulgated by ICAO. In addressing CO_2 emissions, however, ICAO has moved to regulating a whole aircraft. This ICAO extension beyond pollutant emissions from engines to the whole aircraft was described in a 2013 ICAO circular.[61] Several factors are considered when addressing whole-aircraft CO_2 emissions, as the CO_2 emissions are influenced by aerodynamics, weight, and engine-specific fuel consumption. Since each of these factors may affect aircraft engine fuel consumption, they ultimately affect CO_2 emissions. Rather than viewing CO_2 as a measurable emission from engines, therefore, ICAO now addresses CO_2 emissions as a characteristic applicable to the entirety of the aircraft based on fuel consumption. In this proposed action, we are giving advance notice that the EPA may propose to adopt domestic GHG emission standards (which may take the form of CO_2 standards) for aircraft engines used in covered aircraft as an outgrowth of the international negotiations that commenced in 2010 under the auspices ICAO/CAEP. Such standards could then discharge the EPA's duties under CAA sections 231(a)(2)(A) and 231(a)(3), if triggered by final positive endangerment and cause or contribute findings, to ''issue proposed emission standards applicable to the emission of'' GHG

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

[54] 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.

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

[56] In the existing EPA regulations, 40 CFR part 87, newly-certified 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.

[57] 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).

[58] U.S. EPA, 2005: *Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures; Final Rule,* 70 FR 2521 (November 17, 2005).

[59] 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).

[60] While ICAO's standards were not limited to ''commercial'' aircraft engines, our 1997 standards were explicitly limited to commercial engines, as our finding that NO_X and carbon monoxide emissions from aircraft 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 Section 231(a)(2)(A) of the Clean Air Act to include such emissions from both commercial and non-commercial aircraft engines based on the physical and operational similarities between commercial and noncommercial civilian aircraft and to bring our standards into full alignment with ICAO's.

[61] ICAO, 2013: *CAEP/9 Agreed Certification Requirement for the Aeroplane CO_2 Emissions Standard*, Circular (Cir) 337, AN/192. Available at *http://www.icao.int/publications/catalogue/cat_2015_en.pdf* (last accessed May 12, 2015). The ICAO Circular 337 is found on page 85 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. CIR337.

from aircraft engines and to issue final ''regulations with such modifications as [she] deems appropriate.''

III. Legal Framework for This Action

The EPA has previously made an endangerment finding for GHGs under Title II of the CAA, in the 2009 Endangerment Finding for section 202(a) source categories. In the 2009 Endangerment Finding, the EPA explained its legal framework for making an endangerment finding under section 202(a) of the CAA (74 FR 18886, 18890–94 (April 24, 2009), and 74 FR 66496, 66505–10 (December 15, 2009)). The text in section 202(a) that was the basis for the 2009 Endangerment Finding addresses ''the emission of any air pollutant from any class or classes of new motor vehicles or new motor vehicle engines, which in [the Administrator's] judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare.'' Similarly, section 231(a)(2)(A) concerns ''the emission of any air pollutant from any class or classes of aircraft engines which in [the Administrator's] judgment causes, or contributes to, air pollution which may reasonably be anticipated to endanger public health or welfare.'' Thus, the text of the CAA section concerning aircraft emissions in section 231(a)(2)(A) mirrors the text of CAA section 202(a) that was the basis for the 2009 Endangerment Finding.

The EPA's approach in the 2009 Endangerment Finding (described below in Sections III.A and III.B) was affirmed by the U.S. Court of Appeals for the D.C. Circuit in *Coalition for Responsible Regulation, Inc.* v. *EPA,* 684 F.3d 102 (D.C. Cir. 2012), reh'g denied 2012 U.S. App. LEXIS 26313, 26315, 25997 (D.C. Cir 2012) (*CRR*). In particular, the D.C. Circuit ruled that the 2009 Endangerment Finding (including the agency's denial of petitions for reconsideration of that Finding) was not arbitrary or capricious, was consistent with the U.S. Supreme Court's decision in *Massachusetts* v. *EPA* and the text and structure of the CAA, and was adequately supported by the administrative record. *CRR,* 684 F.3d at 116–128. The D.C. Circuit found that the EPA had based its decision on ''substantial scientific evidence'' and noted that the EPA's reliance on major scientific assessments was consistent with the methods that decision-makers often use to make a science-based judgment. *Id.* at 120–121. Petitions for certiorari were filed in the Supreme Court, and the Supreme Court granted six of those petitions but ''agreed to decide only one question: 'Whether EPA permissibly determined that its regulation of greenhouse gas emissions from new motor vehicles triggered permitting requirements under the Clean Air Act for stationary sources that emit greenhouse gases.' '' *Utility Air Reg. Group* v. *EPA,* 134 S. Ct. 2427, 2438 (2014); see also *Virginia* v. *EPA,* 134 S. Ct. 418 (2013), *Pac. Legal Found.* v. *EPA,* 134 S. Ct. 418 (2013), and *CRR,* 134 S. Ct. 468 (2013) (all denying cert.). Thus, the Supreme Court did not disturb the D.C. Circuit's holding that affirmed the 2009 Endangerment Finding. Accordingly, the Agency proposes that it is reasonable to use that same approach under section 231(a)(2)(A)'s similar endangerment text, and as explained in the following discussion, is acting consistently with that judicially sanctioned framework for purposes of this proposed section 231 finding.

Two provisions of the CAA govern this proposal. Section 231(a)(2)(A) sets forth a two-part predicate for regulatory action under that provision: Endangerment and cause or contribute. Section 302 of the Act contains definitions of the terms ''air pollutant'' and ''welfare'' used in section 231(a)(2)(A). These statutory provisions are discussed below.

A. Section 231(a)(2)(A)—Endangerment and Cause or Contribute

As noted above, section 231(a)(2)(A) of the CAA (like section 202(a)) calls for the Administrator to exercise her judgment and make two separate determinations: First, whether the relevant kind of air pollution—here, GHGs—may reasonably be anticipated to endanger public health or welfare, and second, whether emissions of any air pollutant from classes of the sources in question (aircraft engines under section 231 and new motor vehicles or engines under section 202) cause or contribute to this air pollution.[62]

The Administrator interprets the two-part test required under section 231(a)(2)(A) as being the same as that explained in the 2009 Endangerment Finding. (*See* 74 FR 66505–06, December 15, 2009.) As in the section 202(a) context, this analysis entails a scientific judgment by the Administrator about the potential risks posed by GHG emissions to public health and welfare. *See CRR,* 684 F.3d at 117–118.[63]

In making this scientific judgment, the Administrator is guided by five principles. First, the Administrator is required to protect public health and welfare. She is not asked to wait until harm has occurred but instead must be ready to take regulatory action to prevent harm before it occurs.[64] The Administrator is thus to consider both current and future risks.

Second, the Administrator is to exercise judgment by weighing risks, assessing potential harms, and making reasonable projections of future trends and possibilities. It follows that when exercising her judgment the Administrator balances the likelihood and severity of effects. This balance involves a sliding scale: On one end the severity of the effects may be significant, but the likelihood low, while on the other end the severity may be less significant, but the likelihood high.[65] At different points along this scale, the Administrator is permitted to find endangerment. Accordingly, the Administrator need not set a precise or minimum threshold of risk or harm as part of making an endangerment finding, but rather may base her determination on '' 'a lesser risk of greater harm . . . or a greater risk of lesser harm' or any combination in between.'' *CRR,* 684 F.3d at 123 (quoting *Ethyl Corp.* v. *EPA,* 541 F.2d, 1, 18 (D.C. Cir. 1976)).

Third, because scientific knowledge is constantly evolving, the Administrator may be called upon to make decisions while recognizing the uncertainties and limitations of the data or information available, as risks to public health or welfare may involve the frontiers of scientific or medical knowledge.[66] At the same time, the Administrator must exercise reasoned decision making, and avoid speculative inquiries.

Fourth, the Administrator is to consider the cumulative impact of sources of a pollutant in assessing the risks from air pollution, and is not to look only at the risks attributable to a single source or class of sources. We additionally note that in making an endangerment finding, the Administrator is not limited to

[62] *See CRR,* 684 F.3d at 117 (explaining two-part analysis under section 202(a)).

[63] When agencies such as the EPA make determinations based on review of scientific data within their technical expertise, those decisions are given an ''extreme degree of deference'' by the D.C. Circuit, and as that court noted in reviewing the 2009 endangerment finding, ''although we perform a searching and careful inquiry into the facts underlying the agency's decisions, we will presume the validity of the agency action as long as a rational basis for it is presented.'' *CRR,* 684 F.3d at 120 (internal citations and marks omitted).

[64] *See id.* at 121–122.

[65] *See id.* at 122–123 (noting that the § 202(a)(1) inquiry ''necessarily entails a case-by-case, sliding scale approach'' because endangerment is '' 'composed of reciprocal elements of risk and harm, or probability and severity' '' (quoting *Ethyl Corp.* v. *EPA,* 541 F.2d, 1, 18 (D.C. Cir. 1976)).

[66] See *id.* at 121–122.

considering only those impacts that can be traced to the amount of air pollution directly attributable to the GHGs emitted by the subject source classes. Such an approach would collapse the two prongs of the test by requiring that any climate change impacts upon which an endangerment determination is made result solely from the GHG emissions of aircraft. *See* 74 FR 66542, December 15, 2009 (explaining the same point in the context of analogous language in section 202(a)). Similarly, the Administrator is not, in making the endangerment and cause or contribute findings, to consider the effect of emissions reductions from the resulting standards.[67] The threshold endangerment and cause or contribute criteria are separate and distinct from the standard setting criteria that apply if the threshold findings are met, and they serve a different purpose. Indeed, the more serious the endangerment to public health and welfare, the more important it may be that action be taken to address the actual or potential harm even if no one action alone can solve the problem, and a series of actions is called for.

Fifth, the Administrator is to consider the risks to all parts of our population, including those who are at greater risk for reasons such as increased susceptibility to adverse health effects. If vulnerable subpopulations are especially at risk, the Administrator is entitled to take that point into account in deciding the question of endangerment. Here too, both likelihood and severity of adverse effects are relevant. As explained previously in the 2009 Endangerment Finding and as reiterated below for this proposed section 231 finding, vulnerable subpopulations face serious health risks as a result of climate change.

As the Supreme Court recognized in *Massachusetts* v. *EPA,* 549 U.S. at 534, the EPA may make an endangerment finding despite the existence of ''some residual uncertainty'' in the scientific record. *See also CRR,* 684 F.2d at 122. Thus, this framework recognizes that regulatory agencies such as the EPA must be able to deal with the reality that ''[m]an's ability to alter his environment has developed far more rapidly than his ability to foresee with certainty the effects of his alterations.'' *See Ethyl Corp* v. *EPA,* 541 F.2d 1, 6 (D.C. Cir.), cert. denied 426 U.S. 941 (1976). Both ''the Clean Air Act 'and common sense * * * demand regulatory action to prevent harm, even if the regulator is less than certain that harm is otherwise inevitable.' '' *See Massachusetts* v. *EPA,* 549 U.S. at 506, n.7 (citing *Ethyl Corp.*); *see also CRR,* 684 F.3d at 121–122.

In the 2009 Endangerment Finding, the Administrator recognized that the scientific context for an action addressing climate change was unique at that time because there was a very large and comprehensive base of scientific information that had been developed over many years through a global consensus process involving numerous scientists from many countries and representing many disciplines. 74 FR 66506, December 15, 2009. That informational base has since grown. The Administrator also previously recognized that there are varying degrees of uncertainty across many of these scientific issues, which remains true. It is in this context that she is exercising her judgment and applying the statutory framework in this proposed section 231 finding. Further discussion of the language in section 231(a)(2)(A), and parallel language in 202(a), is provided below to explain more fully the basis for this interpretation, which the D.C. Circuit upheld in the 202(a) context.

1. The Statutory Language

The interpretation described above flows from the statutory language itself. The phrase ''may reasonably be anticipated'' and the term ''endanger'' in section 231(a)(2)(A) (as in section 202(a)) authorize, if not require, the Administrator to act to prevent harm and to act in conditions of uncertainty. They do not limit her to merely reacting to harm or to acting only when certainty has been achieved; indeed, the references to anticipation and to endangerment imply that to fail to look to the future or to less than certain risks would be to abjure the Administrator's statutory responsibilities. As the D.C. Circuit explained, the language ''may reasonably be anticipated to endanger public health or welfare'' in CAA § 202(a) requires a ''precautionary, forward-looking scientific judgment about the risks of a particular air pollutant, consistent with the CAA's precautionary and preventive orientation.'' *CRR,* 684 F.3d at 122 (internal citations omitted). The court determined that ''[r]equiring that EPA find 'certain' endangerment of public health or welfare before regulating greenhouse gases would effectively prevent EPA from doing the job that Congress gave it in § 202(a)—utilizing emission standards to prevent reasonably anticipated endangerment from maturing into concrete harm.'' *Id.* The same language appears in section 231(a)(2)(A), and the same interpretation applies in that context.

Moreover, by instructing the Administrator to consider whether emissions of an air pollutant cause or contribute to air pollution in the second part of the two-part test, the Act makes clear that she need not find that emissions from any one sector or class of sources are the sole or even the major part of an air pollution problem. The use of the term ''contribute'' clearly indicates that such emissions need not be the sole or major cause of the pollution. Finally, the phrase ''in [her] judgment'' authorizes the Administrator to weigh risks and to consider projections of future possibilities, while also recognizing uncertainties and extrapolating from existing data.

Finally, when exercising her judgment in making both the endangerment and cause-or-contribute findings, the Administrator balances the likelihood and severity of effects. Notably, the phrase ''in [her] judgment'' modifies both ''may reasonably be anticipated'' and ''cause or contribute.''

2. How the Origin of the Current Statutory Language Informs the EPA's Interpretation of Section 231(a)(2)(A)

In the proposed and final 2009 Endangerment Finding, the EPA explained that when Congress revised the section 202(a) language that governed that finding, along with other provisions, as part of the 1977 amendments to the CAA, it was responding to decisions issued by the D.C. Circuit in *Ethyl Corp.* v. *EPA* regarding the pre-1977 version of section 211(c) of the Act. 74 FR 18891, (April 24, 2009); *see also* 74 FR 66506, (December 15, 2009). Section 231 was one of those other CAA provisions included in the 1977 amendments; therefore, the Agency's discussion for the 2009 Endangerment Finding regarding the history of section 202 and how it supports the EPA's approach is also relevant for section 231. The legislative history of those amendments, particularly the report by the House Committee on Interstate and Foreign Commerce, demonstrates that the EPA's interpretation of the section 231(a)(2)(A) language as set forth here in support of the Agency's section 231 finding (which is the same as its interpretation of the parallel language in section 202(a) as explained in the 2009 Endangerment Finding), is fully consistent with Congress' intention in crafting these provisions. See H.R. Rep. 95–294 (1977),

[67] As the D.C. Circuit explained in reviewing the 2009 Endangerment Finding under analogous language in section 202(a): ''At bottom, § 202(a)(1) requires EPA to answer only two questions: Whether particular 'air pollution'—here, greenhouse gases—'may reasonably be anticipated to endanger public health or welfare,' and whether motor-vehicle emissions 'cause, or contribute to' that endangerment.'' *CRR,* 648 F.3d at 117.

as reprinted in 4 A Legislative History of the Clean Air Act Amendments of 1977 (1978) at 2465 (hereinafter LH).[68]

The legislative history clearly indicates that the House Committee believed the *Ethyl Corp.* decisions posed several ''crucial policy questions'' regarding the protection of public health and welfare. H.R. Rep. 95–294 at 48, 4 LH at 2515.[69] The following paragraphs summarize the *en banc* decision in *Ethyl Corp.* v. *EPA* and describe how the House Committee revised the endangerment language in the 1977 amendments to the CAA to serve several purposes consistent with that decision. In particular, the language: (1) Emphasizes the preventive or precautionary nature of the CAA[70]; (2) authorizes the Administrator to reasonably project into the future and weigh risks; (3) assures the consideration of the cumulative impact of all sources; (4) instructs that the health of susceptible individuals, as well as healthy adults, should be part of the analysis; and (5) indicates an awareness of the uncertainties and limitations in information available to the Administrator. H.R. rep. 95–294 at 49–50, 4 LH 2516–17.[71]

In revising the statutory language, Congress relied heavily on the *en banc* decision in *Ethyl Corp.* v. *EPA,* which reversed a 3-judge panel opinion regarding an EPA rule restricting the content of lead in leaded gasoline.[72] After reviewing the relevant facts and law, the full court evaluated the statutory language at issue to see what level of ''certainty [was] required by the Clean Air Act before EPA may act.'' 541 F.2d at 7.

The petitioners argued that the statutory language ''will endanger'' required proof of actual harm, and that the actual harm had to come from emissions from the fuels in and of themselves. *Id.* at 12, 29. The *en banc* court rejected this approach, finding that the term ''endanger'' allowed the Administrator to act when harm is threatened, and did not require proof of actual harm. *Id.* at 13. ''A statute allowing for regulation in the face of danger is, necessarily, a precautionary statute.'' *Id.* Optimally, the court held, regulatory action would not only precede, but prevent, a perceived threat. *Id.*

The court also rejected petitioner's argument that any threatened harm must be ''probable'' before regulation was authorized. Specifically, the court recognized that danger ''is set not by a fixed probability of harm, but rather is composed of reciprocal elements of risk and harm, or probability and severity.'' *Id.* at 18. Next, the court held that the EPA's evaluation of risk is necessarily an exercise of judgment, and that the statute did not require a factual finding. *Id.* at 24. Thus, ultimately, the Administrator must ''act, in part on 'factual issues,' but largely 'on choices of policy, on an assessment of risks, [and] on predictions dealing with matters on the frontiers of scientific knowledge * * *.'' *Id.* at 29 (citations omitted). Finally, the *en banc* court agreed with the EPA that even without the language in section 202(a) (which is also in section 231(a)(2)(A)) regarding ''cause or contribute to,'' it was appropriate for the EPA to consider the cumulative impact of lead from numerous sources, not just the fuels being regulated under section 211(c). *Id.* at 29–31.

The dissent in the original *Ethyl Corp.* decision and the en banc opinion were of ''critical importance'' to the House Committee which proposed the revisions to the endangerment language in the 1977 amendments to the CAA. H.R. Rep. 95–294 at 48, 4 LH at 2515. The Committee addressed those questions with the language that now appears in section 231(a)(2)(A) and several other CAA provisions—''emission of any air pollutant * * * which in [the Administrator's] judgment causes, or contributes to, air pollution which may reasonably be anticipated to endanger public health or welfare.''

As noted above in section III.A.1, the phrase ''in [her] judgment'' calls for the Administrator to make a comparative assessment of risks and projections of future possibilities, consider uncertainties, and extrapolate from limited data. Thus, the Administrator must balance the likelihood of effects with the severity of the effects in reaching her judgment. The Committee emphasized that the Administrator's exercise of ''judgment''[73] may include making projections, assessments and estimates that are reasonable, as opposed to a speculative or '' 'crystal ball' inquiry.'' Moreover, procedural safeguards apply to the exercise of judgment, and final decisions are subject to judicial review. Also, the phrase ''in [her] judgment'' modifies both the phrases ''cause and contribute'' and ''may reasonably be anticipated,'' as discussed above. H.R. Rep. 95–294 at 50–51, 4 LH at 2517–18.

As the Committee further explained, the phrase ''may reasonably be anticipated'' points the Administrator in the direction of assessing current and future risks rather than waiting for proof of actual harm. This phrase is also intended to instruct the Administrator to consider the limitations and difficulties inherent in information on public health and welfare. H.R. Rep. 95–294 at 51, 4 LH at 2518.[74]

Finally, the phrase ''cause or contribute'' ensures that all sources of the contaminant which contribute to air pollution are considered in the endangerment analysis (*e.g.,* not a single source or category of sources). It is also intended to require the Administrator to consider all sources of exposure to a pollutant (for example, food, water, and air) when determining risk. *Id.*

3. Additional Considerations for the Cause or Contribute Analysis

By instructing the Administrator to consider whether emissions of an air pollutant cause or contribute to air pollution, the statute is clear that she need not find that emissions from any one sector or class of sources are the sole or even the major part of an air pollution problem. The use of the term

[68] The committee explained that its action addressed not only section 211(c)(1)(A) but rather the entire proposal, and would thus apply its interpretation to all other sections of the Act relating to public health protection. 4 LH at 2516. It also noted that it had used the same basic formulation in section 202 and section 231, as well as in other sections. *Id.* at 2517.

[69] The Supreme Court recognized that the current language in section 202(a)(1), which uses the same formulation as that in section 231(a)(2)(A), is ''more protective'' than the 1970 version that was similar to the section 211 language before the D.C. Circuit in *Ethyl Corp. Massachusetts* v. *EPA,* 549 U.S. at 506, fn 7.

[70] *See* H.R. Rep. 95–294 at 49, 4 LH at 2516 (''To emphasize the preventive or precautionary nature of the Act, *i.e.* to assure that regulatory action can effectively prevent harm before it occurs'').

[71] Congress also standardized this language across the various sections of the CAA which address emissions from both stationary and mobile sources. H.R. Rep. 95–294 at 50, 4 LH at 2517; section 401 of the CAA Amendments of 1977.

[72] At the time of the 1973 rules requiring the reduction of lead in leaded gasoline, section 211(c)(1)(A) of the CAA stated that the Administrator may promulgate regulations that: ''Control or prohibit the manufacture, introduction into commerce, offering for sale, or sale of any fuel or fuel additive for use in a motor vehicle or motor vehicle engine (A) if any emissions product of such fuel or fuel additive will endanger the public health or welfare * * *.'' CAA 211(c)(1)(A) (1970).

[73] Throughout this Notice under CAA section 231, as throughout the previous Notices concerning the 2009 Endangerment Finding under section 202, the judgments on endangerment and cause or contribute are described as a finding or findings. This is for ease of reference only, and is not intended to imply that the Administrator's judgment is solely a fact finding exercise; rather, the Administrator's exercise of judgment is to consider and weigh multiple factors when applying the scientific information to the statutory criteria.

[74] Thus, the statutory language does not require that the EPA prove the effects of climate change ''beyond a reasonable doubt.'' Indeed, such an approach is inconsistent with the concepts of reasonable anticipation and endangerment embedded in the statute. *See also CRR,* 684 F.3d at 121–122.

contribute clearly indicates a lower threshold than the sole or major cause.

Moreover, like the section 202(a) language that governed the 2009 Endangerment Finding, the statutory language in section 231(a)(2)(A) does not contain a modifier on its use of the term ''contribute.'' Unlike other CAA provisions, it does not require ''significant'' contribution. Compare, *e.g.,* CAA sections 111(b); 213(a)(2), (4). Congress made it clear that the Administrator is to exercise her judgment in determining contribution, and authorized regulatory controls to address air pollution even if the air pollution problem results from a wide variety of sources. While the endangerment test looks at the entire air pollution problem and the risks it poses, the cause or contribute test is designed to authorize the EPA to identify and then address what may well be many different sectors, classes, or groups of sources that are each part of the problem.

As explained for the 2009 Endangerment Finding, the D.C. Circuit has discussed the concept of contribution in the CAA, and its case law supports the EPA's interpretation that the level of contribution need not be significant. 74 FR 66542, December 15, 2009. In *Catawba County* v. *EPA,* 571 F.3d 20 (D.C. Cir. 2009), the court upheld EPA's PM[2.5] attainment and nonattainment designation decisions, analyzing CAA section 107(d), which requires EPA to designate an area as nonattainment if it ''contributes to ambient air quality in a nearby area'' not attaining the national ambient air quality standards. *Id.* at 35. The court noted that it had previously held that the term ''contributes'' is ambiguous in the context of CAA language. *See EDF* v. *EPA,* 82 F.3d 451, 459 (D.C. Cir. 1996). ''[A]mbiguities in statutes within an agency's jurisdiction to administer are delegations of authority to the agency to fill the statutory gap in reasonable fashion.'' 571 F.3d at 35 (citing *Nat'l Cable & Telecomms. Ass'c* v. *Brand X Internet Servs,* 545 U.S. 967, 980 (2005)). The court then proceeded to consider and reject petitioners' argument that the verb ''contributes'' in CAA section 107(d) necessarily connotes a significant causal relationship. Specifically, the D.C. Circuit again noted that the term is ambiguous, leaving it to EPA to interpret in a reasonable manner. In the context of this discussion, the court noted that ''a contribution may simply exacerbate a problem rather than cause it * * *.'' 571 F.3d at 39.

This is consistent with the D.C. Circuit's discussion of the concept of contribution in the context of CAA section 213 and rules for nonroad vehicles in *Bluewater Network* v. *EPA,* 370 F.3d 1 (D.C. Cir. 2004). In that case, industry argued that section 213(a)(3) requires a finding of a significant contribution before the EPA can regulate, while the EPA's view was that the CAA requires a finding only of contribution. *Id.* at 13. Section 213(a)(3), like section 231(a)(2)(A), is triggered by a finding that certain sources ''cause, or contribute to,'' air pollution, while an adjacent provision, section 213(a)(2), is triggered by a finding of a ''significant'' contribution. The court looked at the ''ordinary meaning of 'contribute' '' when upholding the EPA's reading. After referencing dictionary definitions of ''contribute,'' the court also noted that ''[s]tanding alone, the term has no inherent connotation as to the magnitude or importance of the relevant 'share' in the effect; certainly it does not incorporate any 'significance' requirement.'' 370 F.3d at 13.[75] The court found that the bare ''contribute'' language invests the Administrator with discretion to exercise judgment regarding what constitutes a sufficient contribution for the purpose of making a cause or contribute finding. *Id.* at 14.[76]

Like the statutory language considered in *Catawba County* and *Bluewater Network,* as well as the section 202(a) language that governed the Agency's previous findings for GHGs emitted by other types of mobile sources, section 231(a)(2)(A) refers to contribution and does not specify that the contribution must be significant before an affirmative finding can be made. To be sure, any finding of a ''contribution'' requires some threshold to be met; a truly trivial or *de minimis* ''contribution'' might not count as such. The Administrator therefore has ample discretion in exercising her reasonable judgment and determining whether, under the circumstances presented, the cause or contribute criterion has been met.[77] As noted above, in addressing provisions in section 202(a), the D.C. Circuit has explained that the Act at the endangerment finding step did not require the EPA to identify a precise numerical value or ''a minimum threshold of risk or harm before determining whether an air pollutant endangers.'' *CRR,* 684 F.3d at 122–123. Accordingly, EPA ''may base an endangerment finding on 'a lesser risk of greater harm . . . or a greater risk of lesser harm' or any combination in between.'' *Id.* (quoting *Ethyl Corp.,* 541 F.2d at 18). Recognizing the substantial record of empirical data and scientific evidence that the EPA relied upon in the 2009 Endangerment Finding, the court determined that its ''failure to distill this ocean of evidence into a specific number at which greenhouse gases cause 'dangerous' climate change is a function of the precautionary thrust of the CAA and the multivariate and sometimes uncertain nature of climate science, not a sign of arbitrary or capricious decision-making.'' *Id.* at 123. As the language in section 231(a)(2)(A) is analogous to that in section 202(a), it is clearly reasonable to apply this interpretation to the endangerment determination under section 231(a)(2)(A). Moreover, the logic underlying this interpretation supports the general principle that under CAA section 231 the EPA is not required to identify a specific minimum threshold of contribution from potentially subject source categories in determining whether their emissions ''cause or contribute'' to the endangering air pollution. The reasonableness of this principle is further supported by the fact that section 231 does not impose on the EPA a requirement to find that such contribution is ''significant,'' let alone the sole or major cause of the endangering air pollution. This context further supports the EPA's interpretation that section 231(a)(2)(A) requires some level of contribution that, while exceeding *de minimis* or trivial thresholds, does not need to rise to a pre-determined numerical level of significance.

In addition, when exercising her judgment in making a cause or contribute determination, the Administrator not only considers the cumulative impact, but also looks at the totality of the circumstances (*e.g.,* the air pollutant, the air pollution, the nature of the endangerment, the type or classes of sources at issue, the number of sources in the source sector or class, and the number and type of other source sectors or categories that may emit the air

[75] Specifically, the decision noted that '' 'contribute' means simply 'to have a share in any act or effect,' Webster's Third New International Dictionary 496 (1993), or 'to have a part or share in producing,' 3 Oxford English Dictionary 849 (2d ed. 1989).'' *Id.* at 13.

[76] The court explained, ''[t]he repeated use of the term 'significant' to modify the contribution required for all nonroad vehicles, coupled with the omission of this modifier from the 'cause, or contribute to' finding required for individual categories of new nonroad vehicles, indicates that Congress did not intend to require a finding of 'significant contribution' for individual vehicle categories.'' *Id.* at 13.

[77] Section V discusses the evidence in this case that supports the proposed finding of contribution. The EPA need not determine at this time the circumstances in which emissions would be trivial or de minimis and would not warrant a finding of contribution.

pollutant) when determining whether the emissions ''justify regulation'' under the CAA. *See Catawba County,* 571 F.3d at 39 (discussing EPA's interpretation of the term ''contribute'' under CAA § 107(d) and finding it reasonable for the agency to adopt a totality of the circumstances approach); *see also* 74 FR at 66542, (December 15, 2009). Further discussion of this issue can be found in sections IV and V of this preamble.

B. Air Pollutant, Public Health and Welfare

The CAA defines both ''air pollutant'' and ''welfare.'' Air pollutant is defined as: ''Any air pollution agent or combination of such agents, including any physical, chemical, biological, radioactive (including source material, special nuclear material, and byproduct material) substance or matter which is emitted into or otherwise enters the ambient air. Such term includes any precursors to the formation of any air pollutant, to the extent the Administrator has identified such precursor or precursors for the particular purpose for which the term 'air pollutant' is used.'' CAA section 302(g). Greenhouse gases fit well within this capacious definition. See *Massachusetts* v. *EPA,* 549 U.S. at 532. They are ''without a doubt'' physical chemical substances emitted into the ambient air. *Id.* at 529. Section V below contains further discussion of the ''air pollutant'' for purposes of this section 231 proposed contribution finding, which uses the same definition of air pollutant as the EPA adopted for purposes of the 2009 Endangerment Finding.

Regarding ''welfare,'' the CAA states that ''[a]ll language referring to effects on welfare includes, but is not limited to, effects on soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being, whether caused by transformation, conversion, or combination with other air pollutants.'' CAA section 302(h). This definition is quite broad. Importantly, it is not an exclusive list due to the use of the term ''includes, but is not limited to, * * *.'' Effects other than those listed here may also be considered effects on welfare.

Moreover, the terms contained within the definition are themselves expansive. For example, deterioration to property could include damage caused by extreme weather events. Effects on vegetation could include impacts from changes in temperature and precipitation as well as from the spreading of invasive species or insects. Prior welfare effects evaluated by the EPA in other contexts include impacts on vegetation, as well as reduced visibility, changes in nutrient balance and acidity of the environment, soiling of buildings and statues, and erosion of building materials. *See, e.g.,* Final Secondary National Ambient Air Quality Standards for Oxides of Nitrogen and Sulfur, 77 FR 20218, April 3, 2012; Control of Emissions from Nonroad Large Spark Ignition Engines and Recreational Engines (Marine and Land-Based), 67 FR 68242, November 8, 2002; Final Heavy-Duty Engine and Vehicle Standards and Highway Diesel Sulfur Control Requirements, 66 FR 5002, January 18, 2001.

Although the CAA defines ''effects on welfare'' as discussed above, there are no definitions of ''public health'' or ''public welfare'' in the Clean Air Act. The Supreme Court has discussed the concept of ''public health'' in the context of whether costs can be considered when setting National Ambient Air Quality Standards. *Whitman* v. *American Trucking Ass'n,* 531 U.S. 457 (2001). In *Whitman,* the Court imbued the term with its most natural meaning: ''The health of the public.'' *Id.* at 466. When considering public health, the EPA has looked at morbidity, such as impairment of lung function, aggravation of respiratory and cardiovascular disease, and other acute and chronic health effects, as well as mortality. *See, e.g.,* Final National Ambient Air Quality Standard for Ozone, 73 FR 16436, March 27, 2008.

IV. The Proposed Endangerment Finding Under CAA Section 231

This section describes the Administrator's proposed endangerment finding under CAA section 231(a)(2) and its basis. Beginning with the air pollution under consideration, the Administrator is proposing to use the same definition of the ''air pollution'' under CAA section 231(a)(2) as that used under CAA section 202(a)(1), namely the mix of six well-mixed GHGs mentioned above: CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. As described in section IV.A below, it is the Administrator's view that the reasons detailed in the 2009 Endangerment Finding for defining the scope and nature of the air pollution to be these six well-mixed GHGs remain valid and well-supported by the current science and are therefore reasonable bases for adopting the same definition of ''air pollution'' in this section 231(a)(2)(A) finding. Information from the new scientific assessments described in section IV.B below provides further support that the six well-mixed GHGs are the primary cause and driver of climate change. The Administrator considered other climate-forcing agents both in the 2009 Endangerment Finding and in this action; however, these substances are not included in the air pollution definition proposed in this action for the reasons discussed below in section IV.B.4.

The Administrator is proposing to find, for purposes of CAA section 231(a)(2)(A), that elevated concentrations of the six well-mixed GHGs constitute air pollution that endangers both the public health and the public welfare of current and future generations. The Administrator's view is that the body of scientific evidence amassed in the record for the 2009 Endangerment Finding compellingly supports an endangerment finding under CAA section 231(a). Information from the new scientific assessments described in section IV.B below provides further support and justification for this proposed finding.

Section IV.A below summarizes the 2009 Endangerment Finding under CAA section 202, explains the approach EPA took in compiling an extensive record to inform the Administrator's judgment on that finding, and describes the recent judicial affirmation of the 2009 Endangerment Finding. Section IV.B provides a summary of new scientific assessments that strengthen or provide further scientific evidence, in addition to that which the Administrator relied upon in making her prior judgment, for a finding that GHGs endanger public health and welfare.[78] Finally, section IV.C summarizes the Administrator's conclusion for purposes of section 231, in light of the evidence, analysis, and conclusions that led to the 2009 Endangerment Finding as well as more recent evidence, that emissions of the six well-mixed GHGs in the atmosphere endanger public health and welfare.

A. Scientific Basis of the 2009 Endangerment Finding Under CAA Section 202(a)(1)

In the 2009 Endangerment Finding, the Administrator found that elevated concentrations of the well-mixed GHGs in the atmosphere may reasonably be

[78] While the EPA is providing a summary of newer scientific assessments below, the EPA is also relying on the same scientific and technical evidence discussed in the notices for the 2009 Endangerment Finding in this proposed finding for purposes of CAA section 231. See sections III of the 2009 Proposed Endangerment Finding and sections III and IV of the 2009 Endangerment Finding.

anticipated to endanger public health and welfare of current and future generations. *See, e.g.,* 74 FR 66516, December 15, 2009. The Administrator reached this judgment by carefully considering a significant body of scientific evidence and public comments submitted to the Agency. The sections below summarize the scope and nature of the relevant air pollution for the 2009 Endangerment Finding, as well as the public health and welfare considerations within the finding.

1. The Definition of Air Pollution in the 2009 Endangerment Finding

The Administrator defined the scope and nature of the relevant air pollution as the aggregate group of six key, well-mixed GHGs: CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.[79] The Administrator considered five primary reasons for focusing on this aggregate group as the air pollution in the 2009 Endangerment Finding: (1) They share common physical properties that influence their climate effects; (2) on the basis of these common physical properties, they have been determined to be the primary cause of human-induced climate change, are the best-understood driver of climate change, and are expected to remain the key driver of future climate change; (3) they are the common focus of climate change science research and policy analyses and discussions; (4) using the combined mix of these gases as the definition (versus an individual gas-by-gas approach) is consistent with the science, because risks and impacts associated with GHG-induced climate change are not assessed on an individual gas-by-gas basis; and (5) using the combined mix of these gases is consistent with past EPA practice, where separate substances from different sources, but with common properties, may be treated as a class (*e.g.,* oxides of nitrogen, particulate matter, volatile organic compounds).[80]

The common physical properties these six GHGs share that are relevant to the climate change problem include the following: All are long-lived in the atmosphere; [81] all become globally well mixed in the atmosphere, resulting in similar GHG concentrations around the globe regardless of geographic location of emissions; all trap outgoing heat that would otherwise escape to space; and all are directly emitted as GHGs rather than becoming a GHG in the atmosphere after emission of a precursor gas. The Administrator acknowledged that other anthropogenic climate forcers also play a role in climate change but for various scientific and policy reasons, these substances were not included in the air pollution definition.[82]

As explained in more detail in the 2009 Endangerment Finding, the EPA made the judgment that the scientific evidence is compelling that elevated concentrations of heat-trapping GHGs are the root cause of recently observed climate change and that the scientific record showed that most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations. The attribution of observed climate change to anthropogenic activities was based on multiple lines of evidence.[83] The first line of evidence arises from our basic physical understanding of the effects of changing concentrations of GHGs, natural factors, and other human impacts on the climate system. The second line of evidence arises from indirect, historical estimates of past climate changes that suggest that the changes in global surface temperature over the last several decades are unusual. The third line of evidence arises from the use of computer-based climate models to simulate the likely patterns of response of the climate system to different forcing mechanisms (both natural and anthropogenic).

2. Public Health Impacts Detailed in the 2009 Endangerment Finding

Climate change resulting from anthropogenic GHG emissions threatens multiple aspects of public health.[84] In determining that the well-mixed GHG air pollution is reasonably anticipated to endanger public health for current and future generations, the Administrator noted her view that climate change can increase the risk of morbidity and mortality.[85] In making that public health finding, the Administrator considered direct temperature effects, air quality effects, the potential for changes in vector-borne diseases, and the potential for changes in the severity and frequency of extreme weather events. In addition, the Administrator considered whether and how susceptible populations may be particularly at risk. As explained in more detail in the 2009 Endangerment Finding, with respect to direct temperature effects, by raising average temperatures, climate change increases the likelihood of heat waves, which are associated with increased deaths and illnesses. Climate change is also expected to lead to reductions in cold-related mortality. The 2009 Endangerment Finding, while noting uncertainty about how heat and cold related mortality would change in the future, also pointed to a USGCRP assessment report discussion that increases in heat-related mortality due to global warming in the United States was unlikely to be compensated for by decreases in cold-related mortality (74 FR 66525, December 15, 2009). With regard to air quality effects, climate change is expected to increase ozone pollution over broad areas of the country, including large metropolitan population centers, and thereby increase the risks of respiratory infection, aggravation of asthma, and premature death. Other public health threats stem from the potential for increased deaths, injuries, infectious and waterborne diseases, stress-related disorders, and other adverse effects associated with increased hurricane intensity and increased frequency of intense storms and heavy precipitation associated with climate change. In addition, climate change is expected to be associated with an increase in the spread of food-, water-, and vector-borne diseases in susceptible populations. Climate change also has the potential to change aeroallergen production (for example, through lengthening the growing season for allergen-producing plants), and subsequent human exposures could increase allergenic illnesses. Children, the elderly, and the poor are among the most vulnerable to climate-related health effects.

3. Public Welfare Impacts Detailed in the 2009 Endangerment Finding

Climate change resulting from anthropogenic GHG emissions also threatens multiple aspects of public welfare.[86] In determining that the well-

[79] 74 FR 66516, December 15, 2009.

[80] 74 FR 66517 to 66519, December 15, 2009.

[81] We use ''long-lived'' here to mean that the gas has a lifetime in the atmosphere sufficient to become globally well-mixed throughout the entire atmosphere, which requires a minimum atmospheric lifetime of about one year. IPCC also refers to these six greenhouse gases as long-lived. According to the most recent IPCC Fifth Assessment Report (2014), methane has an atmospheric lifetime of about 12 years. One of the most commonly used hydrofluorocarbons (HFC–134a) has a lifetime of about 13 years. Nitrous oxide has a lifetime of around 130 years; sulfur hexafluoride over 3,000 years; and some perfluorocarbons up to 10,000 to 50,000 years. CO_2 is sometimes approximated as having a lifetime of roughly 100 years, but for a given amount of CO_2 emitted a better description is that some fraction of the atmospheric increase in concentration is quickly absorbed by the oceans and terrestrial vegetation, some fraction of the atmospheric increase will only slowly decrease over a number of years, and a small portion of the increase will remain for many centuries or more.

[82] 74 FR 66519 to 66521, December 15, 2009.

[83] 74 FR 66518, December 15, 2009.

[84] 74 FR 66524 to 66530, December 15, 2009.

[85] 74 FR 66524, December 15, 2009.

[86] 74 FR 66530 to 66536, December 15, 2009.

mixed GHG air pollution is reasonably anticipated to endanger public welfare for current and future generations, the Administrator considered the multiple pathways by which GHG air pollution and resultant climate change affect public welfare by evaluating the numerous and far-ranging risks to food production and agriculture; forestry; water resources; sea level rise and coastal areas; energy, infrastructure, and settlements; and ecosystems and wildlife. The Administrator also considered impacts on the U.S. population from climate change effects occurring outside of the United States. As explained in more detail in the 2009 Endangerment Finding, the potential serious adverse impacts of extreme events, such as wildfires, flooding, drought, and extreme weather conditions provided strong support for the determination. Climate change is expected to place large areas of the country at serious risk of reduced water supplies, increased water pollution, and increased occurrence of extreme events such as floods and droughts. Coastal areas are expected to face increased risks from storm and flooding damage to property, as well as adverse impacts from rising sea level such as land loss due to inundation, erosion, wetland submergence and habitat loss. Climate change is expected to result in an increase in peak electricity demand, and extreme weather from climate change threatens energy, transportation, and water resource infrastructure. Climate change may exacerbate existing environmental pressures in certain settlements, particularly in Alaskan indigenous communities. Climate change is also very likely to fundamentally change U.S. ecosystems over the 21st century and to lead to predominantly negative consequences for biodiversity, ecosystem goods and services, and wildlife. Though there may be some benefits for agriculture and forestry in the next few decades, the body of evidence points towards increasing risks of net adverse impacts on U.S. food production, agriculture and forest productivity as average temperature continues to rise. Looking across all sectors discussed above, the risk and the severity of adverse impacts on public welfare are expected to increase over time. Lastly, these impacts are global and may exacerbate problems outside the United States that raise humanitarian, trade, and national security issues for the United States.

4. The Science Upon Which the Agency Relied

As outlined in section III.A of the 2009 Endangerment Finding,[87] the EPA's approach to providing the technical and scientific information to inform the Administrator's judgment regarding the question of whether GHGs endanger public health and welfare was to rely primarily upon the recent, major assessments by the USGCRP, the IPCC, and the NRC. These assessments addressed the scientific issues that the EPA was required to examine, were comprehensive in their coverage of the GHG and climate change issues, and underwent rigorous and exacting peer review by the expert community, as well as rigorous levels of U.S. government review, in which the EPA took part. Primary reliance on the major scientific assessments provided assurance that the Administrator was basing her judgment on the best available, well-vetted science that reflected the consensus of the climate science research community. The major findings of the USGCRP, IPCC, and NRC assessments supported the Administrator's determination that elevated concentrations of GHGs in the atmosphere may reasonably be anticipated to endanger the public health and welfare of current and future generations. The EPA presented this scientific support at length in the comprehensive record for the 2009 Endangerment Finding. Relevant sections of documents from the 2009 Endangerment Finding record have been placed in the docket for this proposed finding under CAA section 231.

The EPA then reviewed ten administrative petitions for reconsideration of the Endangerment Finding in 2010.[88] In the Reconsideration Denial, the Administrator denied those petitions on the basis of the Petitioners' failure to provide substantial support for their argument that the EPA should revise the Endangerment Finding and their objections' lack of ''central relevance'' to the Finding. The EPA prepared an accompanying three-volume Response to Petitions document to provide additional information, often more technical in nature, in response to the arguments, claims, and assertions by the Petitioners to reconsider the Endangerment Finding.[89]

The 2009 Endangerment Finding and the 2010 Reconsideration Denial were challenged in a lawsuit before the U.S. Court of Appeals for the D.C. Circuit.[90] On June 26, 2012, the Court upheld the Endangerment Finding and the Reconsideration Denial, ruling that the Finding (including the Reconsideration Denial) was not arbitrary or capricious, was consistent with the U.S. Supreme Court's decision in *Massachusetts* v. *EPA* (which affirmed the EPA's authority to regulate greenhouse gases) [91] and the text and structure of the CAA, and was adequately supported by the administrative record.[92] The Court also agreed with the EPA that the Petitioners had ''not provided substantial support for their argument that the Endangerment Finding should be revised.'' [93] The Court found that the EPA had based its decision on ''substantial scientific evidence,'' observing that ''EPA's scientific evidence of record included support for the proposition that greenhouse gases trap heat on earth that would otherwise dissipate into space; that this 'greenhouse effect' warms the climate; that human activity is contributing to increased atmospheric levels of greenhouse gases; and that the climate system is warming,'' as well as providing extensive scientific evidence for EPA's determination that anthropogenically induced climate change threatens both public health and welfare.[94] The court further noted that the EPA's reliance on assessments was consistent with the methods decision-makers often use to make a science-based judgment.[95] Moreover, the Court supported the EPA's reliance on the major scientific assessment reports conducted by USGCRP, IPCC, and NRC and found:

> The EPA evaluated the processes used to develop the various assessment reports, reviewed their contents, and considered the depth of the scientific consensus the reports

[87] 74 FR 66510 to 66512, December 15, 2009.

[88] Administrative petitions are available from *http://www.epa.gov/climatechange/endangerment/petitions.html* (last accessed May 12, 2015), and in the docket for the 2009 Endangerment Finding: EPA–HQ–OAR–2009–017.

[89] U.S. EPA, 2010: *Denial of the Petitions to Reconsider the Endangerment and Cause or Contribute Findings for Greenhouse Gases Under section 202(a) of the Clean Air Act,* 75 FR 49557 (August 13, 2010) (''Reconsideration Denial''). In that notice, the EPA thoroughly considered the scientific and technical information relevant to the petitions. In addition to the other information discussed in the present notice, the EPA is also relying on the scientific and technical evidence discussed in that prior notice for purposes of its proposed determination under CAA section 231. See section III of the Reconsideration Denial.

[90] *Coalition for Responsible Regulation, Inc.* v. *Environmental Protection Agency,* 684 F.3d 102 (D.C. Cir. 2012),), reh'g en banc denied, 2012 U.S. App. LEXIS 25997, 26313, 26315 (D.C. Cir. 2012) (*CRR*).

[91] 549 U.S. 497 (2007).

[92] *CRR,* 684 F.3d at 117–27.

[93] *Id.* at 125

[94] *Id.* at 120–121.

[95] *Id.* at 121

represented. Based on these evaluations, the EPA determined the assessments represented the best source material to use in deciding whether GHG emissions may be reasonably anticipated to endanger public health or welfare. . . . It makes no difference that much of the scientific evidence in large part consisted of ''syntheses'' of individual studies and research. Even individual studies and research papers often synthesize past work in an area and then build upon it. This is how science works. The EPA is not required to re-prove the existence of the atom every time it approaches a scientific question.[96]

In addition, the EPA's reliance on the major assessments to inform the Administrator's judgment allowed for full and explicit recognition of scientific uncertainty regarding the endangerment posed by the atmospheric buildup of GHGs. The Administrator considered the fact that ''some aspects of climate change science and the projected impacts are more certain than others.'' [97] The D.C. Circuit subsequently noted that ''the existence of some uncertainty does not, without more, warrant invalidation of an endangerment finding.'' [98]

As noted above the Supreme Court granted some of the petitions for *certiorari* that were filed, while denying others, but agreed to decide only the question: ''Whether EPA permissibly determined that its regulation of greenhouse gas emissions from new motor vehicles triggered permitting requirements under the Clean Air Act for stationary sources that emit greenhouse gases.'' [99] Thus, the Supreme Court did not disturb the D.C. Circuit's holding that affirmed the 2009 Endangerment Finding.

B. Recent Science Further Supports the Administrator's Judgment That the Six Well-Mixed Greenhouse Gases Endanger Public Health and Welfare

Since the closure of the administrative record concerning the 2009 Endangerment Finding (including the denial of petitions for reconsideration), a number of new major, peer-reviewed scientific assessments have been released. The EPA carefully reviewed the updated scientific conclusions in these assessments, largely to evaluate whether they would lead the EPA in this CAA section 231(a)(2)(A) finding to propose a different interpretation of, or place more or less weight on, the major findings reflected in the previous assessment reports that underpinned the Administrator's judgment that the six well-mixed GHGs endanger public health and welfare. From its review, the EPA finds that these new assessments are largely consistent with, and in many cases strengthen and add to, the already compelling and comprehensive scientific evidence detailing the role of the six well-mixed GHGs in driving climate change, detailed in the 2009 Endangerment Finding. Therefore, the new scientific assessments do not provide any reasonable basis on which to propose under CAA section 231(a)(2)(A) a different conclusion than the one the EPA reached in 2009 under CAA section 202(a). Rather, they provide further support for this proposed finding under section 231. In particular, the new assessments discussed in this preamble provide additional detail regarding public health impacts, particularly on groups and people at certain lifestages especially vulnerable to climate change including children, the elderly, low-income communities and individuals, indigenous groups, and communities of color.

The subsections below present brief summaries of the relevant key findings from the new major peer-reviewed scientific assessments, which include the following:

- IPCC's 2013–2014 Fifth Assessment Report (AR5) [100]
- IPCC's 2012 ''Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation'' (SREX) [101]
- USGCRP's 2014 ''Climate Change Impacts in the United States: the Third National Climate Assessment'' (NCA3) [102]
- NRC's 2010 ''Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean'' (Ocean Acidification) [103]
- NRC's 2011 ''Climate Change, the Indoor Environment, and Health'' (Indoor Environment) [104]
- NRC's 2011 ''Report on Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia'' (Climate Stabilization Targets) [105]
- NRC's 2011 ''National Security Implications for U.S. Naval Forces'' (National Security Implications) [106]
- NRC's 2011 ''Understanding Earth's Deep Past: Lessons for Our Climate Future'' (Understanding Earth's Deep Past) [107]
- NRC's 2012 ''Sea Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future'' (Sea Level Rise) [108]
- NRC's 2013 ''Climate and Social Stress: Implications for Security Analysis'' (Climate and Social Stress) [109]

[96] *Id.* at 120.

[97] 74 FR at 66524, December 15, 2009.

[98] *CRR,* 684 F.3d at 121.

[99] *Utility Air Reg. Group* v. *EPA,* 134 S. Ct. 2427, 2438 (2014) (internal marks and citations omitted). *See also Virginia* v. *EPA,* 134 S. Ct. 418 (2013), *Pac. Legal Found.* v. *EPA,* 134 S. Ct. 418 (2013), and *CRR,* 134 S. Ct. 468 (2013) (all denying cert.).

[100] IPCC, 2013: *Climate Change 2013: The Physical Science Basis.* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, 1535 pp, doi:10.1017/CBO9781107415324; IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, 1132 pp; IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, 688 pp; and 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.

[101] IPCC, 2012: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.* A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, 582 pp.

[102] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment.* U.S. Global Change Research Program, 841 pp.

[103] NRC, 2010: *Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean.* The National Academies Press, 188 pp.

[104] NRC Institute of Medicine, 2011: *Climate Change, the Indoor Environment, and Health.* Washington, DC: The National Academies Press, 272 pp.

[105] NRC 2011: *Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia.* The National Academies Press, 298 pp.

[106] NRC, 2011: *National Security Implications of Climate Change for U.S. Naval Forces.* The National Academies Press, 226 pp.

[107] NRC, 2011: *Understanding Earth's Deep Past: Lessons for Our Climate Future.* The National Academies Press, 212 pp.

[108] NRC, 2012: *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future.* The National Academies Press, 201 pp.

[109] NRC, 2013: *Climate and Social Stress: Implications for Security Analysis.* The National Academies Press, 280 pp.

• NRC's 2013 ''Abrupt Impacts of Climate Change'' (Abrupt Impacts) [110]
• NRC's 2014 ''The Arctic in the Anthropocene: Emerging Research Questions'' (Arctic) [111].

1. More Recent Evidence That Elevated Atmospheric Concentrations of the Six Greenhouse Gases Are the Root Cause of Observed Climate Change

The EPA has carefully reviewed the recent assessments regarding elevated concentrations of the six well-mixed GHGs in the atmosphere. The EPA finds that the new assessments of the IPCC, USGCRP, and NRC support and strengthen the science underlying the 2009 Endangerment Finding that the six well-mixed GHGs are the root cause of recently observed climate change. Key findings are described briefly here.

According to the IPCC AR5, observations of the Earth's globally averaged combined land and ocean surface temperature over the period 1880 to 2012 show a warming of 0.85 [0.65 to 1.06] degrees Celsius or 1.53 [1.17 to 1.91] degrees Fahrenheit.[112] The IPCC AR5 concludes that the global average net effect of the increase in atmospheric GHG concentrations, plus other human activities (*e.g.,* land use change and aerosol emissions), on the global energy balance since 1750 has been one of warming. This total net heating effect, referred to as ''forcing,'' is estimated to be 2.3 Watts per square meter (W/m2), which has increased from the previous 2007 IPCC Fourth Assessment Report (AR4) total net estimate of 1.6 Watts per square meter (W/m2) that was referred to in the record for the 2009 Endangerment Finding. The reasons for this increase include continued increases in GHG concentrations, as well as reductions in the estimated negative forcing due to aerosols. The IPCC AR5 rates the level of confidence [113] in their radiative forcing estimates as ''high'' for methane and ''very high'' for CO_2 and nitrous oxide.

The new assessments also have greater confidence in attributing recent warming to human causes. The IPCC AR5 stated that it is extremely likely (>95 percent likelihood) that human influences have been the dominant cause of warming since the mid-20th century, which is a stronger statement than the AR4 conclusion that it is very likely (>90 percent likelihood) that most of the increase in temperature since the mid-20th century was due to the increase in GHG concentrations. The AR4 conclusion was referred to in the record for the 2009 Endangerment Finding. In addition, the IPCC AR5 found that concentrations of CO_2 and several other of the major GHGs are higher than they have been in at least 800,000 years. This is an increase from what was reported in IPCC AR4, which found higher concentrations than in at least 650,000 years.

The USGCRP NCA3 states that there is very high confidence [114] that the global climate change of the past 50 years is primarily due to human activities. Human activities are affecting climate through increasing atmospheric levels of heat-trapping gases, through changing levels of various particles that can have either a heating or cooling influence on the atmosphere, and through activities such as land use changes that alter the reflectivity of the Earth's surface and cause climatic warming and cooling effects. The USGCRP concludes that ''considering all known natural and human drivers of climate since 1750, a strong net warming from long-lived greenhouse gases produced by human activities dominates the recent climate record.'' [115]

These recent and strong conclusions attributing recent observed global warming to human influence have been made despite what some have termed a warming slowdown or ''hiatus'' over the past 15 years or so. The IPCC AR5 notes that global mean surface temperature exhibits substantial natural decadal and interannual variability, such that trends based on short records are very sensitive to the beginning and end dates and do not in general reflect long-term climate trends. As an example, the IPCC AR5 notes that the rate of warming over the 15 year period from 1998–2012 was less than that over the period 1951–2012. This short term variability does not alter the long-term climate trend that the IPCC AR5 finds after its review of independently verified observational records: ''Each of the past three decades has been successively warmer at the Earth's surface than all the previous decades in the instrumental record, and the first decade of the 21st century has been the warmest.'' [116] [117]

The NRC Climate Stabilization Targets assessment concludes that CO_2 emissions are currently altering the atmosphere's composition and will continue to alter Earth's climate for thousands of years. The NRC Understanding Earth's Deep Past assessment finds that ''the magnitude and rate of the present greenhouse gas increase place the climate system in what could be one of the most severe increases in radiative forcing of the global climate system in Earth history.'' [118] This assessment finds that if no emissions reductions are made CO_2 concentrations by the end of the century are projected to increase to levels that Earth has not experienced for more than 30 million years.

2. More Recent Evidence That Greenhouse Gases Endanger Public Health

The EPA has carefully reviewed the key conclusions in the recent assessments regarding human-induced climate change risks and impacts on public health. The EPA finds that the new assessments are consistent with or strengthen the underlying science considered in the 2009 Endangerment Finding regarding public health effects from changes in temperature, air quality, extreme weather, and climate-sensitive diseases and aeroallergens. These key findings are described briefly here.

[110] NRC, 2013: *Abrupt Impacts of Climate Change: Anticipating Surprises.* The National Academies Press, 250 pp.

[111] NRC, 2014: *The Arctic in the Anthropocene: Emerging Research Questions.* The National Academies Press, 220 pp.

[112] ''IPCC, 2013: *Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis.* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, 29 pp.

[113] The IPCC expresses levels of confidence using five qualifiers: very low, low, medium, high, and very high. These levels are based on a qualitative evaluation of the robustness of the evidence (considering the type, amount, quality, and consistency of evidence such as data, mechanistic understanding, theory, models, and expert judgment) and the degree of agreement among the findings.

[114] The NCA expresses levels of confidence using four qualifiers: low, medium, high, and very high. These levels are based on the strength and consistency of the observed evidence; the skill, range, and consistency of model projections; and insights from peer-reviewed sources.

[115] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment.* U.S. Global Change Research Program, p. 741

[116] IPCC, 2013: *Climate Change 2013: The Physical Science Basis.* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, p. 161.

[117] Furthermore, we would note that according to both NOAA and NASA, 2014 was the warmest year in the modern instrumental record for globally averaged surface temperature, and that the ten warmest years, with the exception of 1998, have now occurred since 2000. Available at *http://www.giss.nasa.gov/research/news/20150116/* (last accessed May 12, 2015).

[118] NRC, 2011: *Understanding Earth's Deep Past: Lessons for Our Climate Future.* The National Academies Press, p. 138.

Regarding temperature effects, the conclusions of the assessment literature cited in the 2009 Endangerment Finding were uncertain with respect to the exact balance of how heat- versus cold-related mortality will change in the future, but noted that the available evidence suggested that the increased risk from heat would exceed the decreased risk from cold in a warming climate. The most recent assessments now have greater confidence that increases in heat-related mortality will be larger than the decreases in cold-related mortality. The USGCRP NCA3 concludes that, ''While deaths and injuries related to extreme cold events are projected to decline due to climate change, these reductions are not expected to compensate for the increase in heat-related deaths.'' [119] The IPCC AR5 also notes a potential benefit of climate change could include ''modest reductions in cold-related mortality and morbidity in some areas due to fewer cold extremes (low confidence),'' [120] but that, ''[o]verall, we conclude that the increase in heat-related mortality by mid-century will outweigh gains due to fewer cold periods.'' [121]

Regarding air quality effects, the assessment literature cited in the 2009 Endangerment Finding concluded that climate change is expected to increase regional ozone pollution, with associated risks in respiratory illnesses and premature death, but that the directional effect of climate change on ambient particulate matter levels was less certain. The USGCRP NCA3 similarly concludes that, ''Climate change is projected to harm human health by increasing ground-level ozone and/or particulate matter air pollution in some locations. . . . There is less certainty in the responses of airborne particles to climate change than there is about the response of ozone.'' [122] The IPCC AR5 finds that ozone and particulate matter have been associated with adverse health effects in many locations in North America, and that ozone concentrations could increase under future climate change scenarios if emissions of precursors were held constant. For particulate matter, both the USGCRP NCA3 and IPCC AR5 discuss increasing wildfire risk under climate change, and explain that wildfire smoke exposure can lead to various respiratory and cardiovascular impacts. The NRC Indoor Environment assessment identifies potential adverse health risks associated with climate-change induced alterations in the indoor environment, including possible exposure to air pollutants like ozone via changes in outdoor air quality. Other risks include potential for alterations in indoor allergens due to climate change-related increases in outdoor pollen levels, potential chemical exposures due to greater use of pesticides to address changes in geographic ranges of pest species, and dampness/mold associated symptoms and illness due to potential flooding and water damage in buildings from projected climate change-related increases in storm intensity and extreme precipitation events in some regions of the United States.

Regarding extreme weather events (*e.g.,* storms, heavy precipitation, and, in some regions of the United States, floods and droughts), the conclusions of the assessment literature cited in the 2009 Endangerment Finding found potential for increased deaths, injuries, infectious and waterborne diseases, and stress-related disorders. Similarly, the USGCRP NCA3 discusses elevated waterborne disease outbreaks and the potential for mold contamination and degraded indoor air quality following heavy precipitation. Other impacts include mortality associated with flooding and impacts on mental health, such as anxiety and post-traumatic stress disorder. The IPCC AR5 also discusses death and injury in coastal zones and regions vulnerable to inland flooding. The USGCRP NCA3 and the IPCC AR5 both find that climate change may increase exposure to and health risks associated with drought conditions, which includes impacts from wildfires, dust storms, extreme heat events, flash flooding, degraded water quality, reduced water quantity, and water-related diseases. The IPCC SREX assessment projects further increases in some extreme weather and climate events during this century, and specifically notes that changes in extreme weather events have implications for disaster risk in the health sector.

The effects of climate change on climate-sensitive diseases were also cited in the 2009 Endangerment Finding, including a likely increase in the spread of several food and water-borne pathogens among susceptible populations, and the potential for range expansion of some zoonotic disease carriers such as the Lyme disease-carrying tick. The new assessment literature similarly focuses on increased exposure risk for some diseases under climate change, finding that increasing temperatures may expand or shift the ranges of some disease vectors like mosquitoes, ticks, and rodents. The IPCC AR5 notes that climate change may influence the ''growth, survival, persistence, transmission, or virulence of pathogens'' [123] that cause food and water-borne disease. The USGCRP NCA3 notes that uncertainty remains regarding future projections of increased human burden of vector-borne disease, given complex interacting factors such as ''local, small-scale differences in weather, human modification of the landscape, the diversity of animal hosts, and human behavior that affects vector-human contact, among other factors.'' [124]

Regarding aeroallergens, the assessment literature cited in the 2009 Endangerment Finding found potential for climate change to affect the prevalence and severity of allergy symptoms, but that definitive data or conclusions were lacking on how climate change might impact aeroallergens in the United States. The most recent assessments now express greater confidence that climate change will influence production of pollen, which in turn could affect the incidence of asthma and other allergic respiratory illnesses such as allergic rhinitis, as well as effects on conjunctivitis and dermatitis. Both the USGCRP NCA3 and the IPCC AR5 found that increasing temperature has lengthened the allergenic pollen season for ragweed, and that increased CO_2 by itself can elevate production of plant-based allergens. The IPCC AR5 concludes that in North America, ''warming will lead

[119] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment.* U.S. Global Change Research Program, p. 224.

[120] IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, p. 713.

[121] Ibid. at p. 721.

[122] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment.* U.S. Global Change Research Program, p. 222.

[123] IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, p. 726.

[124] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment.* U.S. Global Change Research Program, p. 225.

to further changes in the seasonal timing of pollen release (high confidence).'' [125]

The assessment literature cited in the 2009 Endangerment Finding concluded that certain populations, including children, the elderly, and the poor, are most vulnerable to climate-related health effects. The 2009 Endangerment Finding also described climate change impacts facing indigenous peoples in the United States, particularly Alaska Natives. The new assessment literature strengthens these conclusions by providing more detailed findings regarding these populations' vulnerabilities and the projected impacts they may experience. In addition, the most recent assessment reports provide new analysis about how some populations defined jointly by ethnic/racial characteristics and geographic location may be vulnerable to certain climate change health impacts. The following paragraphs summarize information from the most recent assessment reports on these vulnerable populations.

The USGCRP NCA3 finds that, ''Climate change will, absent other changes, amplify some of the existing health threats the nation now faces. Certain people and communities are especially vulnerable, including children, the elderly, the sick, the poor, and some communities of color.'' [126] Limited resources make low-income populations more vulnerable to ongoing climate-related threats, less able to adapt to anticipated changes, and less able to recover from climate change impacts. Low-income populations also face higher prevalence of chronic health conditions than higher income groups, which increases their vulnerability to the health effects of climate change.

According to the USGCRP NCA3 and IPCC AR5, some populations defined jointly by ethnic/racial characteristics and geographic location are more vulnerable to certain health effects of climate change due to factors such as existing health disparities (*e.g.,* higher prevalence of chronic health conditions), increased exposure to health stresses, and social factors that affect local resilience and ability to recover from impacts.

The USGCRP NCA3 also finds that climate change, in addition to chronic stresses such as extreme poverty, is affecting indigenous peoples' health in the United States through impacts such as reduced access to traditional foods, decreased water quality, and increasing exposure to health and safety hazards. The IPCC AR5 finds that climate change-induced warming in the Arctic and resultant changes in environment (*e.g.,* permafrost thaw, effects on traditional food sources) have significant observed and projected impacts on the health and well-being of Arctic residents, especially indigenous peoples. Small, remote, predominantly-indigenous communities are especially vulnerable given their ''strong dependence on the environment for food, culture, and way of life; their political and economic marginalization; existing social, health, and poverty disparities; as well as their frequent close proximity to exposed locations along ocean, lake, or river shorelines.'' [127] In addition, increasing temperatures and loss of Arctic sea ice increases the risk of drowning for those engaged in traditional hunting and fishing.

The USGCRP NCA3 concludes that children will suffer disproportionately from climate change given the unique physiological and developmental factors that occur during this lifestage. Impacts on children are expected from heat waves, air pollution, infectious and waterborne illnesses, and mental health effects resulting from extreme weather events. The IPCC AR5 indicates that children are among those especially susceptible to most allergic diseases, as well as health effects associated with heat waves, storms, and floods.

Both the USGCRP and IPCC conclude that climate change will increase health risks facing the elderly. Older people are at much higher risk of mortality during extreme heat events. Pre-existing health conditions also make older adults susceptible to cardiac and respiratory impacts of air pollution and to more severe consequences from infectious and waterborne diseases. Limited mobility among older adults can also increase health risks associated with extreme weather and floods.

3. More Recent Evidence That Greenhouse Gases Endanger Public Welfare

The EPA has carefully reviewed the recent scientific conclusions in the assessments regarding human-induced climate change impacts on public welfare.[128] The EPA finds that they are largely consistent with or strengthen the underlying science supporting the 2009 Endangerment Finding regarding public welfare effects on food production and agriculture; forestry; water resources; sea level rise and coastal areas; energy, infrastructure, and settlements; ecosystems and wildlife; and impacts on the U.S. population from climate change effects occurring outside of the United States. These key findings are described briefly here.

Regarding agriculture, the assessment literature cited in the 2009 Endangerment Finding found potential for increased CO_2 levels to benefit yields of certain crops in the short-term, but with considerable uncertainty. The body of evidence pointed towards increasing risk of net adverse impacts on U.S. food production and agriculture over time, with the potential for significant disruptions and crop failure in the future. The most recent assessments now have greater confidence that climate change will negatively affect U.S. agriculture over this century. Specifically, the USGCRP NCA3 concludes, ''While some U.S. regions and some types of agricultural production will be relatively resilient to climate change over the next 25 years or so, others will increasingly suffer from stresses due to extreme heat, drought, disease, and heavy downpours. From mid-century on, climate change is projected to have more negative impacts on crops and livestock across the country.'' [129] The IPCC AR5 concludes, ''Overall yields of major crops in North America are projected to decline

[125] IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, p. 1465–1466.

[126] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment.* U.S. Global Change Research Program, p. 221.

[127] IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, p. 1581.

[128] The CAA states that ''[a]ll language referring to effects on welfare includes, but is not limited to, effects on soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being, whether caused by transformation, conversion, or combination with other air pollutants.'' CAA section 302(h). This language is quite broad. Importantly, it is not an exclusive list due to the use of the term ''includes, but is not limited to, ...'' Effects other than those listed here may also be considered effects on welfare.

[129] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment.* U.S. Global Change Research Program, p. 16.

modestly by mid-century and more steeply by 2100 among studies that do not consider adaptation (very high confidence).'' [130] The IPCC AR5 notes that in the absence of extreme events, climate change may benefit certain regions and crops, but that in North America significant harvest losses have been observed due to recent extreme weather events. In addition, the IPCC SREX assessment specifically notes that projected changes in extreme weather events will increase disaster risk in the agriculture sector.

Regarding forestry, the assessment literature cited in the 2009 Endangerment Finding found that near term benefits to forest growth and productivity in certain parts of the country from elevated CO_2 concentrations and temperature increases to date are offset by longer term risks from wildfires and the spread of destructive pests and disease that present serious adverse risks for forest productivity. The most recent assessments provide further support for this conclusion. Both the USGCRP NCA3 and the IPCC AR5 conclude that climate change is increasing risks to forest health from fire, tree disease and insect infestations, and drought. The IPCC AR5 also notes risks to forested ecosystems associated with changes in temperature, precipitation amount, and CO_2 concentrations, which can affect species and ecological communities, leading to ecosystem disruption, reorganization, movement or loss. The NRC Arctic assessment states that climate change is likely to have a large negative impact on forested ecosystems in the high northern latitudes due to the effects of permafrost thaw and greater wildfire frequency, extent, and severity. The NRC Climate Stabilization Targets assessment found that for an increase in global average temperature of 1 to 2°C above pre-industrial levels, the area burnt by wildfires in western North America will likely more than double.

Regarding water resources, the assessment literature cited in the 2009 Endangerment Finding concluded that increasing temperatures and increased variability in precipitation associated with climate change will impact water quality and quantity through changes in snowpack, increased risk of floods, drought, and other concerns such as water pollution. Similarly, the new assessments further support projections of water resource impacts associated with increased floods and short-term drought in most U.S. regions. The USGCRP NCA3 also finds that, ''[c]limate change is expected to affect water demand, groundwater withdrawals, and aquifer recharge, reducing groundwater availability in some areas.'' [131] The IPCC AR5 finds that in part of the western United States, ''water supplies are projected to be further stressed by climate change, resulting in less water availability and increased drought conditions.'' [132] The IPCC AR5 also projects that climate change will degrade surface water quality, including the Great Lakes, and will negatively affect drinking water treatment/distribution and sewage collection systems.

The assessment literature cited in the 2009 Endangerment Finding found that the most serious potential adverse effects to coastal areas are the increased risk of storm surge and flooding in coastal areas from sea level rise and more intense storms. Coastal areas also face other adverse impacts from sea level rise such as land loss due to inundation, erosion, wetland submergence, and habitat loss. The most recent assessments provide further evidence in line with the science supporting the 2009 Endangerment Finding. The USGCRP NCA3 finds that, ''Sea level rise, combined with coastal storms, has increased the risk of erosion, storm surge damage, and flooding for coastal communities, especially along the Gulf Coast, the Atlantic seaboard, and in Alaska.'' [133]

The IPCC AR5, the USGCRP NCA3, and three of the new NRC assessments provide estimates of projected global sea level rise. These estimates, while not always directly comparable as they assume different emissions scenarios and baselines, are at least 40 percent larger than, and in some cases more than twice as large as, the projected rise estimated in the IPCC AR4 assessment, which was referred to in the 2009 Endangerment Finding.[134] The NRC Sea Level Rise assessment projects a global sea level rise of 0.5 to 1.4 meters by 2100, which is sufficient to lead to a relative rise in sea level even around the northern coasts of Washington State, where the land is still rebounding from the disappearance of the great ice sheets. The NRC National Security Implications assessment suggests that ''the Department of the Navy should expect roughly 0.4 to 2 meters global average sea-level rise by 2100.'' [135] The NRC Climate Stabilization Targets assessment states that an increase of 3°C will lead to a sea level rise of 0.5 to 1 meter by 2100. While these NRC and IPCC assessments continue to recognize and characterize the uncertainty inherent in accounting for ice sheet processes, these revised estimates are consistent with the assessments underlying the 2009 Endangerment Finding.

Regarding climate impacts on energy, infrastructure, and settlements, the 2009 Endangerment Finding cited the assessment literature's findings that temperature increases will change heating and cooling demand; that declining water quantity may adversely impact the availability of cooling water and hydropower in the energy sector; and that changes in extreme weather events will threaten energy, transportation, water, and other key societal infrastructure, particularly on the coast. The most recent assessments provide further evidence in line with the science supporting the 2009 Endangerment Finding. For example, the USGCRP NCA3 finds that, ''Coastal infrastructure, including roads, rail lines, energy infrastructure, airports, port facilities, and military bases, are increasingly at risk from sea level rise and damaging storm surges.'' [136] The NRC Arctic assessment identifies threats to human infrastructure in the Arctic from increased flooding, erosion, and shoreline ice pile-up, or *ivu,* associated

[130] IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, p. 1462.

[131] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment.* U.S. Global Change Research Program, p. 70.

[132] IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, p. 1456–1457.

[133] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment.* U.S. Global Change Research Program, p. 9.

[134] The 2007 IPCC AR4 assessment cited in 2009 Endangerment Finding estimated a projected sea level rise of between 0.18 and 0.59 meters by the end of the century, relative to 1990. It should be noted that in 2007, the IPCC stated that including poorly understood ice sheet processes could lead to an increase in the projections.

[135] NRC, 2011: *National Security Implications of Climate Change for U.S. Naval Forces.* The National Academies Press, p. 28.

[136] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment.* U.S. Global Change Research Program, p. 9.

with summer sea ice loss and the increasing frequency and severity of storms.

Regarding ecosystems and wildlife, the assessment literature cited in the 2009 Endangerment Finding found that climate change will predominantly adversely impact both terrestrial and marine biodiversity and the ability of these ecosystems to provide goods and services. The NRC Arctic assessment states that major marine and terrestrial biomes will likely shift pole ward, with significant implications for changing species composition, food web structures, and ecosystem function. The NRC Climate Stabilization Targets assessment found that coral bleaching will increase due both to warming and ocean acidification. The NRC Understanding Earth's Deep Past assessment notes four of the five major coral reef crises of the past 500 million years were caused by acidification and warming that followed GHG increases of similar magnitude to the emissions increases expected over the next hundred years. Similarly, the NRC Ocean Acidification assessment finds that ''[t]he chemistry of the ocean is changing at an unprecedented rate and magnitude due to anthropogenic CO_2 emissions; the rate of change exceeds any known to have occurred for at least the past hundreds of thousands of years.'' [137] The assessment notes that the full range of consequences is still unknown, but the risks ''threaten coral reefs, fisheries, protected species, and other natural resources of value to society.'' [138] The IPCC AR5 also projects biodiversity losses in marine ecosystems, especially in the Arctic and tropics.

In general, climate change impacts related to public welfare are expected to be unevenly distributed across different regions of the United States and have a greater impact on certain populations, such as indigenous peoples and the poor. The USGCRP NCA3 finds climate change impacts such as the rapid pace of temperature rise, coastal erosion and inundation related to sea level rise and storms, ice and snow melt, and permafrost thaw are affecting indigenous people in the United States. Particularly in Alaska, critical infrastructure and traditional livelihoods are threatened by climate change and, ''[i]n parts of Alaska, Louisiana, the Pacific Islands, and other coastal locations, climate change impacts (through erosion and inundation) are so severe that some communities are already relocating from historical homelands to which their traditions and cultural identities are tied.'' [139] The IPCC AR5 notes, ''Climate-related hazards exacerbate other stressors, often with negative outcomes for livelihoods, especially for people living in poverty (high confidence). Climate-related hazards affect poor people's lives directly through impacts on livelihoods, reductions in crop yields, or destruction of homes and indirectly through, for example, increased food prices and food insecurity.'' [140]

In the 2009 Endangerment Finding, the Administrator considered impacts on the U.S. population from climate change effects occurring outside of the United States, such as national security concerns that may arise as a result of climate change impacts in other regions of the world. The most recent assessments provide further evidence in line with the science supporting the 2009 Endangerment Finding. The NRC Climate and Social Stress assessment found that it would be ''prudent for security analysts to expect climate surprises in the coming decade . . . and for them to become progressively more serious and more frequent thereafter.'' [141] The NRC National Security Implications assessment recommends preparing for increased needs for humanitarian aid; responding to the effects of climate change in geopolitical hotspots, including possible mass migrations; and addressing changing security needs in the Arctic as sea ice retreats.

In addition, the NRC Abrupt Impacts report examines the potential for tipping points, thresholds beyond which major and rapid changes occur in the Earth's climate system, as well as in natural and human systems that are impacted by the changing climate. The Abrupt Impacts report did find less cause for concern than some previous assessments regarding some abrupt events within the next century such as disruption of the oceanic Atlantic Meridional Overturning Circulation (AMOC) and sudden releases of high-latitude methane from hydrates and permafrost. But, the same report found that the potential for abrupt changes in ecosystems, weather and climate extremes, and groundwater supplies critical for agriculture now seem more likely, severe, and imminent. The assessment found that some abrupt changes were already underway (*e.g.,* Arctic sea ice retreat and increases in extinction risk due to the speed of climate change), and cautioned that even abrupt changes such as the AMOC disruption that are not expected in this century can have severe impacts if/when they happen.

4. Consideration of Other Climate Forcers

Both in the 2009 Endangerment Finding and in this action, the Administrator recognizes that there are other substances in addition to the six well-mixed GHGs that are emitted from human activities and affect Earth's climate (referred to as climate forcers). These can be grouped into two categories: (1) other substances with similar physical properties to the six well-mixed GHGs—these include the ozone-depleting substances of chlorofluorocarbons, hydrochlorofluorocarbons, and halons, as well as nitrogen trifluoride and similar recently identified substances; and (2) short-lived substances—tropospheric ozone and its precursor gases, water vapor, and aerosol particles and precursors. For some short-lived substances—namely, water vapor; NO_X; and aerosol particles including black carbon—their physical properties result in these substances having different, and often larger, climate effects when emitted at high altitudes. However, the very properties that lead to differential climate effects depending on the altitude of emission—properties that are different from those of the six well-mixed, long-lived GHGs—lead to more uncertainty in the scientific understanding of these short-lived substances' total effect on Earth's climate. More detail is provided below.

As described in section III.B of the 2009 Endangerment Finding and in section IV.A.1 of this preamble, the primary reasons for defining the air pollution as the aggregate group of the six well-mixed GHGs include their common physical properties relevant to climate change (*i.e.,* long-lived, well-mixed, directly emitted), the fact that these gases are considered the primary drivers of climate change, and the fact that these gases remain the best

[137] NRC, 2010: *Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean.* The National Academies Press, p. 5.

[138] Ibid.

[139] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment.* U.S. Global Change Research Program, p. 17.

[140] IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, p. 796.

[141] NRC, 2013: *Climate and Social Stress: Implications for Security Analysis.* The National Academies Press, p. 18.

understood drivers of anthropogenic climate change. The common physical properties of the six well-mixed GHGs not only support grouping them together as a class, but also contribute to their higher degree of scientific understanding related to climate change, relative to short-lived substances that are not well-mixed, or substances that are formed indirectly rather than being directly emitted. After considering additional information in the new assessments regarding the climate-relevant substances outside the basket of the six well-mixed GHGs, it is the Administrator's view that the reasons originally stated for not including these substances in the scope of the GHG air pollution still apply at this time. For example, nitrogen triflouride and some other recently discovered substances are not as well studied or understood as the six well-mixed GHGs. Similarly, for tropospheric ozone—a short-lived gas in the atmosphere that is not directly emitted (it forms from emissions of various precursor gases)—the understanding and quantification of the link between precursor emissions and climate change is not as strong as for the six well-mixed GHGs.

Regarding the short-lived substances with different climate effects when emitted at high altitudes, the Aircraft Petition (see section II of this preamble) mentions the effects of water vapor and NO_X on clouds and atmospheric chemistry. The major peer-reviewed scientific assessments of the IPCC and NRC provide the current state of scientific understanding of these effects; the USGCRP assessments have not dealt specifically with emissions at high altitude. The EPA considered the following assessment reports to obtain the best estimates of these substances' net impact on the climate system, which is generally discussed in terms of radiative forcing: the IPCC AR5, the IPCC 2007 Fourth Assessment Report (AR4),[142] the IPCC Special Report: Aviation and the Global Atmosphere (IPCC 1999),[143] the NRC's Advancing the Science of Climate Change (NRC 2010),[144] and the NRC's Atmospheric Effects of Aviation: A Review of NASA's Subsonic Assessment Project (NRC 1999).[145] In addition to high altitude water vapor and NO_X, the literature indicates that aerosol particles, including black carbon, emitted at high altitudes have more interactions with clouds and therefore have different effects on the global energy balance than do particles emitted at the surface.

The state of the science as represented in the assessment literature highlights significant scientific uncertainties regarding the total net forcing effect of water vapor, NO_X, and aerosol particles when emitted at high altitudes. Given these uncertainties, the Agency is not including them in the proposed definition of air pollution for purposes of the endangerment finding under section 231 of the CAA. The short-lived nature of these substances means that, unlike the long-lived GHGs, the climatic impact of the substance is dependent on a number of factors such as the location and time of its emission. The magnitude, and often the direction (positive/warming or negative/cooling), of the globally averaged climate impact will differ depending on the location of the emission due to the local atmospheric conditions (*e.g.,* due to differing concentrations of other compounds with which the emissions can react, background humidity levels, or the presence or absence of clouds). In addition, for emissions at any given location, the spatial and temporal pattern of the climate forcing will be heterogeneous, again often differing in direction (for example, in the case of NO_X emissions, the near term effect in the hemisphere in which the emissions occur is usually warming due to increased ozone concentrations, but the longer term effects, and effects in the other hemisphere, are often cooling due to increased destruction of methane). As the climatic effects of these substances when emitted at high altitudes were not addressed at length in the 2009 Endangerment Finding, the following subsections briefly summarize the findings of the major scientific assessments regarding these substances' climatic effects at altitude and the various sources of uncertainty surrounding these estimates.

a. Changes in Clouds From High Altitude Emissions of Water Vapor and Particles

Aviation-induced cloudiness (sometimes called AIC) refers to all changes in cloudiness associated with aviation operations, which are primarily due to the effects of high altitude emissions of water vapor and particles (primarily sulfates and black carbon). Changes in cloudiness affect the climate by both reflecting solar radiation (cooling) and trapping outgoing longwave radiation (warming). Unlike the warming effects associated with the six long-lived, well-mixed GHGs, the warming effects associated with changes in cloud cover are more regional and temporal in nature. The three key components of aviation-induced cloudiness are persistent contrails, contrail-induced cirrus, and induced cirrus.

Aircraft engine emissions of water vapor at high altitudes during flight can lead to the formation of condensation trails, or contrails, under certain conditions such as ice-supersaturated air masses with specific humidity levels and temperature. The NRC estimates that persistent contrails increased cloudiness above the United States by two percent between 1950 and 1988, with similar results reported over Europe.[146] As stated above, clouds can have both warming and cooling effects, and persistent contrails were once considered to have significant net warming effects. However, more recent estimates suggest a smaller overall climate forcing effect of persistent contrails. The IPCC AR5 best estimate for the global mean radiative forcing from contrails is 0.01 W/m² (medium confidence and with an uncertainty range of 0.005 to 0.03 W/m²).[147] To put this number into context, some examples of other IPCC AR5 best estimates for global mean radiative forcing include: 1.68 W/m² for CO_2 (very high confidence and with an uncertainty range of 1.33 to 2.03 W/m²), 0.97 W/m² for methane (high confidence and with an uncertainty range of 0.74 to 1.20 W/m²), and 0.17 W/m² for nitrous oxide (very high confidence and with an uncertainty

[142] IPCC, 2007: *Climate Change 2007: The Physical Scientific Basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)] Cambridge University Press, 996 pp.

[143] IPCC, 1999: *Aviation and the Global Atmosphere,* Special Report to the Intergovernmental Panel on Climate Change [Penner, J.E., D.H. Lister, D.J. Griggs, D.J. Dokken, M. McFarland (eds.)] Cambridge University Press, 373 pp.

[144] NRC, 2010: *Advancing the Science of Climate Change.* The National Academies Press, 528 pp.

[145] NRC, 1999: *Atmospheric Effects of Aviation: A Review of NASA's Subsonic Assessment Project.* The National Academies Press, 54 pp.

[146] NRC, 1999: *Atmospheric Effects of Aviation: A Review of NASA's Subsonic Assessment Project.* The National Academies Press, 54 pp.

[147] IPCC, 2013: *Climate Change 2013: The Physical Science Basis.* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, 1535 pp.

range of .013 to 0.21 W/m^2).[148] In addition, the NRC (2010) assessment suggested that contrails may affect regional diurnal temperature differences, but this has been called into question by the recent findings presented in the IPCC AR5, which suggests that aviation contrails do not have an effect on mean or diurnal range of surface temperatures (medium confidence).

Persistent contrails also sometimes lose their linear form and develop into cirrus clouds, an effect referred to as contrail-induced cirrus. Studies to date have been unable to isolate this climate forcing effect, but the IPCC AR5 provides a combined contrail and contrail-induced cirrus best estimate of 0.05 W/m^2 (low confidence and with an uncertainty range of 0.02 and 0.15 W/m^2).[149]

Particles emitted or formed in the atmosphere as a result of aircraft emissions may also act as ice nuclei and modify naturally forming cirrus clouds, an effect referred to as ''induced cirrus.'' The two primary aviation-induced particles are sulfates and black carbon, and their effects on cirrus cloud modification is an area of active research. There are significant challenges in estimating the climatic impacts of induced cirrus; for example, the 2007 IPCC AR4 characterizes our knowledge of the natural freezing modes in cirrus conditions as ''poor,'' and notes that cirrus cloud processes are not well represented in global models.[150] Neither IPCC AR4 nor AR5 provided global or regional estimates related to this forcing.

Given differences in scientific understanding of the three components of aviation-induced cloudiness, the more recent assessments have not provided estimates of the net climate forcing effect of changes in clouds from high altitude emissions of water vapor and particles. Going back to the 1999 IPCC assessment, the science is characterized as ''very uncertain'' with a range for the best estimate between 0 to 0.040 W/m^2.[151]

b. Direct Radiative Forcing Effects of High Altitude Particle Emissions

The 2009 Endangerment Finding noted that much of the uncertainty range surrounding the estimate of total net forcing due to all human activities was due to uncertainties about the cooling and warming effects of aerosols[152] (though from all sources, not just aircraft). The Finding noted that the magnitude of aerosol effects can vary immensely with location and season of emissions, and also discussed black carbon as a specific type of aerosol particle, noting that estimates of its total climate forcing effect have a large uncertainty range.[153] Here, we discuss the direct radiative forcing effects of high altitude emissions of the two primary aviation-induced particles, sulfates and black carbon.

Aircraft emit precursor gases that convert to sulfate particles in the atmosphere, such as sulfur dioxide. Sulfate particles have direct effects on the climate by scattering solar radiation, which results in cooling. The more recent assessments have not quantified this effect from aviation. Going back to the 1999 IPCC assessment, the direct effect of sulfate aerosols from aviation for the year 1992 is estimated at -0.003 W/m^2 with an uncertainty range between -0.001 and -0.009 W/m^2.[154]

Black carbon emissions from aviation, which are produced by the incomplete combustion of jet fuel, primarily absorb solar radiation and heat the surrounding air, resulting in a warming effect. The more recent assessments have not quantified this effect from aviation. The 1999 IPCC assessment estimates the global mean radiative forcing of black carbon emissions to be 0.003 W/m^2 with uncertainty spanning 0.001 to 0.009 W/m^2.[155] The IPCC 1999 assessment suggests that because the contribution of black carbon in the stratosphere (which actually contribute to cooling of the surface rather than warming) was not included in its calculations, its estimates of radiative forcing were likely to be too high.

c. Changes in Atmospheric Chemistry From High Altitude Nitrogen Oxides Emissions

Emissions of NO_X do not themselves have warming or cooling effects, but affect the climate through catalyzing changes in the chemical equilibrium of the atmosphere. High altitude emissions of NO_X increase the concentration of ozone, which has a warming effect in the short term. Elevated NOx concentrations also lead to an increased rate of destruction of methane, which has a cooling effect in the long-term. The reduced methane concentrations eventually contribute to decreases in ozone, which also decreases the long-term net warming effect. Thus, the net radiative impact of NO_X emissions depends on the balance between the reductions in methane versus the production of ozone, which in turn depends on the time scale under consideration. Quantifying these impacts is an area of active study with large uncertainties. The quantification of the net global effect of NO_X is difficult because the atmospheric chemistry effects are heavily dependent on highly localized atmospheric properties and mixing ratios. Because the background atmospheric concentration of NO_X is important for quantifying the impact of aviation NO_X emissions on ozone and methane concentrations, the location of aircraft emissions would be an important additional factor. In addition, NO_X has different residence times in the atmosphere depending on the altitude at which it is emitted. The residence time of NO_X in the upper troposphere, or roughly the cruise altitude for jet aircraft, is on the order of several days. Going back to the IPCC 1999 assessment, the globally averaged radiative forcing estimates for aircraft emissions of NO_X in 1992 were 0.023 W/m^2 for O_3-induced changes (uncertainty range of 0.011 to 0.046 W/m^2), and -0.014 W/m^2 for methane-induced changes (uncertainty range of -0.005 to -0.042 W/m^2).[156]

The IPCC AR5 presents the impact of aviation NO_X emissions using a different metric, global warming potential (GWP), which is a measure of the warming impact of a pulse of

[148] IPCC, 2013: *Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis.* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, 29 pp.

[149] IPCC, 2013: *Climate Change 2013: The Physical Science Basis.* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)].Cambridge University Press, 1535 pp.

[150] IPCC, 2007: *Climate Change 2007: The Physical Scientific Basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)] Cambridge University Press, 996 pp.

[151] IPCC, 1999: *Aviation and the Global Atmosphere,* Special Report to the Intergovernmental Panel on Climate Change [Penner, J.E., D.H. Lister, D.J. Griggs, D.J. Dokken, M. McFarland (eds.)] Cambridge University Press, 373 pp.

[152] 74 FR at 66517, December 15, 2009.

[153] 74 FR at 66520, December 15, 2009.

[154] IPCC, 1999: *Aviation and the Global Atmosphere,* Special Report to the Intergovernmental Panel on Climate Change [Penner, J.E., D.H. Lister, D.J. Griggs, D.J. Dokken, M. McFarland (eds.)] Cambridge University Press, 373 pp.

[155] Ibid.

[156] IPCC, 1999: *Aviation and the Global Atmosphere,* Special Report to the Intergovernmental Panel on Climate Change [Penner, J.E., D.H. Lister, D.J. Griggs, D.J. Dokken, M. McFarland (eds.)] Cambridge University Press, 373 pp.

emissions of a given substance over 100 years relative to the same mass of CO_2. The AR5 presents a range from −21 to +75 for GWP of aviation NO_X.[157] The uncertainty in sign indicates uncertainty whether the net effect is one of warming or cooling. This report further suggests that at cruise altitude there is strong regional sensitivity of ozone and methane to NO_X, particularly notable at low latitudes.

The Administrator notes that NO_X emissions are already regulated under the EPA's rules implementing CAA section 231, at 40 CFR part 87. The prerequisite endangerment and cause or contribute findings that formed the basis for these standards, however, did not rely upon any conclusions regarding the climate forcing impacts of NO_X, but rather the role of NO_X emissions as a precursor to ozone formation in areas that did not meet the National Ambient Air Quality Standard (NAAQS) for ozone.[158] The continuing significant uncertainties regarding NO_X as a climate forcer do not undermine the Agency's prior conclusion under CAA section 231 that emissions of NO_X from aircraft engines cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare due to their contribution to ozone concentrations that exceed the NAAQS.

d. Summary

Overall, the state of the science as represented in the assessment literature highlights significant scientific uncertainties regarding the total net forcing effect of water vapor, NO_X, and aerosol particles, when emitted at high altitudes. The dependence of the effects on where the substance is emitted, and the complex temporal and spatial patterns that result, mean that the current level of understanding regarding these short-lived substances is much lower than for the six long-lived, well-mixed GHGs. Given the aforementioned scientific uncertainties at present, the Agency is not including these constituents in the proposed definition of air pollution for purposes of the endangerment finding under section 231 of the CAA.

C. Summary of the Administrator's Proposed Endangerment Finding Under CAA Section 231

In sum, the Administrator proposes to find, for purposes of CAA section 231(a)(2)(A), that elevated atmospheric concentrations of the six well-mixed GHGs constitute air pollution that endangers both the public health and the public welfare of current and future generations. In this proposed action under CAA section 231(a)(2)(A), the EPA relies primarily on the extensive scientific and technical evidence in the record supporting the 2009 Endangerment Finding, including the major, peer-reviewed scientific assessments used to address the question of whether GHGs in the atmosphere endanger public health and welfare, and on the analytical framework and conclusions upon which the EPA relied in making that finding. This proposed finding under section 231 accounts for the EPA's careful consideration not only of the scientific and technical record for the 2009 Endangerment Finding, but also of new, major scientific assessments issued since closing the administrative record for the 2009 Endangerment Finding. No recent information or analyses published since late 2009 suggest that it would be reasonable for the EPA to now reach a different or contrary conclusion for purposes of CAA section 231(a)(2)(A) than the Agency reached for purposes of section 202(a). In proposing this finding for purposes of section 231, we are not reopening or revisiting our 2009 Endangerment Finding. To the contrary, in light of the recent judicial decisions upholding those findings, the EPA believes the 2009 Endangerment Finding is firmly established and well settled.[159] Moreover, there is no need for the EPA to reopen or revisit that finding for purposes of making an additional finding under section 231 of the CAA. Therefore, public comments addressing this finding for purposes of section 231(a)(2)(A) should be limited to the section 231 context; the EPA will not consider or respond to comments on this proposal that seek a reevaluation of our 2009 Endangerment Finding for purposes of section 202(a).

V. The Proposed Cause or Contribute Finding for Greenhouse Gases Under CAA Section 231

As noted above, the Administrator has proposed to define the air pollution for purposes of the endangerment finding under CAA section 231 to be the aggregate of six well-mixed GHGs in the atmosphere. The second step of the two-part endangerment test for this proposed finding is for the Administrator to determine whether the emission of any air pollutant from certain classes of aircraft engines causes or contributes to this air pollution. This is referred to as the cause or contribute finding, and is the second proposed finding by the Administrator in this action.

Section V.A of this proposal describes the Administrator's reasoning for using the same definition and scope of the GHG air pollutant that was used in the 2009 Endangerment Finding. Section V.0 puts forth the Administrator's proposed finding that emissions of well-mixed GHGs from classes of aircraft engines used in covered aircraft contribute to the air pollution which endangers public health and welfare.

A. The Air Pollutant

1. Proposed Definition of Air Pollutant

Under section 231, the Administrator is to determine whether *emissions of any air pollutant* from any class or classes of aircraft engines cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare. As with the 2009 Endangerment Finding that the EPA conducted for purposes of CAA section 202(a), when making a cause or contribute finding under section 231(a)(2), the Administrator must first define the air pollutant being evaluated. The Administrator has reasonably and logically considered the relationship between the GHG air pollution and air pollutant: while the air pollution is the concentration (*e.g.,* stock) of the well-mixed GHGs in the atmosphere, the air pollutant is the same combined grouping of the well-mixed GHGs, the emissions of which are analyzed for contribution (*e.g.,* the flow into the stock). See 74 FR at 66537, (December 15, 2009), (similar discussion with respect to the finding for section 202). Thus, for purposes of section 231, the Administrator is proposing to use the same definition of the air pollutant that was used in the 2009 Endangerment Finding, namely, the aggregate group of the same six GHGs: CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. See 74 **Federal Register** at 66536–66537, (December 15, 2009), (discussing the definition of the GHG air pollutant with respect to the finding for section 202). That is, as for the 2009 Endangerment Finding, the Administrator is proposing to define a

[157] IPCC, 2013: *Climate Change 2013: The Physical Science Basis.* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, 1535 pp.

[158] U.S. EPA, ''Control of Air Pollution from Aircraft and Aircraft Engines, Emission Standards and Test Procedures for Aircraft.'' Final Rule, 38 FR 19088, July 17, 1973.

[159] *CRR,* 684 F.3d at 117 (D.C. Cir. 2012), reh'g en banc denied, 2012 U.S. App. LEXIS 25997, 26313, 26315 (D.C. Cir. 2012); *see also Utility Air Reg. Group* v. *EPA,* 134 S. Ct. at 2438 (2014).

single air pollutant made up of these six GHGs.

To reiterate what the Agency has previously stated on this subject, this collective approach for the contribution test is consistent with the treatment of GHGs by those studying climate change science and policy, where it is common practice to evaluate GHGs on a collective, CO_2-equivalent basis.[160] This collective approach to defining the air pollutant is not unique; grouping of many substances with common attributes as a single pollutant is common practice under the CAA, for example with particulate matter and volatile organic compounds (VOC). As noted in section IV, these substances share common attributes that support their grouping as the air pollution for purposes of the endangerment finding. These same common attributes also support the Administrator grouping the six GHGs for purposes of defining the air pollutant for the proposed cause or contribute finding under CAA section 231.

The Administrator recognizes that in this case, the aircraft engines covered by this notice emit two of the six gases, but not the other four gases. Nonetheless, it is entirely appropriate, and in keeping with the 2009 Endangerment Finding and past EPA practice, for the Administrator to define the air pollutant in a manner that recognizes the shared relevant properties of all these six gases, even though they are not all emitted from the classes of sources before her.[161] For example, a source may emit only 20 of the possible 200-plus chemicals that meet the definition of VOC in the EPA's regulations, but that source is evaluated based on its emissions of VOC and not on its emissions of the 20 chemicals by name. The fact that these six substances within the definition of GHGs share common, relevant attributes is true regardless of the type of sources being evaluated for contribution. By proposing to use the definition of the air pollutant as comprised of the six GHGs with common attributes, the Administrator is taking account of these shared attributes and how they are relevant to the air pollution that endangers public health and welfare.

2. How the Definition of Air Pollutant in the Endangerment Determination Affects Section 231 Standards

Under section 231(a), the Administrator is required to set ''emission standards applicable to the emission of any air pollutant'' from classes of aircraft engines that the Administrator determines causes or contributes to air pollution that endangers public health or welfare. If the Administrator makes a final determination under section 231 that the emissions of the GHG air pollutant from certain classes of aircraft engines contribute to the air pollution that may reasonably be anticipated to endanger public health and welfare, then she is called on to set standards applicable to the emissions of this air pollutant. The term ''standards applicable to the emissions of any air pollutant'' is not defined, and the Administrator has the discretion to interpret it in a reasonable manner to effectuate the purposes of section 231 to set standards that either control the emissions of the group of six well-mixed gases as a whole and/or control emissions of individual gases, as constituents of the class. For example, it might be appropriate to set a standard that measures and controls the aggregate emissions of the group of GHGs, weighted by CO_2 equivalent. Depending on the circumstances, however, it may be appropriate to set standards for certain individual gases, or some combination of group and individual standards. These and other similar approaches could appropriately be considered in setting a standard or standards applicable to the emissions of the group of GHGs that are defined as the air pollutant. The Administrator would consider a variety of factors in determining what approach to take in setting the standard or standards; for example, she would consider the characteristics of the aircraft emissions, such as rate and variability, the kind and availability of control technology, and other matters relevant to setting standards under section 231.[162]

B. Proposed Cause or Contribute Finding

1. The Administrator's Approach in Making This Proposed Finding

As it did for the 2009 Endangerment Finding, and consistent with prior practice and current science, the EPA uses annual emissions as a reasonable proxy for contributions to the air pollution, *i.e.,* elevated atmospheric concentrations of GHGs. Cumulative anthropogenic emissions are primarily responsible for the observed change in concentrations in the atmosphere (*i.e.,* the fraction of a country's or an economic sector's cumulative emissions compared to the world's GHG emissions over a long time period will be roughly equal to the fraction of the change in concentrations attributable to that country or economic sector); likewise, annual emissions are a reasonable proxy for annual incremental changes in atmospheric concentrations.

There are a number of possible ways of assessing whether air pollutants cause or contribute to the air pollution which may reasonably be anticipated to endanger public health and welfare, and no single approach is required or has been used exclusively in previous determinations under the CAA. Because the air pollution against which the contribution is being evaluated is the six well-mixed GHGs, the logical starting point for any contribution analysis is a comparison of the emissions of the air pollutant from the section 231 category to the total U.S. and total global emissions of the six GHGs. The Administrator recognizes that there are other valid comparisons that can be considered in evaluating whether emissions of the air pollutant cause or contribute to the combined concentration of the six GHGs. To inform the Administrator's assessment, section V.B.2 presents the following types of simple and straightforward comparisons of U.S. aircraft GHG emissions:

- As a share of current total U.S. GHG emissions;
- As a share of current U.S. transportation GHG emissions;

[160] As detailed in the 2009 Endangerment Finding proposal (74 FR 18904 (April 24, 2009) and continuing today, the UNFCCC, the U.S. and other Parties report their annual emissions of the six GHGs in CO_2-equivalent units. This facilitates comparisons of the multiple GHGs from different sources and from different countries, and provides a measure of the collective warming potential of multiple GHGs. Emissions of different GHGs are compared using GWPs, which as described in section IV.B of this preamble are measures of the warming impact of a pulse of emissions of a given substance over 100 years relative to the same mass of CO_2. Therefore, GWP-weighted emissions are measured in teragrams of CO_2 equivalent (Tg CO_2eq). The EPA's Greenhouse Gas Reporting Program (*http://www.epa.gov/ghgreporting/index.html,* (last accessed May 12, 2015)) also reports GHG emissions on a CO_2-equivalent basis, recognizing the common and collective treatment of the six GHGs.

[161] In the 2009 Endangerment Finding, the Administrator found that four of the six gases that were included in the definition of the air pollutant were emitted by section 202 sources. 74 FR 66496, 66537 (December 15, 2009).

[162] In setting GHG emissions standards for model years 2012–2016 light-duty vehicles, the EPA set fleet-wide average CO_2 equivalent standards for cars and trucks based on a technology assessment analysis which indicated that there was a wide range of technologies available for manufacturers to use when upgrading vehicles to reduce CO_2 emissions and improve fuel economy. The final standards were based on CO_2 emissions-footprint curves, where each vehicle has a different CO_2 emissions compliance target depending on its footprint value (related to the size of the vehicle). The EPA also set standards to cap tailpipe nitrous oxide, methane emissions, and provided compliance credits to manufacturers who improved air conditioning systems, such as through reduced refrigerant leakage (hydrofluorocarbons) and indirect CO_2 emissions related to the increased load on the engine. 75 FR 25324 (May 7, 2010).

- As a share of current total global GHG emissions; and
- As a share of the current global transportation GHG emissions.

All annual GHG emissions data are reported on a CO_2-equivalent (CO_2eq) basis, which as described above is a commonly accepted metric for comparing different GHGs. This approach is consistent with how EPA determined contribution for GHGs under section 202 of the CAA in 2009.

2. Overview of Greenhouse Gas Emissions

Atmospheric concentrations of CO_2 and other GHGs are now at essentially unprecedented levels compared to the distant and recent past.[163] This is the unambiguous result of human emissions of these gases. Global emissions of well-mixed GHGs have been increasing, and are projected to continue increasing for the foreseeable future. According to IPCC AR5, total global (from all major emitting sources including forestry and other land use) emissions of GHGs in 2010 were about 49,000 teragrams[164] of CO_2 equivalent (Tg CO_2eq).[165] This represents an increase in global GHG emissions of about 29 percent since 1990 and 23 percent since 2000. In 2010, total U.S. GHG emissions were responsible for about 14 percent of global GHG emissions (and about 12 percent when factoring in the effect of carbon sinks from U.S. land use and forestry).

Because 2010 is the most recent year for which IPCC emissions data are available, we provide 2011 estimates from another widely used and recognized global dataset, the World Resources Institute's (WRI) Climate Analysis Indicators Tool (CAIT),[166] for comparison. According to WRI/CAIT, the total global GHG emissions in 2011 were 43,816 Tg of CO_2eq, representing an increase in global GHG emissions of about 42 percent since 1990 and 30 percent since 2000 (excluding land use, land use change and forestry). These estimates are generally consistent with those of IPCC. In 2011, WRI/CAIT data indicate that total U.S. GHG emissions were responsible for about 16 percent of global emissions, which is also generally in line with the percentages using IPCC's 2010 estimate described above. According to WRI/CAIT, current U.S. GHG emissions rank only behind China's, which was responsible for 24 percent of total global GHG emissions.

The *Inventory of U.S. Greenhouse Gas Emissions and Sinks Report*[167] (hereinafter "U.S. Inventory"), in which 2013 is the most recent year for which data are available, indicates that total U.S. GHG emissions increased by 5.7 percent from 1990 to 2013 (or by about 4.7 percent when including the effects of carbon sinks), and emissions increased from 2012 to 2013 by 1.8 percent. This 2012 to 2013 increase was attributable to multiple factors including an increase in carbon intensity of fuels consumed for electricity generation, a small increase in vehicle miles traveled and vehicle fuel use, and a colder winter leading to an increase in heating requirements. The U.S. Inventory also shows that while overall U.S. GHG emissions grew between 1990 and 2013, transportation GHG emissions grew at a significantly higher rate, 15 percent, more rapidly than any other U.S. sector. Within the transportation sector, aircraft remain the single largest source of GHG emissions not yet subject to any GHG regulations.

Section V.B.2.a which follows describes U.S. aircraft GHG emissions within the domestic context, while section V.B.2.b describes these same GHG emissions in the global context. Section V.B.2.c addresses future projections of aircraft GHG emissions.

a. U.S. Aircraft GHG Emissions Relative to U.S. GHG Transportation and Total U.S. GHG Inventory

Relying on data from the U.S. Inventory, we compare U.S. aircraft GHG emissions to the transportation sector and to total U.S. GHG emissions as an indication of the role this source plays in the total domestic contribution to the air pollution that is causing climate change. In 2013, total U.S. GHG emissions from all sources were 6,774 Tg CO_2eq. As stated above, total U.S. GHG emissions have increased by almost 6 percent between 1990 and 2013, while U.S. transportation GHG emissions from all categories have grown 15 percent since 1990. The U.S. transportation sector was the second largest GHG emitting sector (behind electricity generation), contributing 1,911 Tg CO_2eq or about 30 percent of total U.S. GHG emissions in 2013. This sectoral total and the total U.S. GHG emissions include emissions from combustion of U.S. international bunker fuels, which are fuels used for transport activities, from aviation (both commercial and military) and marine sources.[168] Consistent with IPCC guidelines for common and consistent accounting and reporting of GHGs under the UNFCCC, the "U.S. international aviation bunker fuels" category includes emissions from combustion of fuel purchased in and used by aircraft departing from the United States, regardless of whether they are a U.S. flagged carrier. Total U.S. aircraft emissions clearly contribute to the U.S. transportation sector's emissions, accounting for 216 Tg CO_2eq or 11 percent of such emissions (see Table V.1.). In 2013, emissions from aircraft (216 Tg CO_2eq) were the third largest transportation source of GHGs within the United States, behind light-duty vehicles and medium- and heavy-duty trucks (totaling 1,494 Tg CO_2eq).

For purposes of making this cause or contribute finding, the EPA is focused on, and proposes to include, a set of aircraft engine classes used in types of aircraft as described below, which corresponds to the scope of the international CO_2 emissions standard contemplated by ICAO.

As mentioned earlier in section II.D, traditionally the EPA (and FAA) participates at ICAO in the development of international standards, and then where appropriate, the EPA establishes domestic aircraft engine emission standards under CAA section 231 of at least equivalent stringency to ICAO's standards. An international CO_2 emissions standard is anticipated in February 2016, and provided that the EPA makes a positive endangerment finding and ICAO adopts an

[163] IPCC, 2013: *Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis.* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, p. 11.

[164] One teragram (Tg) = 1 million metric tons = 1 megatonne (Mt). 1 metric ton = 1,000 kg = 1.102 short tons = 2,205 lbs.

[165] 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.

[166] World Resources Institute (WRI) Climate Analysis Indicators Tool (CAIT) Data Explorer (Version 2.0). Available at *http://cait.wri.org* (last accessed May 12, 2015).

[167] U.S. EPA, 2015: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013,* 564 pp. Available at *http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html#fullreport,* (last accessed May 12, 2015).

[168] According to IPCC guidelines for common and consistent accounting and reporting of GHGs under the UNFCCC, the total U.S. GHG emissions from the U.S. Inventory that is reported to the UNFCCC excludes international bunker fuel emissions (aviation and marine international bunker fuel emissions) from the reported total national GHG emissions. However, the total U.S. GHG emissions in this proposed cause or contribute finding section of this action do include international bunker fuel emissions because we want to capture the full contribution of U.S. emissions, including those from U.S. aircraft.

international CO_2 emissions standard that is both consistent with CAA section 231 and appropriate for domestic needs, we would expect to proceed with promulgating a CO_2 emissions standard (or GHG standard) of at least equivalent stringency domestically. As described later in section VI.D, the thresholds of applicability for the international CO_2 emissions standard are based on gross weight as follows: For subsonic jet aircraft, a maximum takeoff mass (MTOM) greater than 5,700 kilograms; and for subsonic propeller driven (*e.g.,* turboprop) aircraft, a MTOM greater than 8,618 kilograms.[169] Applying these gross weight thresholds, our proposed cause or contribute finding applies to GHG emissions from classes of engines used in covered aircraft. Examples of covered aircraft would include smaller jet aircraft such as the Cessna Citation CJ2+ and the Embraer E170, up to the largest commercial jet aircraft—the Airbus A380 and the Boeing 747. Other examples of covered aircraft would include larger turboprop aircraft, such as the ATR 72 and the Bombardier Q400. Our intention is for the scope of the contribution finding to correspond to the aircraft engine GHG emissions that are from aircraft that match the applicability thresholds for the international aircraft CO2 standard. As such we have also identified aircraft that are not covered aircraft for purposes of our proposed contribution finding. That includes aircraft that fall below the international applicability thresholds: Smaller turboprop aircraft, such as the Beechcraft King Air 350i, and smaller jet aircraft, such as the Cessna Citation M2. In addition, ICAO (with U.S. participation) has agreed to exclude ''piston-engine aircraft,'' ''helicopters,'' and ''military aircraft'' [170] from the types of aircraft that would be covered by the anticipated ICAO standards.[171] These aircraft would not be covered aircraft and consequently, we are also not including GHG emissions from classes of engines used in these types of aircraft in our proposed cause or contribute finding.

Thus, for the purposes of the cause or contribute finding, the EPA proposes to include GHG emissions from aircraft engines used in covered aircraft in the scope of this proposed cause or contribute finding. This is an equivalent scope of applicability as that contemplated by ICAO. The majority of the GHG emissions from all classes of aircraft engines would be covered by this scope of applicability. Below we describe the contribution of these U.S. covered aircraft GHG emissions to U.S. GHG emissions, and later in section V.B.2.b we discuss the contribution of these U.S. covered aircraft emissions to global GHG emissions.

In 2013, GHG emissions from U.S. covered aircraft (which includes U.S. international aviation bunker fuels in certain cases) comprised 90 percent (195 Tg CO_2eq) of total U.S. aircraft GHG emissions [172] and 10 percent of total U.S. transportation sector GHG emissions (See Table V.1.). Overall, U.S. covered aircraft comprised the third largest source of GHG emissions in the U.S. transportation sector behind only the light-duty vehicle and medium- and heavy-duty truck sectors, which is the same ranking as total U.S. aircraft.[173] The U.S. covered aircraft also represent 3 percent of total U.S. GHG emissions, which is approximately equal to the contribution from total U.S. aircraft of 3.2 percent (Table V.1).[174]

It is important to note that in regard to the six well-mixed GHGs (CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride), only two of these gases—CO_2 and nitrous oxide—are reported as non-zero emissions for total aircraft and covered aircraft.[175] CO_2 represents 99 percent of all GHGs from both total aircraft (214 Tg CO_2eq) and U.S. covered aircraft (193 Tg CO_2eq), and nitrous oxide represents about one percent from total aircraft (2 Tg CO_2eq) and covered aircraft (1.8 Tg CO_2eq). Modern aircraft do not emit methane,[176] and hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are not products of aircraft engine combustion.

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[169] ICAO, 2013: *CAEP/9 Agreed Certification Requirement for the Aeroplane CO_2 Emissions Standard,* Circular (Cir) 337, AN/192, Available at *http://www.icao.int/publications/ICAOProducts&Services2015catalogue/cat_2015en.pdf* (last accessed May 12, 2015). The ICAO Circular 337 is found on page 85 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. CIR337.

[170] ICAO regulations only apply to civil aviation (aircraft and aircraft engines), and consequently, ICAO regulations do not apply to military aircraft.

[171] The applicability of the anticipated international CO_2 standard would be limited to subsonic aircraft, and would not extend to supersonic aircraft. Since space vehicles (or spacecraft) will be operated at supersonic speeds, space vehicles would not be covered by the anticipated international CO_2 standard.

[172] Eastern Research Group, Incorporated (ERG), *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, May 7, 2015.

[173] Compared independently, total U.S. aircraft GHG emissions and U.S. covered aircraft GHG emissions are both ranked the third largest source in the U.S. transportations sector, behind only light-duty vehicle and medium- and heavy-duty truck sectors.

[174] Total U.S. aircraft GHG emissions and U.S. covered aircraft GHG emissions were from 12 to 32 percent greater in 2000 and 2005 than in 1990. These increases in aircraft GHG emissions are primarily because aircraft operations (or number of flights) grew by similar amounts during this time period. Also, total U.S. aircraft GHG emissions and U.S. covered aircraft GHG emissions were from 10 to 17 percent greater in 2000 and 2005 than in 2013. These decreases in aircraft GHG emissions are partly because aircraft operations decreased by similar amounts during this time period. In addition, the decreases in aircraft emissions are due in part to improved operational efficiency that results in more direct flight routing, improvements in aircraft and engine technologies to reduce fuel burn and emissions, and the accelerated retirement of older, less fuel efficient aircraft.

Also, the U.S. transportation GHG emissions were changing at similar rates as total U.S. aircraft GHG emissions and U.S. covered aircraft GHG emissions for these same time periods, and thus, the aircraft GHG emissions share of U.S. Transportation remains approximately constant (over these time periods).

(U.S. EPA, 2015: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013,* 564 pp. Available at *http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html#fullreport*, Last accessed May 12, 2015; U.S. FAA. 2015, *APO Terminal Area Forecast Summary Report—Forecast Issued January 2015, http://aspm.faa.gov/apowtaf/* .).

[175] U.S. EPA, 2015: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013,* 564 pp. Available at *http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html#fullreport*, (last accessed May 12, 2015).

[176] Emissions of methane from jet fuels are no longer considered to be emitted (based on the latest studies) across the time series from aircraft gas turbine engines burning jet fuel A at higher power settings (EPA, *Recommended Best Practice for Quantifying Speciated Organic Gas Emissions from Aircraft Equipped with Turbofan, Turbojet and Turboprop Engines,* EPA–420–R–09–901, May 27, 2009 (see *http://www.epa.gov/otaq/regs/nonroad/aviation/420r09901.pdf (last accessed May 12, 2015)*). Based on this data, methane emissions factors for jet aircraft were reported as zero to reflect the latest emissions testing data. Also, the 2006 IPCC Guidelines indicate the following: ''Methane (CH_4) may be emitted by gas turbines during idle and by older technology engines, but recent data suggest that little or no CH_4 is emitted by modern engines.'' (IPCC, 2006: *IPCC Guidelines for National Greenhouse Gas Inventories,* The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan.) The EPA uses an emissions factor of zero to maintain consistency with the IPCC reporting guidelines, while continuing to stay abreast of the evolving research in this area. For example, one recent study has indicated that modern aircraft jet engines operating at higher power modes consume rather than emit methane (Santoni et al., 2011: *Aircraft Emissions of Methane and Nitrous Oxide during the Alternative Aviation Fuel Experiment,* Environ. Sci. Technol., 45, pp. 7075–7082).

TABLE V.1—COMPARISONS OF U.S. AIRCRAFT GHG EMISSIONS TO TOTAL U.S. TRANSPORTATION AND TOTAL U.S. GHG EMISSIONS

	1990	2000	2005	2010	2011	2012	2013
Total U.S. Aircraft GHG emissions (Tg CO_2eq)	228	262	254	216	215	212	216
Share of U.S. Transportation	14%	13%	12%	11%	11%	11%	11%
Share of total U.S. Inventory	3.6%	3.6%	3.4%	3.1%	3.1%	3.2%	3.2%
U.S. Covered Aircraft GHG emissions (Tg CO_2eq)	169	223	217	190	193	190	195
Share of U.S. aircraft GHG emissions	74%	85%	85%	88%	90%	90%	90%
Share of U.S. Transportation	10%	11%	10%	9.7%	10%	9.9%	10%
Share of total U.S. Inventory	2.6%	3%	2.9%	2.7%	2.8%	2.9%	2.9%
Transportation Sector emissions (Tg CO_2eq)	1,659	2,044	2,137	1,966	1,932	1,907	1,911
Share of total U.S. Inventory	26%	28%	29%	28%	28%	29%	28%
Total U.S. GHG emissions	6,406	7,315	7,464	7,017	6,889	6,652	6,744

b. U.S. Aircraft GHG Emissions Relative to Global Aircraft GHG Inventory and the Total Global GHG Inventory

For background information and context, we first provide information on the contribution of GHG emissions from global aircraft and the global transportation sector to total global GHG emissions, and describe how this compares to the emissions from aircraft that would be covered by the anticipated ICAO CO_2 standard. We then compare U.S. aircraft GHG emissions to the global aircraft sector, to the global transport sector, and to total global GHG emissions as an indication of the role this source plays in the total global contribution to the air pollution that is causing climate change. As in the preceding section, we present comparisons from both total U.S. aircraft and U.S. covered aircraft.

According to IPCC AR5, global aircraft GHG emissions in 2010 were 11 percent of global transport GHG emissions and 2 percent of total global GHG emissions. Data from ICAO's 2013 Environmental Report indicate that the vast majority of global emissions from the aircraft sector are emitted by the types of aircraft that would be covered by the anticipated ICAO CO_2 standard (''ICAO covered aircraft'').[177] When compared to global data from IPCC AR5, worldwide GHG emissions from ICAO covered aircraft represented about 93 percent (688 Tg CO_2eq) of global aircraft GHG emissions,[178] 10 percent of global transport GHG emissions, and 1.5 percent of total global GHG emissions in 2010.

Comparing data from the U.S. Inventory to IPCC AR5, we find that total U.S. aircraft GHG emissions represented about 29 percent of global aircraft GHG emissions, about 3.1 percent of global transport GHG emissions, and about 0.5 percent of total global GHG emissions in 2010 (see Table V.2). For U.S. covered aircraft in 2010 GHG emissions represented about 26 percent of global aircraft GHG emissions, 2.7 percent of global transport GHG emissions, and 0.5 percent of total global GHG emissions (see Table V.2). Because 2010 is the most recent year for which IPCC emissions data are available, we also made comparisons using 2011 estimates from WRI/CAIT and the International Energy Agency (IEA) [179] and found that they yield very similar results.[180]

TABLE V.2—COMPARISONS OF U.S. AIRCRAFT GHG EMISSIONS TO TOTAL GLOBAL GREENHOUSE GAS EMISSIONS IN 2010

	2010 (Tg CO_2 eq)	Total U.S. Aircraft Share (%)	U.S. Covered Aircraft Share (%)	Global Aircraft Share (%)
Global Aircraft GHG emissions	743	29	26	
Global Transport GHG emissions	7,000	3.1	2.7	11
Total Global GHG emissions	49,000	0.5	0.5	2

For additional background information and context, we used 2011 WRI/CAIT and IEA data to make comparisons between the aircraft sector and the emissions inventories of entire countries and regions. When compared to entire countries, total global aircraft GHG emissions in 2011 ranked 9th overall, behind only China, United States, India, Russian Federation, Japan, Brazil, Germany, and Indonesia, and ahead of about 175 other countries. Total U.S. aircraft GHG emissions have historically been and continue to be by far the largest contributor to global aircraft GHG emissions. Total U.S. aircraft GHG emissions are about 7 times higher than aircraft GHG emissions from China, which globally is the second ranked country for aircraft GHG emissions, and about 5 times higher than aircraft GHG emissions from all of Asia. U.S. covered aircraft GHG emissions are about 6 times more than aircraft GHG emissions from China, and about 4 times more than aircraft GHG emissions from all of Asia. If U.S.

[177] ICAO CAEP, 2013: *ICAO Environmental Report 2013, Aviation and Climate Change,* 224 pp. Available at *http://cfapp.icao.int/Environmental-Report-2013/* (last accessed May 12, 2015).

[178] Worldwide GHG emissions from ICAO covered aircraft include emissions from both international and domestic aircraft operations around the world.

[179] International Energy Agency, Data Services. Available at *http://data.iea.org* (last accessed May 12, 2015).

[180] Data from WRI/CAIT and IEA show that, in 2011, total U.S. aircraft emissions represented about 28 percent of global aircraft GHG emissions, about 3.7 percent of global transport GHG emissions, and about 0.5 percent of total global GHG emissions. U.S. covered aircraft represented about 25 percent of global aircraft GHG emissions, 3.3 percent of global transport GHG emissions, and 0.5 percent of total global GHG emissions in 2011.

covered aircraft emissions of GHGs were ranked against total GHG emissions for entire countries, these covered aircraft emissions would rank ahead of Belgium, Czech Republic, Ireland, Sweden and about 150 other countries in the world.

c. Aircraft GHG Emissions Are Projected To Increase in the Future

While overall GHG emissions from U.S. covered aircraft increased by about 13 percent from 1990 to 2010, the portion attributable to U.S. international aviation bunker fuels [181] increased by about 90 percent.[182] During this same time period, global aircraft GHG emissions grew by about 40 percent, and the portion attributable to global international aviation bunker fuels increased by 80 percent.[183] [184] Notwithstanding the substantial growth in GHG emissions from U.S. international aviation bunker fuels, U.S. covered aircraft emissions have not increased as much as global aircraft emissions primarily because the U.S. aviation market was relatively mature compared to the markets in Europe and other emergent markets, and because during this time period the U.S. commercial air carriers suffered several major shocks that reduced demand for air travel.[185] [186] After consolidation and restructuring in recent years, the U.S. commercial air carriers have regained profitability and are forecasted by the FAA to grow more over the next 20 to 30 years.[187] With regard to global aircraft GHG emissions, the aviation markets in Asia/Pacific, Europe (where airline deregulation has stimulated significant new demands in this period), and the Middle East (and other emerging markets) have been growing rapidly, and the global market is expected to continue to grow significantly over the next 20 to 30 years.[188]

Recent studies estimate that both ICAO covered aircraft and U.S. covered aircraft will experience substantial growth over the next 20 to 30 years in their absolute fuel burn, and that this will translate into increased GHG emissions. ICAO estimates that the global fuel burn from ICAO covered aircraft will increase by about 120 percent from 2010 to 2030 and by about 210 percent from 2010 to 2040 (for a scenario with moderate technology and operational improvements).[189] The FAA projects that the fuel consumption from U.S. air carriers and general aviation aircraft operating on jet fuel will grow by 49 percent from 2010 to 2035, corresponding to an average annual increase rate in fuel consumption of 1.6 percent.[190] These aircraft groups (U.S. air carriers and general aviation aircraft operating on jet fuel) are of similar scope to the U.S. covered aircraft whose engine GHG emissions are the subject of this proposed finding. Using fuel burn growth rates provided above as a scaling factor for growth in GHG emissions (globally and nationally), it is estimated that GHG emissions from ICAO covered aircraft and U.S. covered aircraft would increase at a similar rate as the fuel burn by 2030, 2035, and 2040.

3. Proposed Contribution Finding for the Single Air Pollutant Comprised of the of Six Well-Mixed Greenhouse Gases

Taking into consideration the data summarized in section V.B.2 above, the Administrator proposes to find that GHG emissions from classes of engines used in U.S. covered aircraft, which are 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, contribute to the air pollution that endangers public health and welfare. The Administrator is not at this time proposing a contribution finding for GHG emissions from engines not used in covered aircraft (*i.e.,* those used in smaller turboprops, smaller jet aircraft, piston-engine aircraft, helicopters and military aircraft). We solicit comment on the scope of the proposed contribution finding, whether a broader contribution finding (*e.g.,* including all engines used in aircraft certified by the FAA) would be appropriate, and the extent to which EPA has discretion to establish standards pursuant to a contribution finding that do not impose requirements on every engine or class of engines within the scope of that finding.

It is the Administrator's judgment that the collective GHG emissions from the classes of engines used in U.S. covered aircraft clearly contribute, whether the comparison is domestic (10 percent of all U.S. transportation GHG emissions, representing 3 percent of total U.S. emissions) or global (26 percent of total global aircraft GHG emissions representing 3 percent of total global transportation emissions and 0.5 percent of all global GHG emissions). The proposed scope of GHG emissions from engines used in U.S. covered aircraft under this cause or contribute finding would result in the vast majority (90 percent) of U.S. aircraft GHG emissions being included in this determination. The Administrator believes that consideration of the global context is important for the cause or contribute test, but that the analysis should not solely consider the global context. GHG emissions from engines used in U.S. covered aircraft will become globally well-mixed in the atmosphere, and thus will have an effect not only on the U.S. regional climate but also on the global climate as a whole, for years and indeed many decades to come. It is the Administrator's view that the cause or contribute test used here

[181] The U.S. international aviation bunker fuels category includes emissions from combustion of fuel purchased in and used by aircraft departing from the United States, regardless of whether they are a U.S. flagged carrier. GHG emissions from U.S. international aviation bunker fuels are a subset of GHG emissions from U.S. covered aircraft. From 1990 to 2010, GHG emissions from U.S. covered aircraft increased from 169 to 190 Tg CO2eq, and GHG emissions from the portion attributable to U.S. international aviation bunker fuels grew from 30 to 58 Tg CO2eq during this same time period. From 1990 to 2011, GHG emissions from U.S. covered aircraft increased from 169 to 192 Tg CO2eq (about 14 percent), and GHG emissions from the portion attributable to U.S. international aviation bunker fuels grew from 30 to 62 Tg CO2eq (about 110 percent).

[182] U.S. EPA, 2015: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013,* 564 pp. Available at *http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html#fullreport*, (last accessed May 12, 2015).

[183] 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, pp. 599–670.

[184] According to IEA, from 1990 to 2011, global aircraft GHG emissions grew by about 50 percent, and global international aviation bunker fuels increased by 80 percent. International Energy Agency Data Services, Available at *http://data.iea.org* (last accessed May 12, 2015, 2015).

[185] FAA, 2014: *FAA Aerospace Forecast Fiscal Years 2014–2034,* 129 pp. Available at *https://www.faa.gov/about/office_org/headquarters_offices/apl/aviation_forecasts/aerospace_forecasts/2014-2034/media/2014_FAA_Aerospace_Forecast.pdf* (last accessed May 12, 2015).

[186] These shocks include the September 11 terror attacks, significant increases in fuel prices, debt restructuring in Europe and U.S., and a global recession.

[187] According to the *FAA Aerospace Forecast 2014–2034,* in 2013 U.S. air carriers were profitable for the fourth consecutive year.

[188] According to the *FAA Aerospace Forecast 2014–2034,* the International Air Transport Association (IATA) reports that world air carriers (including U.S. airlines) are expected to register an operating profit for 2013. Based on financial data compiled by ICAO and IATA, between 2004 and 2013 world airlines produced cumulative operating profits (with nine years out of ten posting gains) and net profits (with six years out of ten posting gains).

[189] ICAO CAEP, 2013: *ICAO Environmental Report 2013, Aviation and Climate Change,* 224 pp. Available at *http://cfapp.icao.int/Environmental-Report-2013/* (last accessed May 12, 2015).

[190] FAA, 2015: *FAA Aerospace Forecast Fiscal Years 2015–2035,* 134 pp. Available at *https://www.faa.gov/about/office_org/headquarters_offices/apl/aviation_forecasts/aerospace_forecasts/2015-2035/media/2015_National_Forecast_Report.pdf* (last accessed May 12, 2015).

under CAA section 231 can follow the same reasoning that was used in the 2009 GHG cause or contribute finding under CAA section 202; that is, the Administrator believes a positive cause or contribute finding for GHG emissions from engines used in U.S. covered aircraft is justified whether only the domestic context is considered, only the global context is considered, or both the domestic and global GHG emissions comparisons are viewed in combination.

As was the case in 2009, no single GHG source category dominates on the global scale, and many (if not all) individual GHG source categories could appear small in comparison to the total, when, in fact, they could be very important contributors in terms of both absolute emissions or in comparison to other source categories, globally or within the United States. If the United States and the rest of the world are to combat the risks associated with global climate change, contributors must do their part even if their contributions to the global problem, measured in terms of percentage, are smaller than typically encountered when tackling solely regional or local environmental issues.'' [191] Moreover, as the Supreme Court explained in *Massachusetts* v. *EPA,* agencies commonly take an incremental approach to resolving large issues, stating that, ''[a]gencies, like legislatures, do not generally resolve massive problems in one fell regulatory swoop. . . . They instead whittle away at them over time, refining their preferred approach as circumstances change and as they develop a more nuanced understanding of how best to proceed.'' 549 U.S. 497, 524 (2007) (citations omitted). The Administrator continues to believe that these unique, global aspects of the climate change problem—including that from a percentage perspective there are no dominating sources emitting GHGs and few sources that would even be considered to be close to dominating—tend to support consideration of contribution to the air pollution at lower percentage levels than EPA typically encounters when analyzing contribution towards a more localized air pollution problem. Thus, the Administrator, similar to the approach taken in the 2009 GHG cause or contribute finding under CAA section 202, is placing weight on the fact that engines [192] used in U.S. covered aircraft contribute 3 percent of total U.S. GHG emissions for the proposed contribution finding and comprise the single largest transportation source in the United States that has not yet been regulated for GHG emissions.

4. Additional Considerations

The Administrator is also concerned that reasonable estimates of GHG emissions from engines used in U.S. covered aircraft are projected to grow over the next 20 to 30 years. Given the projected growth in aircraft emissions compared to other sectors, it is reasonable for the Administrator to consider future emissions projections as adding weight to her primary reliance on annual emissions. Recent projections reveal that by 2035 GHG emissions from all aircraft and U.S. covered aircraft engines are likely to increase by almost 50 percent.[193] By contrast, it is estimated that by 2035 the light duty vehicle sector will see a 30 percent *reduction* in GHG emissions from the 2010 baseline, while the heavy duty vehicle sector will experience a 33 percent increase in GHG emissions from the 2010 baseline (this projected increase does not reflect the impact of GHG reductions anticipated from the Phase 2 heavy duty GHG standards that have not yet been promulgated). In addition, by 2035 the rail sector is projected to experience a 6 percent reduction in GHG emissions from 2010 baseline.[194] Because the projected growth in aircraft engine GHG emissions from U.S. covered aircraft appears to be greater in percentage terms than other transportation sources, this future consideration adds weight to the Administrator's proposed positive contribution finding.

VI. Advance Notice of Proposed Rulemaking: Discussion of Ongoing International Proceedings To Develop Aircraft CO_2 Emissions Standard and Request for Comment

For more than four years, the EPA and FAA have been engaged with the ICAO's Committee on Aviation Environmental Protection (ICAO/CAEP) to establish an international CO_2 emissions standard which the EPA could then consider proposing for adoption under its section 231 authority of the CAA. This section of this document serves as an ANPR to discuss the key issues of the ongoing international proceedings prior to February 2016, when ICAO/CAEP is expected to finalize an international aircraft CO_2 standard. An ANPR is intended to solicit comments and/or information from the public prior to an agency determining whether to propose a rulemaking. As such, an ANPR does not propose or impose any regulatory requirements. The EPA may choose to develop an ANPR for actions (such as the promulgation of standards pursuant to CAA section 231 to implement an international aircraft CO_2 standard domestically) which are still in the early stages of development and for which public input may be particularly helpful. This also helps ensure transparency, while assisting the EPA in obtaining input from a wide range of stakeholders as we continue work within CAEP to establish an international CO_2 aircraft standard. The EPA is seeking comments from all interested parties, including small businesses, on a variety of issues related to setting an international CO_2 standard for aircraft, including whether such standards should apply to in-production aircraft instead of new aircraft types only, the appropriate effective dates for the potential international CO_2 standard, as well as the appropriate stringency levels.

CAEP met an important milestone at its 9th meeting (CAEP/9) in 2013 in reaching an agreement on the

[191] 74 FR 66543 (December 15, 2009).

[192] For a standard promulgated under CAA section 231 to be ''applicable to'' emissions of air pollutants from aircraft engines, it could take many forms, and include multiple elements in addition to numeric permissible engine exhaust rate. For example, under CAA section 231, EPA's rules have long-standing regulations addressing fuel venting, as well as test procedures. *See* 40 CFR part 87, subparts B, G and H. 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 U.S. Court of Appeals for the DC Circuit's 2007 *NACAA* v. *EPA* ruling that section 231 confers an unusually broad degree of discretion in establishing aircraft engine emission standards, it should be possible to reconcile an ICAO ''aircraft standard'' that effectively limits aircraft engine GHG emissions with a CAA section 231 aircraft engine emission standard that achieves the same result, even if the GHG standards take a different form than the traditional thrust-based NOx aircraft engine emission standards recently issued by ICAO and the EPA. *See* 40 CFR part 87, subpart C.

[193] As discussed in Section V.B.2.c fuel burn growth rates for air carriers and general aviation aircraft operating on jet fuel are projected to grow by 49 percent from 2010 to 2035 and this provides a scaling factor for growth in GHG emissions which would increase at a similar rate as the fuel burn by 2030, 2035, and 2040.

[194] U.S. Energy Information Administration (EIA), 2015: *Annual Energy Outlook (AEO) 2015 with projections to 2040,* DOE/EIA–0383, 154 pp. EIA's reference case (used as the baseline in this comparison) assumes fuel economy levels for light duty vehicles required to meet federal light duty GHG standards for years 2012–2025, and for heavy duty trucks GHG standards for years 2014–2018, plus improvements in vehicles and engines for all subsectors due to availability of fuel-saving technologies and fuel price effects. EIA counts biofuels as zero tailpipe GHG emissions. Because the comparison in this section focuses on tailpipe emissions, we include them here, at volumes as forecast in the AEO 2015 reference case. Available at *http://www.eia.gov/forecasts/aeo/* (last accessed May 12, 2015).

appropriate metric to be used in assessing fuel efficiency (or CO_2 emissions)[195] of an engine/aircraft combination. They also reached agreement on a mature certification requirement[196] to evaluate CO_2 emissions for new aircraft types and also agreed on certain aspects of the scope of applicability of the CO_2 emissions standard; however, work on applicability options for in-production aircraft continues.

At the CAEP Steering Group meeting in November 2013, there was agreement on a set of stringency options to be used for the cost-effectiveness analysis, and at the Steering Group meeting in September 2014 there was a decision on the associated inputs for costs and technology responses to be utilized in the cost-effectiveness analysis of these stringency options. This analysis, and work on the applicability of the standard to in-production aircraft and the certification requirement are scheduled to be completed prior to the 10th CAEP meeting (CAEP/10) in February 2016. As described in section II.A, the EPA and the FAA traditionally work within the ICAO/CAEP standard-setting process to establish international emission standards and related requirements. 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 of at least equal stringency as ICAO's standards. This approach has been affirmed as reasonable by the U.S. Court of Appeals for the DC Circuit. Provided the EPA makes a positive endangerment finding[197] under CAA section 231 and ICAO adopts an international aircraft CO_2 standard that is consistent with CAA section 231 and U.S. domestic needs, we would expect to proceed with a similar approach promulgating a CO_2 emissions standard (or GHG standard) of at least equivalent stringency domestically.

A. Purpose of the International Standard

At the CAEP Steering Group meeting in 2011, the U.S provided a paper recommending that CAEP agree that the purpose of the international CO_2 emissions standard be ''to achieve CO_2 emissions reductions from the aviation sector beyond expected 'business as usual'—*i.e.,* a standard that achieves CO_2 emissions reductions from the aviation sector beyond what would be achieved in the absence of a standard. This would be analyzed using ICAO criteria of technical feasibility, environmental benefit, cost effectiveness, and impacts of interdependencies.''[198] The Steering Group accepted the U.S. proposal for the purpose of the international CO_2 standard, and it is expected to be included in the standard setting process. The metric system, stringency options, costs, technology responses (inputs to be utilized in the cost-effectiveness analysis), and applicability ultimately chosen will all have an effect on whether the international CO_2 emissions standard adheres to this stated purpose of the standard. The U.S. continues to support the adoption of an international CO_2 emissions standard that meets this stated purpose, and the EPA requests comment on this continued support. The EPA requests comment on how to achieve the purpose of the standard.

B. Applicability of the International CO_2 Emissions Standard

The EPA requests comments on the applicability approaches that CAEP is considering. Specifically, we request comment on whether the aircraft CO_2 standard should apply to in-production aircraft, including aircraft with any engineered fuel efficiency improvements (*e.g.,* different engines, redesigned wings, or engine performance improvement packages, etc.) or whether the aircraft CO_2 standard should apply only to completely new aircraft type designs. CAEP is also considering a third, alternative approach, which would redefine a new aircraft type for CO_2 purposes to include in-production aircraft that have a significant change in CO_2 emissions. We are also requesting comment on this potential alternative option.

In-production aircraft and new aircraft types are defined as follows:

—*In-production aircraft:* Those aircraft types which have already received a Type Certificate, and for which manufacturers either have existing undelivered sales orders or would be willing and able to accept new sales orders.[199] [200] [201]

—*New aircraft types:* Aircraft types that have applied for a Type Certificate[202] after the effective date of a standard and that have never been manufactured prior to the effective date of a standard.

In addition, for context, out of production aircraft are those aircraft types which have already received a Type Certificate, but for which manufacturers either have no existing undelivered sales orders or would not be willing and able to accept new sales orders. These aircraft are aircraft types that are no longer in active production.[203]

As described earlier in section II.E, CAEP's Steering Group meeting in 2010

[195] ICAO, 2013: *CAEP/9 Agreed Certification Requirement for the Aeroplane CO_2 Emissions Standard,* Circular (Cir) 337, AN/192, Available at *http://www.icao.int/publications/catalogue/cat_2015_en.pdf* (last accessed May 12, 2015). The ICAO Circular 337 is found on page 85 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. CIR337. Section 3.2 of this Circular states the following: ''An important Phase 1 milestone in the development of the CO_2 Standard was reached on 11 July 2012, when the CAEP Steering Group agreed unanimously on a CO_2 metric system to measure the aeroplane fuel burn performance and therefore the CO_2 emissions produced.''

[196] ICAO defines a certification requirement as a combination of metric, procedures, instrumentation and measurement methodology, and compliance requirements.

[197] As shorthand in this action, in many places we will use the term ''endangerment finding'' for both endangerment and cause or contribute findings.

[198] CAEP (U.S. Working Paper), ''U.S. Position on the Development of ICAO'S Aircraft CO_2 Standard,'' CAEP–SG/20112–WP/25, Presented by the United States, U.S. Working Paper for CAEP Steering Group meeting, Beijing, China, 12 to 16 September 2011.

[199] ICAO, 2013: *CAEP/9 Agreed Certification Requirement for the Aeroplane CO_2 Emissions Standard.* Available *at http://www.icao.int/publications/catalogue/cat_2015_en.pdf* (last accessed May 12, 2015).The ICAO Circular 337 is found on page 85 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. CIR337.

[200] As described earlier in section D, in existing U.S. aviation emissions regulations, in-production means newly-manufactured or built after the effective date of the regulations—and already certified to pre-existing standards (if emission standards were established previously).). This is similar to the current CAEP definition for in-production aircraft types for purposes of the CO_2 standard.

[201] According to ICAO Cir 337, a Type Certificate is ''[a] document issued by a Contracting State to define the design of an aircraft type and to certify that this design meets the appropriate airworthiness requirements of that State''.

[202] A Type Certificate is a design approval process whereby the FAA ensures the manufacturer's designs meet the minimum requirements for aircraft safety and environmental regulations. This is typically issued only once for each aircraft, and modified as needed as an aircraft is modified over the course of its production life. This Type Certificate (for new aircraft types) would be the initial or new Type Certificate for this aircraft.

[203] Out of production aircraft that are still in operational use would become subject to the international standard only if the standard applied to ''in-use'' aircraft, which it will not since CAEP has agreed that the international aircraft CO_2 standard should not apply to out of production aircraft types. Note, the EPA's CAA section 231 aircraft engine standards have applied to in-use aircraft only in very limited situations, such as the prohibition against fuel venting at 40 CFR 87.11 and smoke number standards at 40 CFR 87.31. Note, however, that unlike the EPA's authority to promulgate emission standards for motor vehicles under CAA section 202(a) or for nonroad engines and vehicles under section 213(a), section 231 of the CAA does not restrict the EPA's authority to set standards for only new aircraft.

agreed that the scope of applicability for the international aircraft CO_2 standard will be subsonic jets with an applicability weight threshold of maximum takeoff mass (MTOM) greater than 5,700 kg (12,566 lb) and turboprop aircraft with a MTOM greater than 8,618 kg (19,000 lb). CAEP also agreed that the international CO_2 standard will apply to new aircraft types, but not apply to out of production aircraft types, and that applying the standard to in-production aircraft types should not be ruled out.[204]

It is important to further describe the difference between new aircraft types and in-production aircraft. There are three categories of aircraft under consideration when describing a CO_2 standard: New aircraft types submitted for certification (known as clean sheet designs), those with lesser levels of design change, such as a new series in an established type and model (considered to be significant partial redesigns), or an aircraft with incremental improvements.[205] New aircraft types or new type designs are significant investments for manufacturers and are used for new and significantly different designs (also characterized as complete redesigns). Significant partial redesigns may be characterized as a new or later series of an established model that may incorporate newly designed wings and give purchasers more choices of engines. Incremental improvements are less extensive changes to an aircraft such as performance improvement packages that may be added to an aircraft or engine at some point during the production cycle.

New aircraft types or new type designs are infrequent. The most recent new type designs introduced in service, such as the Airbus A380 in 2007, the Boeing 787 in 2011, and the original Boeing 777 in 1995,[206 207 208] indicate that it is unlikely a new type design will seek certification in the next 10 to 15 years.[209] (New aircraft types (and similarly for significant partial redesigns) typically yield large fuel burn reductions—10 percent to 20 percent over the prior generation they replace, and as one might expect, these significant fuel burn reductions do not happen frequently. Also, aircraft development programs are expensive. It is not unusual for new type designs to take 8–10 years to develop, from preliminary design to entry into service.[210 211]) Significant partial redesigns do not occur often, but are slightly more frequent than new type designs. For example, after the current significant partial redesign wave[212] has passed (which includes the Boeing 747–8, Boeing 737 Max, Airbus 320 Neo, and Boeing 777–X), we do not currently have knowledge of many additional significant partial redesigns anticipated over the next decade (as the previous wave of significant partial redesigns included the Boeing 777–200LR in 2004, 777–300ER in 2006, 737NG in 1998, Airbus 319 in 1996, and Airbus 330–200 in 1998).[213 214] Incremental improvements will likely be frequent and occur in the near term. One approach CAEP is considering would be to limit the applicability of any international CO_2 standard to only new type designs (or new aircraft types). Under this approach the international CO_2 standard would not apply to significant partial redesigned aircraft and incremental improvements. Under another approach CAEP is considering, CAEP would also apply the international CO_2 standard to in-production aircraft (in addition to new aircraft types). Significant partial redesigned aircraft and incremental improvements would be characterized as changes made to in-production aircraft; thus, these categories of aircraft (or these changes) would need to meet the international CO_2 standard under this approach (or they would need to meet the standard if it also applied to in-production aircraft).[215]

Another approach for applicability of the international CO_2 standard that CAEP could adopt (or CAEP is considering) would be an approach based on criteria addressing significant changes to aircraft designs, which could be considered an applicability requirement different than that for new aircraft types only and in-production aircraft. This alternative approach could redefine a new aircraft type for CO_2 purposes to include in-production aircraft that have a significant change in CO_2 emissions, thus including in-production aircraft in the applicability of the CO_2 standard. The alternative approach could even cover significant partial redesigned aircraft, depending upon the definition. CAEP's current mature certification requirement for the international CO_2 standard[216] provides further detail on technology changes to aircraft that would affect the aircraft's CO_2 metric value. A changed version of an aircraft could be defined as follows: An aircraft which incorporates changes in type design that may adversely affect[217] its CO_2 emissions. This possible definition could also note the

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[204] ICAO, 2013: *CAEP/9 Agreed Certification Requirement for the Aeroplane CO_2 Emissions Standard.* Available at *http://www.icao.int/publications/catalogue/cat_2015_en.pdf* (last accessed May 12, 2015). The ICAO Circular 337 is found on page 85 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. CIR337.

[205] New aircraft types fall under the initial or new Type Certificate, and significant partial redesigns and incremental improvements fall under an amended Type Certificate. Significant partial redesigns would be a new or later series of an established model, and incremental improvements would be a part of the same series as the established model.

[206] 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 May 12, 2015).

[207] The Independent, 2012: *BA reveals Airbus A380 superjumbo flight plans,* by Peter Woodman, December 11. Available at *http://www.independent.co.uk/travel/news-and-advice/ba-reveals-airbus-a380-superjumbo-flight-plans-8405961.html* (last accessed May 12, 2015).

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

[209] Ibid.

[210] Ibid.

[211] Analysts estimate a new single aisle 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 aircraft design, manufacturers are opting to re-wing or just re-engine their aircraft (significant partial redesigns). 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 publically stated they 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 Aircraft,* Final Report, EPA Contract Number EP–C–12–011, March 17, 2015.)

[212] In general, design waves are prompted by the combination of market demand for new aircraft performance needs (*e.g.,* more seats for longer range) and the age of existing aircraft, and design waves are typically enabled by advances in propulsion technology.

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

[214] 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 Aircraft,* Final Report, EPA Contract Number EP–C–12–011, March 17, 2015.)

[215] As described earlier, CAEP has not ruled out applying the international CO_2 standard to in-production aircraft types, which are aircraft types that have already received a Type Certificate and are produced after the effective date of the standard. In-production aircraft types would include significant partial redesigned aircraft and incremental improvements. CAEP is currently considering and analyzing in-production applicability.

[216] ICAO, 2013: *CAEP/9 Agreed Certification Requirement for the Aeroplane CO_2 Emissions Standard. Available at http://www.icao.int/publications/catalogue/cat_2015_en.pdf (last accessed May 12, 2015). The ICAO Circular 337 is found on page 85 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. CIR337.* See Chapter 1.

[217] Due to substantial market forces to alleviate any adverse effects on aircraft fuel burn or CO_2 emissions, adverse changes are rare.

following: (1) Where the proposed change in design, configuration, power or mass is so extensive that a substantially new investigation of compliance with the applicable airworthiness regulations is required, the aircraft should be considered to be a new type design rather than a changed version, and (2) ''adversely'' refers to an increase in CO_2 emissions of more than an amount (or percentage) that has yet to be determined (this amount or criterion is still being considered by CAEP). The EPA requests comment on this change-based criteria approach, including how to identify those changes that would result in treating in-production aircraft as new types subject to the standard.

If CAEP were to limit the scope of applicability to new aircraft types only (and without the significant change criteria approach described above), the international CO_2 standard would not apply to later series aircraft with redesigned wings, aircraft that are available with different engines, or aircraft that undergo incremental improvements. Following are several examples that illustrate this situation. The re-engined Boeing 737 Max is an example of a significant partial redesigned aircraft that is expected to enter into service in 2017.[218] This aircraft would fall under the original Boeing 737 Type Certificate that was issued in 1967 (and entered into service in 1968)—or more specifically it would fall under an amended Type Certificate, and it would not be considered a new aircraft type as defined by CAEP. The current in-production 737s (Next Generation 737s or commonly abbreviated as 737 NGs) feature newer engines, have redesigned wings, and entered service in 1998 under the original 737 Type Certificate that was issued in 1967, and these also were not considered a new type aircraft when they were introduced in 1998.[219] Another example of an aircraft that does not qualify as a new type is the Boeing 747–8 aircraft, that entered into service in 2011, and which included a new wing, new engines, and a lengthened fuselage but fell under an amended Type Certificate for the original Boeing 747 that was certified in 1969 (and entered into service in 1969). An example of incremental improvements to in-production aircraft, is the Boeing Next Generation 737 performance improvement package which was implemented between 2011 and 2013 and the Boeing 767–300 winglets that entered into service in 2008, both of which improve aircraft fuel efficiency. There are many other examples that exist for different manufacturers and aircraft around the world as well, but for conciseness, we are limiting our discussion to these above examples. These examples illustrate the typical certification for significant partial redesigns and incremental improvements by various aircraft certificating or certifying authorities (or national airworthiness authorities) around the world.

Using CAEP's current definition of new aircraft types (clean sheet designs, which are completely new aircraft) we cannot today identify the first aircraft to which the new standard would apply. As the examples above illustrate, new aircraft types are infrequent,[220] and there are no currently announced new type designs that are expected to be introduced after the implementation dates being analyzed by CAEP—2020 and 2023. Furthermore, based on provisions to which CAEP has already agreed,[221] new aircraft types subject to the CO_2 standard would be aircraft that submit an application for a Type Certificate after the implementation dates of 2020 and 2023 (dates for the stringency analysis) which would likely result in entry into service dates of about 2025 or 2028.[222] If the international CO_2 standard is applied only to new aircraft types, then CO_2 emissions would not be expected to begin to deviate from business-as-usual (in comparison to CO_2 emissions reductions that would be achieved in the absence of a standard) before 2025. Therefore, an international standard developed for only new aircraft types may not actually apply to any new aircraft for at least a decade. Even if a few new type aircraft are introduced in this timeframe, it will take even longer for these aircraft to comprise any significant portion of the fleet. Therefore, applying an international standard which applies only to new aircraft types will likely result in no additional CO_2 reductions beyond what would have occurred absent a CO_2 standard, either for the near- and mid-term, about 5 to 10 years from 2016, or even in the longer-term of 20 years plus.[223] [224]

The EPA requests comments on the timeframes described above for introducing new aircraft types and their subsequent penetration into the fleet. Are there any aircraft manufacturer announcements that we missed in regard to new aircraft types that will be introduced or apply for a Type Certificate after 2020 and 2023 (or new aircraft types that will be introduced or apply for a Type Certificate five years after these dates)? [225] If so, what are these new aircraft types? How many new types are projected to enter the fleet in this timeframe and what portion of the fleet will they represent?

The alternative approach being considered by CAEP and described earlier (addressing changes in design of in-production aircraft) may offer an opportunity to cover more aircraft in an earlier timeframe (including significant partial redesigns), but it is unclear what effect this approach would have on

[218] Boeing, *737 Max Program ''LEAPS'' into Engine Testing,* Article by Eric Olson, July 11, 2014. Available at *http://www.boeing.com/boeing/Features/2014/07/bca_737max_leap_07_11_14.page*, (last accessed May 12, 2015).

[219] The original 737 entered service in 1968. The 737 Classic entered service in 1984, and it had new high bypass engines, an updated wing, and other aerodynamic improvements. The 737 NGs entered service in 1998, and they featured a new wing and updated engines. Several mid-life upgrades were produced for the 737 NGs, offering improved range, payload, and efficiency. (ICF International, *CO_2 Analysis of CO_2-Reducing Technologies for Aircraft,* Final Report, EPA Contract Number EP–C–12–011, March 17, 2015.)

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

[221] ICAO, 2013: *CAEP/9 Agreed Certification Requirement for the Aeroplane CO_2 Emissions Standard*. Available at *http://www.icao.int/publications/catalogue/cat_2015_en.pdf (last accessed May.12, 2015).* The ICAO Circular 337 is found on page 85 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. CIR337. Section 1.5 states that that the date to be used in determining the applicability of the CO_2 standard is the date the application for a Type Certificate was submitted to the certificating authority having jurisdiction over the manufacturer responsible for the aircraft design. Section 1.6 specifies that an application shall be effective for the period specified in the designation of the airworthiness regulations appropriate to the aircraft type. An application for a Type Certificate is valid for 5 years.

[222] These dates assume 5 years from application for the aircraft Type Certificate to entry into service, which is how long an application is valid for a Type Certificate.

[223] Approximate time-scales are considered to be 5 years for near-term, 10 years for mid-term, and 20 years or more for long-term.

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

[225] In November 2014, Boeing indicated that it would replace the 737 with a new aircraft type in 2030. Earlier this decade, Boeing was assessing an all new clean sheet 737 replacement, but eventually they decided to re-engine the 737 (the 737 Max) instead. (Flight Club, Paul Thompson, *Here's The Skinny On What's Next For Boeing,* November 16, 2014. Available at *http://flightclub.jalopnik.com/heres-the-skinny-on-whats-next-for-boeing-1656206527 (last accessed May 12, 2015),* Also, Wichita Business Journal, Daniel McCoy, *Boeing planning 737 MAX replacement by 2030—What it could mean for Spirit AeroSystems,* November 5, 2014. Available at *http://www.bizjournals.com/wichita/blog/2014/11/boeing-planning-737-max-replacement-by-2030-what.html*) (last accessed May 12, 2015). We would consider this as a Boeing projection or sketching out of plans for a new aircraft type, but it is not a commitment from Boeing.

additional CO_2 emissions reductions compared to a standard for only new aircraft types. The EPA requests comments on the timeframe for CO_2 emissions reductions and the likely share of annual aircraft production (or share of in-production aircraft built annually) that would be affected under this alternative approach.

If ICAO applies the aircraft CO_2 emission standard to in-production aircraft, and subsequently (provided the EPA makes a positive endangerment finding under CAA section 231(a)) the EPA establishes domestic aircraft engine standards that are equivalent to the ICAO international aircraft CO_2 standard, this means that all aircraft built (in-production) after the effective date would need to certify and comply with the standard to remain in production. This includes (as described earlier) in-production aircraft with incremental improvements (though we reiterate this would not include in-use aircraft). As an example of in-production aircraft, the Gulfstream G650, which is currently in production and expected to remain so after 2020, would need to certify and comply with the new CO_2 standard. In the next section we discuss in more detail how applicability to in-production aircraft could work.

C. CAEP Discussion on In-Production Aircraft Applicability

At the request of the CAEP Steering Group meeting in November 2013, CAEP began work on defining potential options to implement applicability requirements for in-production aircraft. Subsequently, based on the options provided to the 2014 Steering Group meeting, CAEP decided that it should continue to investigate potential in-production aircraft applicability options, and that these should be presented at the July 2015 Steering Group meeting, so that a decision can be taken at the 10th meeting of CAEP (CAEP/10) in February 2016 regarding whether the international CO_2 standard will apply to in-production aircraft. There are a wide range of options under consideration, including both mandatory and voluntary options for reporting and certification processes for in-production aircraft applicability, but the 2014 Steering Group meeting requested that CAEP focus on defining the mandatory options (in contrast to options such as voluntary reporting and certification).

1. Applicability to In-Production Aircraft and Date of Implementation

At the 2014 Steering Group meeting, CAEP also agreed that 2023 represented the earliest possible date for an in-production aircraft standard to allow time to promulgate domestic regulations and process manufacturer certification applications. CAEP did not rule out later dates though and could consider implementation dates for an in-production aircraft CO_2 standard later than 2023 (CAEP could consider applicability dates for in-production aircraft that are five years following the new aircraft type applicability date, *i.e.* dates ranging from 2023 to 2028).

The EPA seeks comments on both a 2023 implementation date and on possible later implementation dates for an in-production domestic CO_2 (or GHG) aircraft engine emissions standard that would be adopted under CAA section 231,[226] the impact the date of implementation might have on per-aircraft GHG or CO_2 emissions rates [227] and the ability of a domestic GHG or CO_2 standard to achieve aircraft emission reductions beyond what would occur in the absence of such a standard.

As described in section VI.F.2, the technologies considered for the CAEP analyses are those technologies that will be widely used on in-production aircraft by 2016 or shortly thereafter.[228] The EPA requests comments regarding whether applying an international CO_2 standard to in-production aircraft is consistent with the purpose of the standard as accepted by the CAEP Steering Group meeting in 2011: ''to achieve CO_2 emission reductions from the aviation sector beyond expected 'business as usual' . . . analyzed using ICAO criteria of technical feasibility, environmental benefit, cost effectiveness, and impacts of interdependencies.'' [229] The International Coalition for Sustainable Aviation (ICSA),[230] which is a CAEP Observer organization, submitted papers to CAEP that analyzed this issue. Also, a member of ICSA [231] has developed similar analyses which indicate that applying the international standard only to new aircraft types would likely result in no additional CO_2 reductions beyond what would have occurred absent a CO_2 standard, either for the near- and mid-term, about 5 to 10 years from 2016, or even in the longer-term of 20 years plus. This occurs, the ICCT states, because the development cycles for new aircraft are very lengthy and it is not unusual for new aircraft to take 8 to 10 years to develop from preliminary design to entry into service and once in service it takes significant time for new aircraft types to penetrate the fleet.[232] [233]

[226] Traditionally, international emission standards have first been adopted by ICAO, and subsequently the EPA had initiated rulemakings under CAA section 231 to establish domestic standards equivalent to ICAO's standards where appropriate. Provided ICAO adopts an international aircraft CO_2 standard that is consistent with CAA section 231 and it is appropriate for domestic needs in the United States, we expect to proceed along a similar approach for the future CAA section 231 aircraft engine CO_2 standard (or aircraft engine GHG standard), provided the EPA issues final positive endangerment and cause or contribute findings under CAA section 231.

[227] For a standard promulgated under CAA section 231 to be ''applicable to'' emissions of air pollutants from aircraft engines, it could take many forms, and include multiple elements in addition to numeric permissible engine exhaust rate. For example, under CAA section 231, EPA's rules have long-standing regulations addressing fuel venting, as well as test procedures. *See* 40 CFR part 87, subparts B, G and H. 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 U.S. Court of Appeals for the D.C. Circuit's 2007 *NACAA* v. *EPA* ruling that section 231 confers an unusually broad degree of discretion in establishing aircraft engine emission standards, it should be possible to reconcile an ICAO ''aircraft standard'' that effectively limits aircraft engine GHG emissions with a CAA section 231 aircraft engine emission standard that achieves the same result, even if the GHG standards take a different form than the traditional thrust-based NO_X aircraft engine emission standards recently issued by ICAO and the EPA. *See* 40 CFR part 87, subpart C.

[228] CAEP determined in 2012 that all technology responses would have to be based on technology that would be in common use by the time the standard was to be decided upon in 2016 or shortly thereafter. This generation of technology was defined within CAEP as a Technology Readiness Level (TRL) 8—an actual system completed and ''flight qualified'' through test and demonstration—by 2016 or shortly thereafter.

[229] CAEP (U.S. Working Paper), ''U.S. Position on the Development of ICAO'S Aircraft CO_2 Standard,'' CAEP–SG/20112–WP/25, Presented by the United States, U.S. Working Paper for CAEP Steering Group meeting, Beijing, China, 12 to 16 September 2011. Available at *http://www.epa.gov/otaq/aviation.htm*. (last accessed May 12, 2015).

International Coalition for Sustainable Aviation (ICSA), ''ICAO'S CO_2 Standard as Part of a Basket of Measures to Meet Emission Reduction Goals'', ICAO Assembly—38th Session, Executive Committee, Agenda Item 17—Environmental Protection, A38–WP/297, EX/99, September 19, 2013.

[230] The International Coalition for Sustainable Aviation (ICSA) is a structured network of environmental non-governmental organizations (NGOs) who share a common concern with civil aviation's contribution to air quality issues, climate change and noise, and who are committed to developing and providing technical expertise, common policy positions and strategies with a view to reducing emissions and noise from aviation. See *http://www.icsa-aviation.org/* (last accessed May 12, 2015).

[231] The International Council on Clean Transportation (ICCT) is a member of ICSA, and ICCT is an independent nonprofit organization founded to provide research and technical and scientific analysis to environmental regulators. See *http://www.theicct.org/* (last accessed May 12, 2015).

[232] ICCT, Efficiency Trends for New Commercial Jet Aircraft 1960 to 2008, November 2009. Available at *http://www.theicct.org/sites/default/files/publications/ICCT_Aircraft_Efficiency_final.pdf* (last accessed May 12, 2015).

Another study funded by the EPA corroborates this analysis.[234] The EPA requests comments on whether applying the international CO_2 aircraft standard only to new aircraft types would be consistent with the accepted purpose of the international standard (the purpose of the standard that has been accepted by the CAEP Steering Group). Lastly, the EPA requests comment on the appropriateness of a possible EPA regulation following either of these approaches (applicability to only new aircraft types or applicability to both new types and in-production aircraft) which are under consideration at CAEP.

Also, there have been concerns raised in CAEP about applying the international CO_2 standard to in-production aircraft. These concerns include (a) the added resource burden on certificating authorities [235] to process manufacturers' certification applications, which will be more numerous compared to new aircraft types; and (b) the potential added costs to manufacturers to certify in-production aircraft. The EPA requests comment on these two concerns, including providing supporting documentation on the extent of these concerns and any other issues the commenters may identify with applying the international CO_2 standard to in-production aircraft.

2. Reporting Requirement for New In-Production Aircraft

CAEP is working to define mandatory in-production aircraft options, and one possible option is a reporting requirement [236] [237] [238] for in-production aircraft CO_2 emissions rates (measured according to the aircraft test procedure that was agreed upon at CAEP/9) as an alternative to establishing an aircraft CO_2 standard for in-production aircraft. Although a reporting requirement provides policy relevant information, it does not necessarily translate into specific emissions reductions. The EPA recognizes that only a mandatory standard for in-production aircraft would ensure that the aircraft CO_2 standard reduces per-aircraft CO_2 emissions rates. However, a reporting requirement could be an important component of an in-production aircraft CO_2 standard, especially if it is implemented shortly after an in-production aircraft standard is adopted. It would ensure that CO_2 emissions rates data are gathered quickly prior to an effective date for the final standard (tracking CO_2 emissions rates is beneficial for the reasons discussed later in this section and for potentially assisting with the assessment of a future CO_2 standard). The EPA requests comment on an aircraft manufacturer reporting requirement that is implemented soon after the adoption of an in-production international aircraft CO_2 standard, as a component of the in-production aircraft CO_2 standard.

In 2009 the EPA promulgated a final GHG reporting rule that applies to many sectors in the United States, including manufacturers of heavy-duty and offroad vehicles and engines, and manufacturers of aircraft engines.[239] [240] The EPA's experience with reporting programs indicates that the EPA and the public would be able to track CO_2 emissions rates trends (*i.e.,* trends of aircraft cruise fuel burn rates) from aircraft over time. Requiring the reporting of aircraft CO_2 emissions rates trends from aircraft over time is appropriate and feasible. Requiring aircraft manufacturers to report aircraft CO_2 emissions rates shortly after an in-production international aircraft standard is adopted would enable and expedite the tracking and understanding of these emission trends. In addition, reporting programs typically raise awareness of emissions and can improve the understanding of the factors that influence emission rates as well as the actions that can be taken to reduce emissions. When similar methods for monitoring, measurement, and reporting are applied across an industry, it can lead to more consistent, accurate, and timely data to inform decision-making for individual manufacturers and the EPA (including a comparison of the CO_2 emissions rates from aircraft of various manufacturers). Thus, a reporting requirement could potentially contribute to efforts to identify and implement future aircraft CO_2 emission reduction opportunities.

Independent of action that CAEP may or may not take in February 2016, the EPA could under its CAA section 114(a) authority pursue a reporting requirement for aircraft cruise GHG or CO_2 emissions rates—to ensure we have GHG or CO_2 emissions rates data on all in-production aircraft (and any new aircraft types that enter service).[241] The EPA could use the same metric agreed to at CAEP/9 (and in ICAO circular 337). This will be described in detail in

[233] ICCT, ''*Could ICAO's CO_2 Standard Not Actually Cover Any Aircraft? Yes, If Nobody's Watching''.* Blog, December 9, 2014. Available at *http://www.theicct.org/blogs/staff/could-icaos-co2-standard-not-cover-any-aircraft* (last accessed May 12, 2015).

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

[235] Pursuant to CAA section 232, the FAA, after consultation with the EPA, shall prescribe regulations to insure compliance with all standards prescribed by the EPA under CAA section 231. Section 232 then directs the FAA to include provisions making the EPA's standards applicable in the issuance, amendment, modification, suspension, or revocation of any certificate authorized by the FAA under part A of subtitle VII of Title 49. Under this unique statutory structure, the EPA promulgates the substantive emission standards, and the FAA enforces the EPA's standards and insures all necessary inspections are accomplished.

[236] Currently, CAEP is developing a publicly available database for aircraft CO_2 emissions (CAEP is now considering format, parameters, etc. for the database), but submissions to this database by aircraft manufacturers would be voluntary. There will not be a CAEP mandatory reporting requirement associated with this potential CO_2 database. In addition, if the international aircraft CO_2 standard applies to only new aircraft types, it could be many years before any data exists in this database.

[237] For many years, ICAO has maintained an Aircraft Engine Emissions Databank for landing and takeoff certificated emissions values of NO_X, hydrocarbon, carbon monoxide, and smoke number (ICAO and the EPA also have aircraft engine emission standards for these pollutants). It contains certified emissions data voluntarily reported from each aircraft engine manufacturer. This databank is available at *https://easa.europa.eu/document-library/icao-aircraft-engine-emissions-databank (last accessed May 12, 2015).*

[238] In 2012, the EPA promulgated annual reporting requirements for aircraft engine emissions of NO_X, hydrocarbon, carbon monoxide, and smoke number and related parameters. One of the reasons that the EPA issued these reporting requirements was due to the varying amount of voluntary data reported by aircraft engine manufacturers. (U.S. EPA, ''Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures.'' Final Rule, 77 FR 36342 (June 18, 2012)).

[239] EPA's 2009 rule on Mandatory Reporting of Greenhouse Gases included engine manufacturers for the following mobile source sectors: Highway heavy-duty (engine and vehicle), non-road, aircraft, locomotive, marine, snowmobiles, and motorcycles. Manufacturers of aircraft jet engines of rated output (or thrust) greater than 26.7 kilonewtons are required under this program to report annually to the EPA CO_2 and NO_X emissions from aircraft engines during the landing and takeoff cycle. Manufacturers of these engines were already measuring and recording CO_2 emissions as part of existing criteria air pollutant emission requirements for the landing and takeoff cycle, but prior to this 2009 rule, these data were not reported to the EPA. Manufacturers voluntarily reported the data to ICAO, but there was no assurance that the EPA would receive this information, and thus, the 2009 rule required reporting of the aircraft engine CO_2 and NO_X emissions during the landing and takeoff cycle to the EPA.

[240] An aircraft manufacturer reporting requirement for in-production aircraft CO_2 emission rates would require the reporting of aircraft CO_2 emissions during the cruise phase of operation to the EPA. The majority of aircraft CO_2 emissions occurs in the cruise phase of operation, and thus, reporting CO_2 emission rates from this phase will improve our ability to track full-flight aircraft CO_2 emission rates over time (in addition to reporting the aircraft engine CO_2 emissions during the landing and takeoff cycle). Also, the aircraft test procedure that was agreed upon at CAEP/9 now enables us to measure aircraft CO_2 emissions during cruise.

[241] This GHG or CO_2 emissions rate data will help to track trends, raise awareness, better understand the technology in the fleet, etc.

VI.D.1 below. In general, the EPA asks for comment on a mandatory reporting requirement for in-production aircraft GHG or CO_2 emissions rates—either as part of the CAEP international standard or as an independent domestic requirement to be adopted by the EPA. If the EPA were to pursue this requirement independently from CAEP, what lead time would be appropriate for manufacturers to report the GHG or CO_2 emissions rates from all of their in-production aircraft [242] (after we promulgate such a requirement)? Additionally, if we were to pursue such an independent reporting requirement, should we require the annual reporting of the GHG or CO_2 emissions rates from in-production aircraft (and any new type aircraft) [243] to enable us to track any updates? We are not at this time proposing to promulgate such a requirement in advance of ICAO's decision. Due to the possibility of ICAO's adoption of a reporting requirement, we believe it is reasonable to await the outcome of that decision in order to determine whether to strictly follow ICAO's possible reporting requirement or make changes to it in the form of an additional U.S. domestic requirement, as appropriate.

D. Metric System, Applicability, and Certification Requirement

The CO_2 metric system and mature certification procedure were agreed upon by CAEP in 2013.[244] This section describes the metric system that was developed, the scope of aircraft to be covered by the international CO_2 standard, the certification test procedures that would be used to demonstrate compliance with the international CO_2 standard, and CAEP's decision to focus on the entire aircraft for the international CO_2 standard.

1. CO_2 Metric System

The metric system was developed to cover a wide range of aircraft types, designs, technology, and uses. To do this, the metric system was designed to differentiate between generations of aircraft and to equitably capture improvements in aerospace technology (structural, propulsion, and aerodynamic) that contribute to a reduction in the airplane CO_2 emissions. In addition, the metric system accommodates a wide range of technologies and designs which manufacturers may choose to implement to reduce CO_2 emissions from their aircraft.

The metric system agreed to at CAEP uses multiple Specific Air Range (SAR) test points to represent cruise fuel burn. SAR is a traditional measure of aircraft cruise performance which measures the distance an aircraft can travel for a unit of fuel. This is similar to the instantaneous ''miles per gallon'' readings in many cars today. However, here the inverse of SAR is used (1/SAR); therefore a lower metric value represents a better fuel efficiency. The SAR data are gathered at three gross weight points. The three equally weighted points are used to represent a range of day to day aircraft operations.[245] The functional form of the metric system is provided below.

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

Equation 1: CO_2 Metric

$(1/SAR)_{avg}$ is calculated at 3 gross weight fractions of Maximum Takeoff Mass (MTOM):

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 measure of the fuselage size on a given aircraft. In analyzing various metric system options it was found that in some instances, namely stretch aircraft, changes in aircraft size, and thus capability, were not reflected in changes to the aircraft's gross weight (MTOM). To account for these occurrences, and the variety of methods that manufacturers may use to make such a change, an adjustment factor was added (the RGF with a 0.24 exponent used in the metric system).

2. Applicability

CAEP has decided the scope of applicability for a future international CO_2 standard should be subsonic jet and propeller-driven aircraft meeting the following criteria:

All subsonic jet aircraft over 12,566 lbs (5,700 kg) MTOM.

All subsonic propeller driven (*e.g.,* turboprop) aircraft over 19,000 lbs (8618 kg) MTOM, except amphibious airplanes and those designed and used for fire-fighting operations.

No military aircraft will be subject to this international standard.

3. Certification Requirement

CAEP has developed a mature certification requirement [246] that would allow for the determination of an aircraft CO_2 metric value for any aircraft meeting the applicability criteria set forth above. This certification requirement incudes the metric system and test procedure. The test procedure was based upon industry's current best practices for establishing the cruise performance of their aircraft, and input from certification authorities. These procedures include specifications for aircraft conformity, weighing, fuel specifications, test condition stability criteria, required confidence intervals, measurement instrumentation required, and corrections to reference conditions.

These CO_2 test procedures are based upon manufacturer's existing practices when certifying new aircraft. This means that there is a very heavy reliance on dedicated flight testing of the aircraft. This potentially poses challenges for the certification of in-production aircraft. Manufacturers have stated that there could be logistical challenges associated with the certification of aircraft for CO_2 that have previously been type certificated (*e.g.* procuring and instrumenting an aircraft for flight testing). To address this, the EPA is currently working within CAEP to encourage the development of a modified or separate equivalent certification test procedure that would reduce this burden on manufacturers

[242] In this case, manufacturers would need to report the GHG or CO_2 emission rates for in-production aircraft (aircraft types which have already received a Type Certificate, and for which manufacturers either have existing undelivered sales order or would be willing and able to accept new sales orders) that are built after a certain date, which has yet to be determined but would likely be a date that occurs shortly after we promulgate the requirement.

[243] By applying a reporting requirement to in-production aircraft after a certain implementation date, this reporting requirement also includes new aircraft types that are produced after this implementation date.

[244] As described earlier, the certification requirement is the combination of metric, procedures, instrumentation and measurement methodology, and compliance requirements. We are using the terms metric system and certification test procedures to describe these elements of the certification requirement.

[245] ICAO, 2013: *CAEP/9 Agreed Certification Requirement for the Aeroplane CO_2 Emissions Standard. Available at http://www.icao.int/publications/catalogue/cat_2015_en.pdf (last accessed May 12, 2015). The ICAO Circular 337 is found on page 85 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. CIR337.*

[246] ICAO, 2013: *CAEP/9 Agreed Certification Requirement for the Aeroplane CO_2 Emissions Standard. Available at http://www.icao.int/publications/catalogue/cat_2015_en.pdf (last accessed May 12, 2015). The ICAO Circular 337 is found on page 85 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. CIR337.*

and allow for quicker/simpler certification of in-production types.

4. Regulating the Entire Aircraft Instead of the Engine

The CO_2 metric system intends to equitably reward improvements in aircraft technologies that reduce emissions, including advances in structures (aircraft weight), propulsion (engine specific fuel consumption), and aerodynamics. These three factors are key to the overall aircraft CO_2 emissions. In addition, CAEP has indicated (and EPA agrees) that it is best to consider the aircraft as a whole instead of only the aircraft engine technology in addressing factors that influence CO_2 emissions, because of the effects and interaction these key factors have on the aircraft CO_2 emissions from engines.[247] The three factors—and technology categories that improve these factors—are described as follows: [248]

Structures: Reducing basic aircraft weight to 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

Aerodynamics: Advancing the aircraft aerodynamics, to reduce drag and its associate impacts on thrust.

Specific examples of technologies that affect these three factors help to further illustrate that it is best to consider the aircraft as a whole in addressing CO_2 emissions. For structural improvements, aircraft manufacturers have shown significant weight reduction results over time due to the progressive introduction of new technologies such as: Advanced alloys and composite materials, improved and new manufacturing processes and techniques (including integration and global evaluation simulation), and new systems (*e.g.* fly-by-wire).[249] [250]

For propulsion improvements, technologies include enhanced compressors (*e.g.,* intercooled compressors) and reduced hub-tip ratio fans.[251] As another example, manufacturers seek higher operating pressure ratios (OPR) to improve combustion and engine cycle refinements.

For aerodynamics, friction and lift-dependent drag are the biggest contributors to aerodynamic drag. Advances in aerodynamics enable significant lift-dependent drag reduction by maximizing effective wing span extension. For example, wing-tip devices can give an increase in the effective aerodynamic span of wings, particularly where wing lengths are limited by airport gate sizes. Manufacturers are also looking at ways of decreasing the drag caused by skin friction. An example of a technology to improve aircraft local skin friction is to utilize riblets (which are micro-grooves on the surface) to maintain laminar flow via Natural Laminar Flow and Hybrid Laminar Flow Control (HLFC) to reduce turbulent skin friction.[252] The first production example of a HLFC system went into service on the new Boeing 787–9 in 2014.

E. Stringency Options

At the Steering Group meeting in November 2013, CAEP agreed to analyze a range of CO_2 stringency options that cover the full range of aircraft in-production and in-development around the world (within the applicable weight thresholds and categories), and this includes the wide range of technology that is currently in the aircraft fleet.[253] Generally, the stringency options that are being evaluated fall into three categories as follows: (1) CO_2 stringency levels that could impact [254] only the oldest, least efficient aircraft in-production around the world, (2) middle range CO_2 stringency levels that could impact many aircraft currently in-production and comprising much of the current operational fleet, and (3) CO_2 stringency levels that could impact aircraft that have either just entered production or are in final design phase but will be in-production by the time the international CO_2 standard becomes effective. We are requesting comment on the level(s) at which the CO_2 stringency options should be set, what factors should be considered in establishing the stringency of the CO_2 standard, and on their potential relationship to any future CAA section 231 standard.

The figures below are intended to show the range of stringency levels under consideration at CAEP and CO_2 metric value levels of today's in-production and in-development [255] aircraft. The data shown were generated by the EPA using a commercially available aircraft modeling tool called PIANO.[256] This model contains non-manufacturer provided estimates of the performance of various aircraft. In contrast, CAEP is using manufacturer-provided estimates of the aircraft metric value performance.

The stringency options under consideration at CAEP are functions of the aircraft CO_2 Metric Value and have a correlating parameter of MTOM. They are upwards sloping and have a ''kink'' at 60,000 kilograms MTOM. The ''kink'' was included in the stringency options as a technical approach to reflect the different behaviors observed between the larger and smaller aircraft.

The official stringency options under consideration at CAEP have not been cleared for release outside of the participating members since deliberations on the standard are still ongoing (proceedings are expected to be completed at CAEP/10 in February 2016). To show the relative efficiency of the aircraft, Figure 1 and Figure 2 below show the aircraft metric values [257] versus MTOM. In place of the official stringency options under consideration, lines of constant technology are used to notionally show how the stringency options were set across the fleet. These lines reflect the three ranges of options discussed above. Lower metric values, for a given MTOM, represent an increased fuel efficiency. Figure 1

[247] ICAO, 2013: *CAEP/9 Agreed Certification Requirement for the Aeroplane CO_2 Emissions Standard. Available at http://www.icao.int/publications/catalogue/cat_2015_en.pdf (last accessed May 12, 2015). The ICAO Circular 337 is found on page 85 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. CIR33.*

[248] ICAO, *Environmental Report 2010—Aviation and Climate Change,* 2010, which is located at *http://www.icao.int/environmental-protection/Pages/EnvReport10.aspx* (last accessed May 12, 2015).

[249] Ibid.

[250] Fly-by-wire refers to a system which transmits signals from the cockpit to the aircraft's control surfaces electronically rather than mechanically. AirlineRatings.com, Available at *http://www.airlineratings.com/did-you-know.php?id=18* (last accessed on May 12, 2015, 2015).

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

[252] ICAO, *Environmental Report 2010—Aviation and Climate Change,* 2010, which is located at *http://www.icao.int/environmental-protection/Pages/EnvReport10.aspx*.(last accessed May 12, 2015).

[253] The ICAO standard has the following applicability weight thresholds: Maximum takeoff mass greater than 5,700 kilograms for subsonic jet aircraft and maximum takeoff mass greater than 8,618 kilograms for turboprops.

[254] The aircraft shown in these charts are in-production and current in-development. These aircraft could be impacted by an in-production standard in that, if they were above the standard, they would need to either implement a technology response or go out of production. For a new type only standard there will be no regulatory requirement for these aircraft to respond.

[255] Aircraft that are currently in-development but will be in production by the applicability dates. These could be new types or significant partial redesigned aircraft.

[256] PIANO (Project Interactive Analysis and Optimization), Aircraft Design and Analysis Software by Dr. Dimitri Simos, Lissys Limited, UK, 1990-present; Available at *www.piano.aero (last accessed May 12, 2015).* This is a commercially available aircraft design and performance software suite used across the industry and academia.

[257] Metric values were generated using PIANO.

shows the makeup of the current production fleet and the in-development aircraft. This is what CAEP is using as the starting point for modeling the effect of the CO_2 standard. Figure 2 shows what the EPA expects the market to look like in 2023, considering the publicly announced plans by industry to replace existing aircraft with new products.

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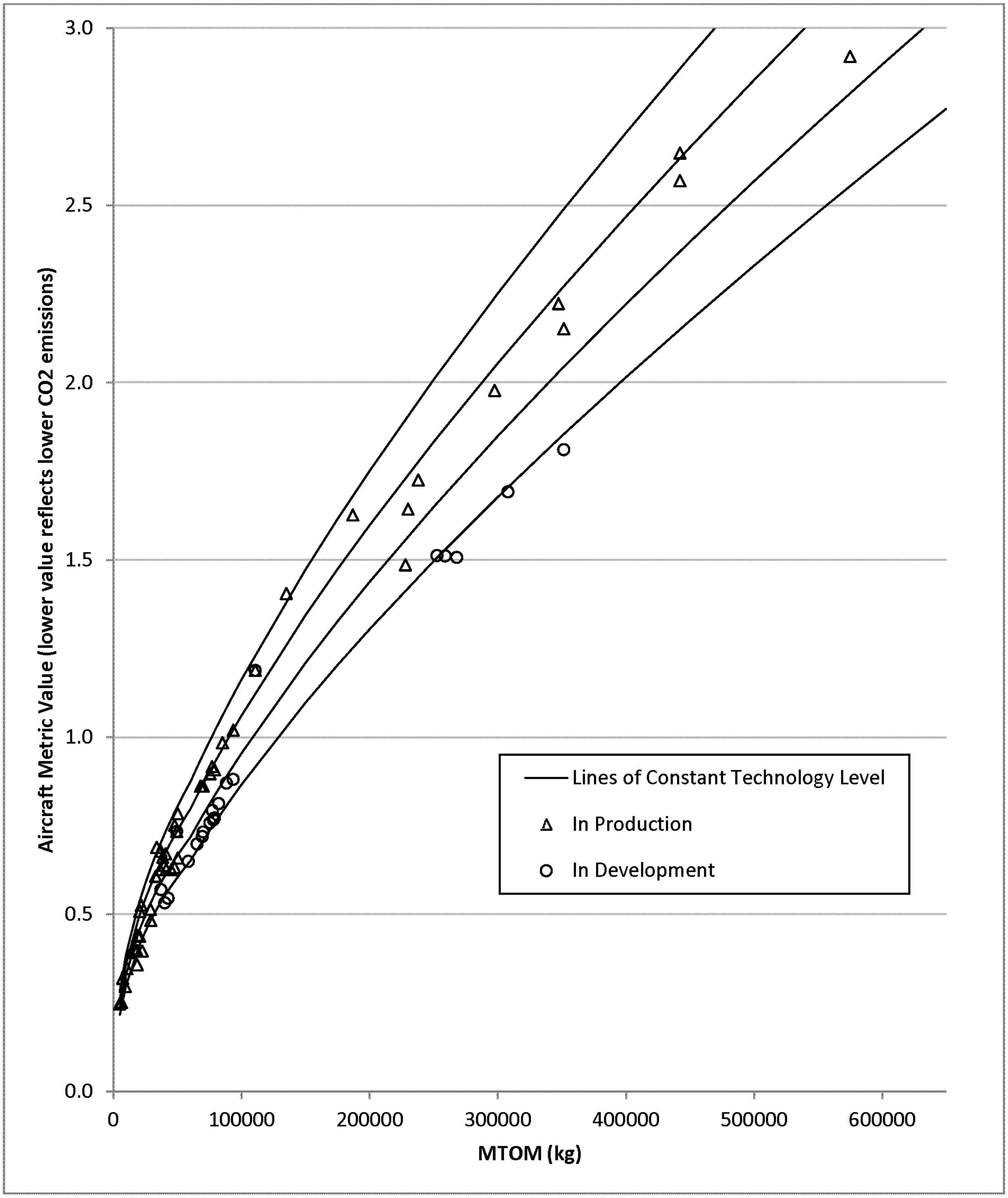

Figure 1 – Lines of constant technology level over the 2014 in-production and in development fleet

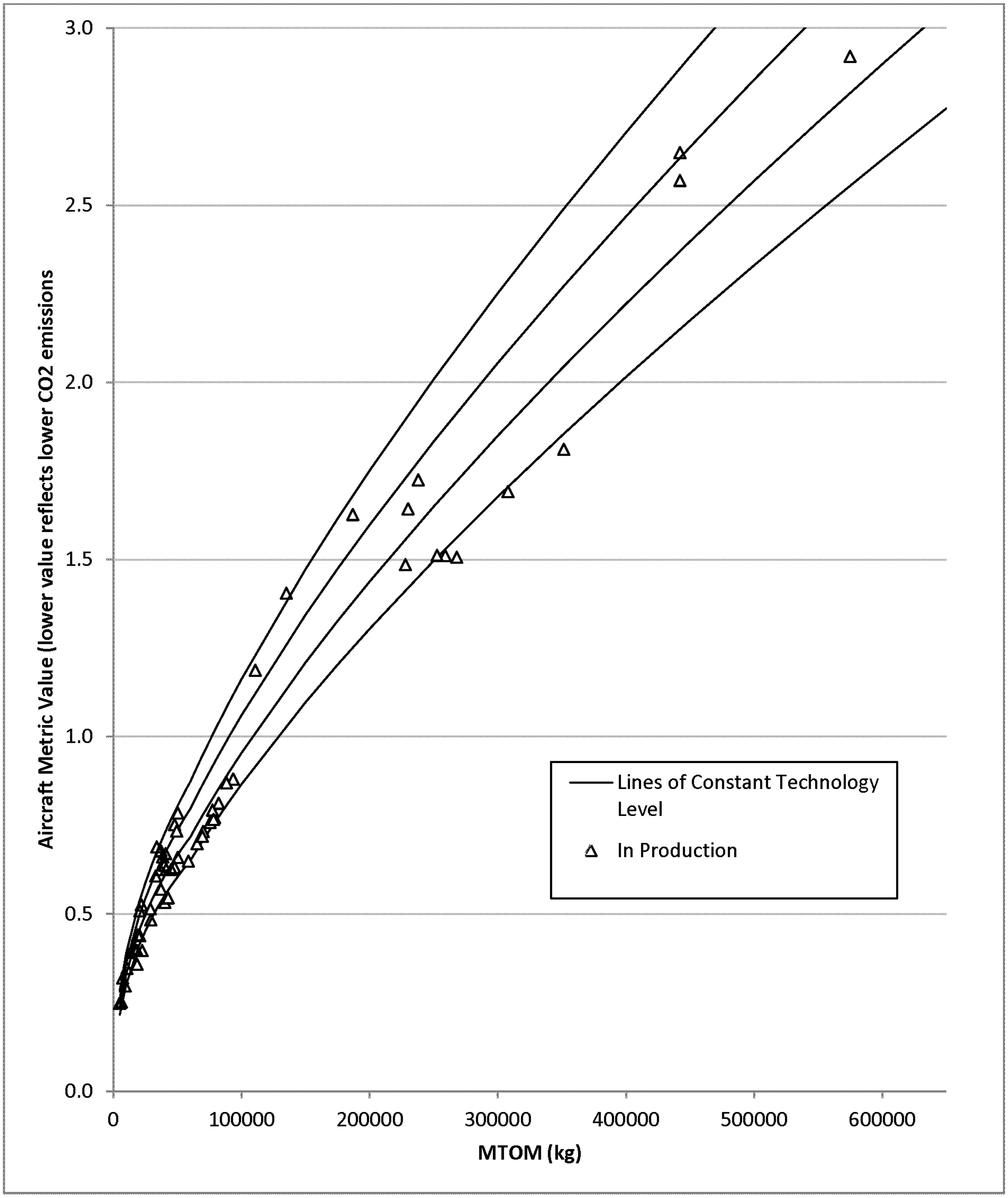

Figure 2 – Lines of constant technology level over the predicted 2023 in-production fleet

A standard set near the upper-most line of constant technology in Figures 1 and 2 would affect a very modest number of aircraft, namely the oldest, least efficient types. Many of the aircraft that would be affected by such a stringency level are being produced in very limited numbers and may not be eligible to operate in U.S. air space (*e.g.,* Russian and Ukraine aircraft).

Aircraft around the middle two lines of constant technology in Figures 1 and 2 reflect the performance of many aircraft that are currently in production and compose much of the current operational fleet. The current generation of single aisle aircraft from Boeing and Airbus are in this middle range.

Aircraft near the lowest line of constant technology in Figures 1 and 2 reflect the most advanced aircraft currently for sale on the market. These are aircraft that have either just entered production or are still in-development but will be in-production by the effective date of a potential in-production the standard. The replacement single aisle aircraft and new twin aisle aircraft from Boeing and Airbus are modeled to be clustered around the lowest line.

While Figures 1 and 2 show the ranges of stringency under consideration and how aircraft fall within those ranges, because of the scale, it is hard to see the range of technology present in the fleet. Therefore Figure 3 and 4 expand the view and show percent differences between the four constant technology lines represented in Figures 1 and 2. This allows for a clearer view of best and worst performing aircraft; Figure 3 provides the perspective from the current in-production and in-development fleet, and Figure 4 projects out to the 2023 fleet. In addition, these figures allow one to compare the technology level and efficiency of aircraft with differing MTOMs.

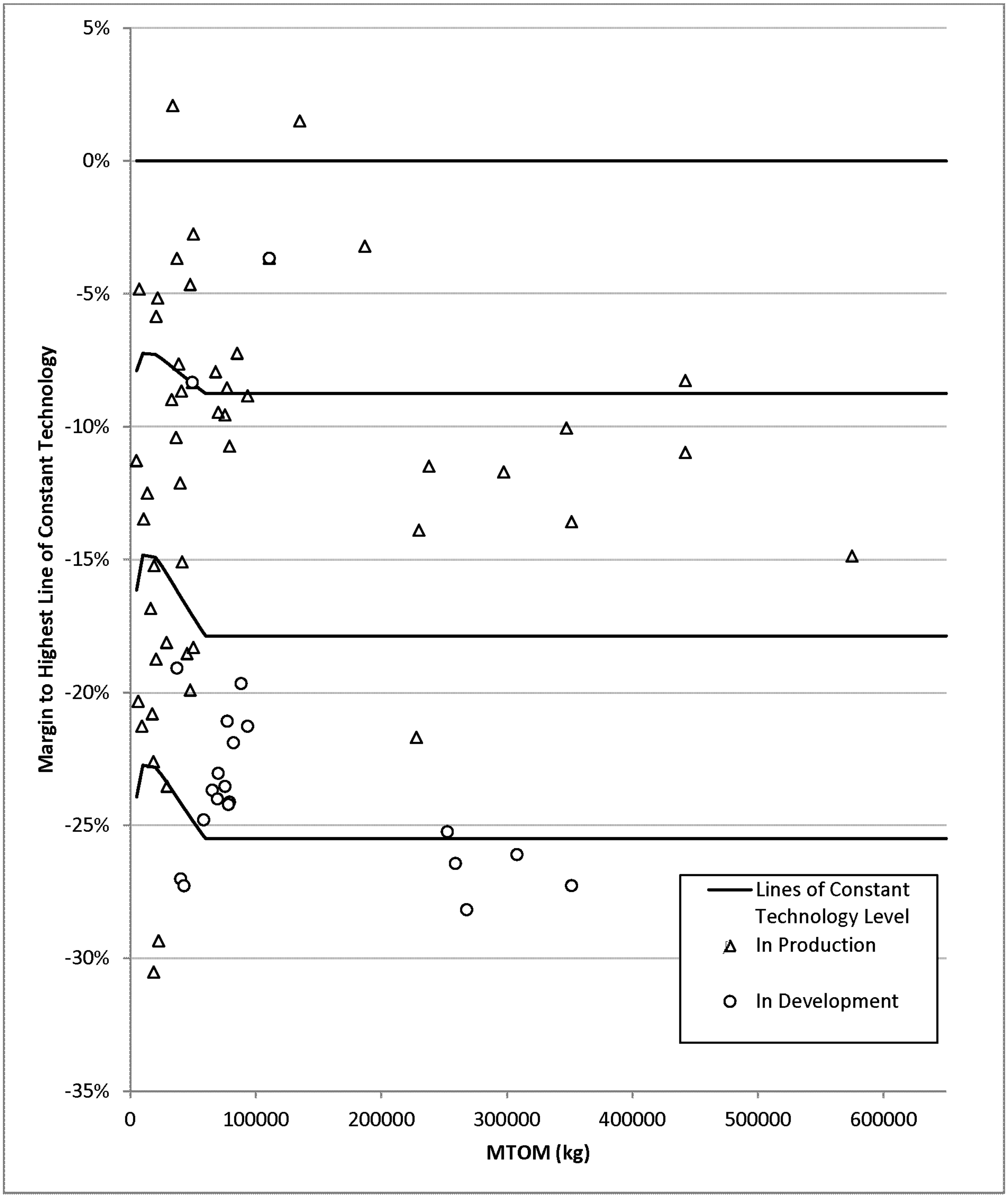

Figure 3 – Percent from least efficient line of constant technology for the 2014 in production and in development fleet

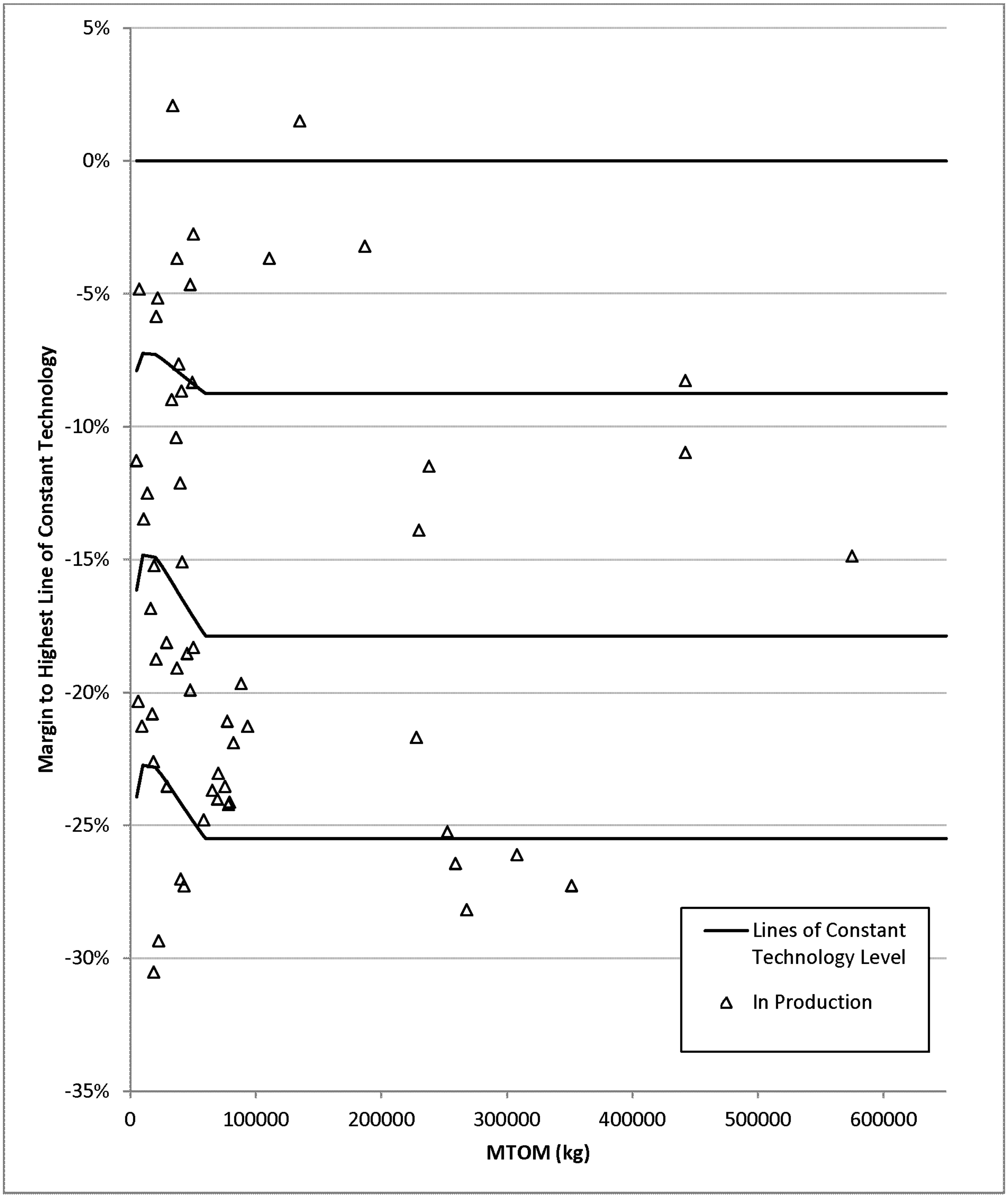

Figure 4 - Percent from least efficient line of constant technology for the predicted 2023 in–production fleet

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The EPA requests comment on a range of stringency options within the constant technology lines identified in Figure 1 and Figure 2, on their potential impact, and on their potential relationship to any future CAA section 231 standard.

CAEP is considering the possibility of adopting two separate CO_2 stringency levels, one for new type aircraft and one for in-production aircraft. This would allow stringencies to be set for both new types and in-production aircraft at a level closer to what could be achieved by each aircraft type. Issues surrounding the potential for in-production standards are discussed in section VI.C.1.

There is ongoing discussion on what appropriate levels of stringency may be for new type and in-production aircraft. Any final decisions will have to wait until the full analysis has been conducted at CAEP. As explained in sections VI.B and VI.C.1, new types are infrequently developed and typically represent a step change in technology. It may be possible to set a level of stringency that is reasonable for in-production aircraft to meet, but at the same time provide an incentive for new type aircraft to improve. However, this is challenging to develop because of the significant efficiency improvements typically seen between in-production and new type aircraft. The EPA requests comment on the potential for developing a standard with two stringency levels at CAEP.

The development of a new aircraft type standard must take into consideration the standard's potential effect on any future type designs. Even the most stringent option under consideration at CAEP is still based on technology available today. Any new type aircraft that may be developed and certified 10 years or more from now would be expected to use more advanced fuel efficient technology that is not yet developed or tested.

The implications for an in-production standard are more significant in the near term for manufacturers. Aircraft currently in-production, and not meeting the level of an in-production standard, would need to be modified to meet the standard to remain in production; this would take time and resources from the manufacturers. The full implications of this have not yet been resolved in CAEP. However, we expect that the effect on aircraft CO_2 emissions would be minimal for less stringent options. The aircraft with the highest CO_2 metric values generally rely on older technology and were designed in the 1980's to early 1990's. Many of these aircraft are also expected to be replaced with updated versions in the near future, before a CO_2 standard would be implemented and go into effect. The EPA requests comment on the levels at which in-production and new type standards might be set and on what factors should be considered in establishing the stringency.

F. Costs, Technology Responses for Stringency Options, and Cost-Effectiveness Analysis

The EPA has been involved in CAEP's effort to analyze the CO_2 stringency options and the potential costs and environmental impacts that would result from both new type only CO_2 standards and in-production international CO_2 standards. CAEP is still determining the best way to conduct portions of this analysis. The inputs that have been developed by the CAEP include non-recurring costs data and technology responses for the various stringency options under consideration. This section describes the development of these inputs. The EPA requests comments on how the modeling should be conducted to differentiate in-production and new type scenarios.

1. Non-Recurring Costs (engineering development costs)

CAEP developed a single cost estimate that could be used for all aircraft as a function of MTOM and percent metric value improvement required. Based on past practice, industry provided estimates for developing clean sheet designs and significant partial redesigns, only including high level information that has been made available to the public. This was considered to be a top down estimate because it included all aircraft development costs (airworthiness certification, noise, etc.) not just those for CO_2 improvements.

Since the initial dataset provided by industry only included major changes (or major improvements), the EPA saw the need to supplement this dataset with an estimate of CO_2-only changes (or CO_2-only improvements), which was considered to be a bottom up estimate. These changes would be much smaller, on the order of a few percent, and could be applied to in-production aircraft at a cost much lower than projected by industry. The EPA contracted with ICF International to develop an estimate of the cost to modify in production aircraft to comply with a CO_2 standard. ICF International conducted a detailed literature search, conducted a number of interviews with industry leaders, and did its own modeling to estimate the cost of making modifications to in production aircraft.[258] The results from this peer-reviewed study (small changes) were then combined with inputs from the industry and the other CAEP participants (large changes) to develop the CO_2 technology response and cost estimation. For the cost estimation, the CAEP combined the two different methodologies to develop the final cost surface.[259]

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

[259] The two datasets were merged together and a single cost surface was then generated to calculate the cost to modify any aircraft based on the MTOM, and percent metric value change needed.

A top-down approach is being used to model large changes to aircraft design, such as what would be seen in significant partial redesigns or new types. For significant partial redesigns that result in new series of an established model, these types of changes may include: Redesigned wings, new engine options, longer fuselages, improved aerodynamics, or reduced weight. When making significant changes to an aircraft many other changes and updates get wrapped into the process that do not have an effect on the CO_2 emissions of the aircraft, and significant partial redesigns may not have been spurred by changes to fuel efficiency (CO_2 reductions). This confluence of changes led CAEP to agree that it was reasonable to use the full development cost for a new type (clean sheet) or significant partial redesign for major changes. Total costs for past projects were used to estimate non-recurring cost for the CAEP analysis. This type of aircraft improvement/development program has historically ranged approximately from 1 to 15 billion Dollars (U.S.) depending on the size of the aircraft and scope of the improvements desired.

A bottom-up approach was used, by CAEP, to model smaller incremental metric value changes to aircraft design. The CAEP agreed that the above top-down approach would not be the best approach for minor changes or incremental improvements because the significant design efforts include many changes that would not be required for smaller CO_2 reductions. The EPA used the information gathered by ICF International to provide input on the cost for individual technologies which were used to build up non-recurring costs for these incremental improvements (a bottom-up approach). The technologies available to make incremental improvements to aircraft is wide ranging and aircraft specific. Some examples of technologies that could be integrated into an aircraft for incremental improvements include improved fan blade design or reduction in turbine clearances in the engine, reducing the gap between control surfaces, carbon brake pads, or advanced wing tip devices. As an example, ICF International estimated that depending on the additive nature of specific technologies and the magnitude improvement required, the cost to incrementally improve the Boeing 767 could range from approximately 230 million to 1.3 billion US dollars (3.5% to 11% metric value improvement).[260]

2. Technology Responses

When CAEP started to develop the technology responses for the stringency options, a determination needed to be made on what level of technology could be considered as a response to the standard. At the outset, CAEP decided the international CO_2 standard would be a technology following standard, rather than a technology forcing one. This means that the international standard would reflect a level of emissions performance that is already achieved by some portion of current in-production aircraft.

Additionally, CAEP determined in 2012 that all technology responses would have to be based on technology that would be in common use by the time the standard was to be decided upon in 2016 or shortly thereafter. This generation of technology was defined within CAEP as a Technology Readiness Level (TRL) 8 [261]—an actual system completed and qualified through test and demonstration—by 2016 or shortly thereafter. This means that the technology responses considered for the future international CO_2 standard, going into effect in 2020 or 2023 for new types and potentially in 2023 or later for in-production, are based on what will be in operation by 2016 or shortly thereafter. Considering the technology response assumptions agreed to at CAEP, the EPA requests comment on how the international CO_2 standard should be established so that it meets the purpose of the standard—to achieve reductions beyond what would have been achieved in the absence of a standard.

3. Cost Effectiveness Analysis

CAEP is currently conducting the cost effectiveness analysis for new-type and in-production aircraft. With rare exceptions CAEP has historically developed new type only standards. To model cost impacts of a new type standard, CAEP has historically used an assumption that the in-production aircraft will respond to the new type standard, even though the standard would not apply to them and has assumed that the aviation sector is competitive enough that market forces will drive manufacturers to voluntarily upgrade their fleet to meet any new type aircraft standard. This scenario is modeled no differently from a mandatory in-production standard. The EPA requests comment on modeling cost and environmental impacts of new-type standards based on the assumed attainment of such emissions levels by in-production aircraft.

Because CAEP has modeled all in-production aircraft as responding by the implementation date of the new-type standard, CAEP has by definition, performed an in-production analysis. More stringent options for new-type aircraft may be restricted due to the assumed in-production impacts.

CAEP has recognized that its past methods for modeling a new-type only standard (by assuming in-production aircraft comply) may not be sufficient for the CO_2 standard analysis. Thus, CAEP developed new methods to model what cost and environmental impacts would result from only new types being regulated under a new-type emission standard. CAEP is still determining the best way to conduct an analysis of impacts only on new types using the agreed upon technology responses and cost estimates. The EPA requests comments on how to model cost impacts for only new types for the future international CO_2 standard, if it were to apply only to new types. The EPA also requests comment on how the modeling should be conducted to differentiate in-production and new type scenarios.

G. Request for Comment on EPA's Domestic Implementation of International CO_2 Standards

As described earlier in section II.E, traditionally international emission standards for aircraft engines have first been adopted by ICAO, and subsequently the EPA has initiated rulemakings to establish domestic standards that are of at least equal stringency as ICAO's engine standards. However, the Chicago Convention,[262] which established ICAO, recognizes that ICAO member states may adopt their own unique standards that are more stringent than ICAO standards. A participating member state (or nation) that adopts more stringent standards is obligated to notify ICAO of the differences between its standards and ICAO's standards.[263]

Section 231(b) of the CAA requires that any emission standards ''take effect after such period as the Administrator finds necessary (after consultation with the Secretary of Transportation) to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance during such period.'' 42 U.S.C. 7571(b). Section 231(a)(2)(B) provides that the Administrator shall consult with the Administrator of the FAA on standards, and ''shall not change the aircraft engine emission standards if such change would significantly increase noise and adversely affect safety.'' 42 U.S.C. 7571(a)(2)(B).

As discussed in the 2005 rule (CAEP/4 aircraft engine NO_X standard),[264] the EPA needs to have a technical basis for expecting the standards will be achievable in a specific period of time. 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 mobile sources, the EPA interprets its authority under section 231 to be similar to those provisions that grant us significant discretion to identify a reasonable balance of specified emissions reduction, and cost without adversely affecting safety or increasing noise. *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). In this regard, we note CAEP's intent for the purpose of the international CO_2 standard (as accepted by the CAEP Steering Group in 2011), which is to achieve aircraft CO_2 emissions reductions beyond that which would

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

[261] 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.

[262] ICAO, 2006: *Doc 7300-Convention on International Civil Aviation, Ninth edition,* Document 7300/9. Available at: *http://www.icao.int/publications/ICAOProducts&Services2015catalogue/cat_2015en.pdf* (last accessed May 12, 2015). The ICAO Document 7300 is found on page 1 of the ICAO Products & Services 2015 catalog and is copyright protected; Order No. 7300.

[263] According to the Chicago Convention, a participating member State that adopts regulations or practices differing in any particular respect from those established by an international standard is obligated to notify ICAO of the differences between its standards and ICAO's standards. However, member States that wish to use aircraft in international transportation must adopt emissions standards and other recommended practices that are at least as stringent as ICAO's standards. Member States may ban the use of any aircraft within their airspace that does not meet ICAO standards.

[264] U.S. EPA, ''Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures;'' Final Rule, 70 FR 2521, November 17, 2005.

have occurred in the absence of a standard.

In ruling on a petition for judicial review of the 2005 rule,[265] the U.S. Court of Appeals for the D.C. Circuit held that the EPA's approach in that action of tracking the ICAO standards was reasonable and permissible under the CAA. *NACAA* v. *EPA,* 489 F.3d 1221, 1230–32 (D.C. Cir. 2007). The Court also held that section 231 of the CAA confers a broad degree of discretion on the EPA to adopt aircraft emission standards that the Agency determines are reasonable. *Id.*

Although the EPA has traditionally established domestic standards that track the ICAO standards, for purposes of having a robust ANPR process, we ask for comment on the possibility of the EPA adopting a more stringent aircraft engine emissions standard than ICAO, provided ICAO/CAEP promulgates a standard in 2016 and the EPA makes a positive endangerment finding. In the same vein, the EPA requests that commenters consider the following factors (among others): The potential to reflect the CO_2 emissions performance of products from U.S. manufacturers, competitive advantages and disadvantages for U.S. manufacturers, certification reciprocity with certificating authorities of other nations, and the EPA's role in the ongoing ICAO negotiations. In addition, the EPA asks for comment on what action the EPA should take if the ICAO/CAEP process fails to result in the adoption of an aircraft CO_2 emissions standard.

VII. Statutory Authority and Executive Order Reviews

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

This action is a significant regulatory action because it raises novel policy issues. Accordingly, it was submitted to the Office of Management and Budget (OMB) for review. This action proposes a finding that GHG emissions from aircraft cause or contribute to air pollution that may be reasonably anticipated to endanger public health and welfare along with an ANPR which provides an overview of the international efforts to reduce GHG emissions, progress to date in establishing global aircraft standards that achieve meaningful CO_2 reductions and, if the EPA finds that aircraft GHG emissions do cause or contribute to endangerment, the potential use of CAA section 231 to implement these standards domestically ensuring transparency and the opportunity for public comment. Any changes made in response to OMB recommendations have been documented in the docket.

[265] Ibid.

B. Paperwork Reduction Act (PRA)

This action does not impose an information collection burden under the PRA. The proposed endangerment and cause or contribute findings under CAA section 231 do not contain any information collection activities.

C. 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. This action will not impose any requirements on small entities. The proposed endangerment and cause or contribute findings under CAA section 231 do not in-and-of-themselves impose any new requirements but rather set forth the Administrator's proposed determination that GHG emissions from certain classes of aircraft engines—those used in U.S. covered aircraft—cause or contribute to air pollution that may be reasonably anticipated to endanger public health and welfare. Accordingly, this action affords no opportunity for the EPA to fashion for small entities less burdensome compliance or reporting requirements or timetables or exemptions from all or part of the proposal.

D. Unfunded Mandates Reform Act (UMRA)

This action does not contain any unfunded mandate 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.

E. 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.

F. Executive Order 13175: Consultation and Coordination with Indian Tribal Governments

This action does not have tribal implications as specified in Executive Order 13175. The proposed endangerment and cause or contribute findings under CAA section 231 do not in-and-of-themselves impose any new requirements but rather set forth the Administrator's proposed determination that GHG emissions from certain classes of aircraft engines—those used in U.S. covered aircraft—cause or contribute to air pollution that may be reasonably anticipated to endanger public health and welfare. Thus, Executive Order 13175 does not apply to this action.

G. 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. The Administrator considered climate change risks to children as part of this proposed endangerment finding under CAA section 231. This action's discussion of climate change impacts on public health and welfare is found in section IV of this preamble. Specific discussion with regard to children are contained in sections IV and I.D of the preamble titled ''Children's Environmental Health.'' A copy of all documents pertaining to the impacts on children's health from climate change have been placed in the public docket for this action.

H. 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. Further, we have concluded that this action is not likely to have any adverse energy effects because the proposed endangerment and cause or contribute findings under section 231 do not in-and-of themselves impose any new requirements but rather set forth the Administrator's proposed determination that GHG emissions from certain classes of aircraft engines—those used in U.S. covered aircraft—cause or contribute to air pollution that may be reasonably anticipated to endanger public health and welfare.

I. National Technology Transfer and Advancement Act (NTTAA)

This action does not involve technical standards.

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

The EPA believes this action will not have potential disproportionately high and adverse human health or environmental effects on minority, low-income, or indigenous populations because this action does not affect the level of protection provided to human health or the environment. The Administrator considered climate change risks to minority, low-income, and indigenous populations as part of this proposed endangerment finding under CAA section 231. This action's discussion of climate change impacts on public health and welfare is found in section IV of the preamble. Specific discussion with regard to minority, low-income, and indigenous populations are found in sections IV and I.E of this preamble titled ''Environmental Justice.'' A copy of all documents pertaining to the impacts on these communities from climate change have been placed in the public docket for this action.

K. Determination Under Section 307(d)

Section 307(d)(1)(V) of the CAA provides that the provisions of section 307(d) apply to ''such other actions as the administrator may determine.'' Pursuant to section 307(d)(1)(V), the Administrator determines that this action is subject to the provisions of section 307(d).

VIII. Statutory Provisions and Legal Authority

Statutory authority for this action comes from 42 U.S.C. 7571, 7601 and 7607.

List of Subjects

40 CFR Part 87

Environmental protection, Air pollution control, Aircraft, Aircraft engines.

40 CFR Part 1068

Environmental protection, Administrative practice and procedure, Confidential business information, Imports, Motor vehicle pollution, Penalties, Reporting and recordkeeping requirements, Warranties.

Dated: June 10, 2015.

Gina McCarthy,

Administrator.

[FR Doc. 2015–15192 Filed 6–30–15; 8:45 am]

BILLING CODE 6560–50–P