The EPA Administrator, Gina McCarthy, signed the following final rule on 07/25/2016, and EPA is submitting it for publication in the Federal Register (FR). While we have taken steps to ensure the accuracy of this Internet version of the rule, it is not the official version of the rule. Please refer to the official version in a forthcoming FR publication, which will appear on the Government Printing Office's FDSys website (www.gpo.gov/fdsys/search/home.action) and on Regulations.gov (www.regulations.gov) in Docket No. EPA-HQ-OAR-2014-0828. Once the official version of this document is published in the FR, this version will be removed from the Internet and replaced with a link to the official version.

6560-50-P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 87 and 1068

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

RIN 2060-AS31

Finding that Greenhouse Gas Emissions from Aircraft Cause or Contribute to Air Pollution that May Reasonably Be Anticipated to Endanger Public Health and Welfare

AGENCY: Environmental Protection Agency (EPA).

ACTION: Final rule.

SUMMARY: In this action, the Administrator finds that elevated concentrations of greenhouse gases in the atmosphere endanger the public health and welfare of current and future generations within the meaning of section 231(a)(2)(A) of the Clean Air Act (CAA, or Act). She makes this finding specifically with respect to the same six well-mixed greenhouse gases—carbon dioxide (CO_2), 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 CAA and that together constitute the primary cause of the climate change problem. The Administrator also finds that emissions of those six well-mixed greenhouse gases from certain classes of engines used in certain aircraft

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are contributing to the air pollution—the aggregate group of the same six greenhouse gases—that endangers public health and welfare under CAA section 231(a)(2)(A).

DATES: These findings are effective on [INSERT DATE 30 DAYS FOLLOWING PUBLICATION IN THE FEDERAL REGISTER].

ADDRESSES: 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 web site. Although listed in the index, some information is not publicly available, e.g., confidential business information (CBI) or other information whose disclosure is restricted by statute. Certain other material, such as copyrighted material, is not placed on the Internet and will be publicly available only in hard copy 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: Lesley Jantarasami, Office of Atmospheric Programs, Climate Change Division, Environmental Protection Agency, 1200 Pennsylvania Ave. NW, Mail Code 6207-A, Washington DC 20460; Telephone number: (202) 343-9990; E-mail address: ghgendangerment@epa.gov. For additional information

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regarding these final findings, please go to the web site

http://www3.epa.gov/otaq/climate/regs-aviation.htm

SUPPLEMENTARY INFORMATION:

Judicial Review

Under CAA section 307(b)(1), judicial review of this final action is available only by filing a petition for review in the U.S. Court of Appeals for the District of Columbia Circuit by [INSERT DATE 60 DAYS FOLLOWING PUBLICATION IN THE FEDERAL REGISTER]. This final action is a nationally applicable action because it triggers the EPA's statutory duty to promulgate aircraft engine emission standards under CAA section 231, which are nationally applicable regulations and for which judicial review will be available only in the U.S. Court of Appeals for the District of Columbia Circuit. In the alternative, even if this action were considered to be only locally or regionally applicable, the Administrator determines that it has nationwide scope and effect within the meaning of CAA section 307(b)(1) both because of the obligation to establish standards under CAA section 231 that it triggers and because it concerns risks from GHG pollution and contributions to such pollution that occur across the nation. Under CAA section 307(d)(7)(B), only an objection to this final action that was raised with reasonable specificity during the period for public comment can be raised during judicial review. This section also provides a mechanism for us to convene a proceeding for reconsideration, "[i]f the person raising an objection can demonstrate to [EPA] that it was impracticable to raise such objection within [the period for public comment] or if the grounds for such objection arose after the period for public comment (but within the time

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specified for judicial review) and if such objection is of central relevance to the outcome of this rule." Any person seeking to make such a demonstration to us should submit a Petition for Reconsideration to the Office of the Administrator, Environmental Protection Agency, Room 3000, William Jefferson Clinton Building, 1200 Pennsylvania Ave. NW, Washington, DC 20460, with a copy to the person listed in the preceding **FOR FURTHER INFORMATION CONTACT** section, and the Associate General Counsel for the Air and Radiation Law Office, Office of General Counsel (Mail Code 2344-A) Environmental Protection Agency, 1200 Pennsylvania Ave. NW, Washington, DC 20460.

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Cause or Contribute to Air Pollution That May Be Reasonably Anticipated To Endanger Public Health and Welfare
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I. General Information

A. Does this Action Apply to Me?

These final findings trigger new duties that apply to the EPA but do not themselves apply new requirements to other entities outside the federal government. Specifically, in issuing these final findings that emissions of the six well-mixed GHGs from certain classes of engines used in certain aircraft cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare, the EPA becomes subject to a duty under CAA section 231 to propose and promulgate aircraft engine emission standards applicable to

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emissions of that air pollutant from those classes of engines. We are anticipating indicating an expected timeline for proposed GHG emission standards for the classes of aircraft engines included in the contribution finding in EPA's Unified Agenda of Federal Regulatory and Deregulatory Actions. Only those future standards will apply to and have an effect on other entities outside the federal government. Entities potentially interested in this final action include 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[1]
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 final action. This table lists the types of entities that the EPA is now aware could potentially have an interest in this final action. By issuing these final findings under CAA section 231(a)(2)(A) regarding emissions of greenhouse gases from aircraft engines, the EPA is now required to undertake a separate notice and comment rulemaking to propose and issue emission standards applicable to greenhouse gas emissions from the classes of aircraft engines subject to the findings, and the Federal Aviation Administration (FAA) is to prescribe regulations to ensure compliance with EPA's future emissions standards pursuant to CAA section 232. Other types of entities not

[1] Manufacturers of new aircraft engines refers to manufacturers of new type engines and in-production engines, and manufacturers of new aircraft refers to manufacturers of new type aircraft and in-production aircraft.

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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 final action, consult the person listed in the preceding **FOR FURTHER INFORMATION CONTACT** section.

II. Introduction: Overview and Context for this Final Action

A. Summary

Pursuant to CAA section 231(a)(2)(A), the Administrator finds that emissions of the six well-mixed[2] greenhouse gases (GHGs) from certain classes of aircraft engines used in certain types of aircraft (referred to interchangeably as "covered aircraft" or "US covered aircraft" throughout this notice) contribute to air pollution that may reasonably be anticipated to endanger the public health and welfare of current and future generations. This final action follows the Administrator's proposed findings,[3] and responds to public comments submitted to the EPA following that proposal. It is based on careful consideration of the scientific evidence, as well as a thorough review of the public comments. In light of the large number of comments received and overlap between many comments, EPA has not responded to each

[2] The term "well-mixed GHGs"—used both in the definition of "air pollution" in the endangerment finding and in the definition of "air pollutant" in the cause or contribute finding—is based on the fact that these gases are sufficiently long lived in the atmosphere such that, once emitted, concentrations of each gas become well mixed throughout the entire global atmosphere. These shared attributes are one of five primary reasons that the EPA considers the six gases as an aggregate group rather than as individual gases. See section IV.B for more information on the definition of "air pollution" and section V.A for more information on the definition of the "air pollutant."

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

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comment individually. Instead, EPA has summarized and provided responses to each significant argument, assertion and question contained within the totality of these comments. Covered aircraft are those aircraft to which the International Civil Aviation Organization (ICAO) has agreed the recently recommended international CO_2 standard will apply[4]: 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 include smaller jet aircraft such as the Cessna Citation CJ3+ 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 include larger turboprop aircraft, such as the ATR 72 and the Bombardier Q400.

In this final action, the EPA is informed by and places considerable weight on the extensive scientific and technical evidence in the record supporting the 2009 Endangerment and Cause or Contribute Findings under CAA section 202(a) (hereafter, collectively referred to as the 2009 Endangerment Finding).[5] This includes the major, peer-reviewed scientific assessments that were used to address the question of whether elevated concentrations of GHGs in the atmosphere endanger public health and welfare under CAA section 202(a), as well as the analytical framework and conclusions upon which the EPA relied in making that

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[4] ICAO, 2013: *CAEP/9 Agreed Certification Requirement for the Aeroplane CO2 Emissions Standards*, Circular (Cir) 337, 40 pp, AN/192, Available at: http://www.icao.int/publications/catalogue/cat_2016_en.pdf (last accessed May 9, 2016). The ICAO Circular 337 is found on page 87 of the catalog and is copyright protected; Order No. CIR337.

[5] 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)

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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)(2)(A). Furthermore, this finding under section 231(a)(2)(A) 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 the public health and welfare of current and future generations. No information or assessments 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).

The Administrator defines the "air pollution" referred to in section 231(a)(2)(A) of the CAA to be the combined mix of CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride (henceforth the six "well-mixed GHGs"). 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 welfare of current and future generations within the meaning of CAA section 231(a)(2)(A). The Administrator is not at this time making a finding regarding whether other substances emitted from aircraft engines cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare.

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Under CAA section 231(a)(2)(A), 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 using 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)(2)(A)—that is, the aggregate group of the same six well-mixed GHGs. With respect to this pollutant, based on the data summarized in section V.B, the Administrator finds that emissions of the six well-mixed GHGs from aircraft engines used in covered aircraft contribute to the air pollution that endangers public health and welfare under section 231(a)(2)(A). The Administrator is not at this time making a cause or contribute finding regarding GHG emissions, or emissions of other substances, from engines used in non-covered aircraft.

The Administrator's final 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 CAA section 231(a)(2)(A) for the GHG emissions from aircraft. Further, the EPA anticipates that the 39th ICAO Assembly will approve a final CO_2 emissions standard in October 2016, and that subsequently, ICAO will formally adopt the final CO_2 emissions standard in March 2017. These final endangerment and cause or contribute findings for aircraft engine GHG emissions are also part of preparing for a subsequent domestic rulemaking process under CAA section 231. If an international standard is approved and finalized by ICAO, member

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states that wish to use aircraft in international transportation will then be required under the Chicago Convention[6] 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. This notice does not take action or respond to comments on the 2015 U.S. EPA Aircraft Greenhouse Gas Emissions Advance Notice of Proposed Rulemaking (henceforth the "2015 ANPR"),[7] which discussed such standards. Technical issues and comments for the 2015 ANPR would be addressed in a future notice of proposed rulemaking related to such standards.

B. Background Information Helpful to Understanding This Final Action

1. Greenhouse Gases and Their Effects

GHGs in the atmosphere have the effect of trapping 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

[6] ICAO, 2006: *Convention on International Civil Aviation, Ninth Edition*, Document 7300/9, 114 pp. Available at: http://www.icao.int/publications/Documents/7300_9ed.pdf (last accessed May 9, 2016). .
[7] 80 FR 37758 (July 1, 2015).

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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 degrees Celsius or 1.53 degrees Fahrenheit.[8] The Intergovernmental Panel on Climate Change's (IPCC) 2013-2014 Fifth Assessment Report concluded that 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.[9] Further information about 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 determination under CAA section 231(a)(2)(A) (EPA-HQ-OAR-2014-0828). 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 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 2014, aircraft remained the single largest GHG-emitting transportation source not yet subject to any GHG standards. Aircraft clearly contribute to

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[8] 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.
[9] Ibid.

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U.S. transportation emissions, accounting for 12 percent of all U.S. transportation GHG emissions and representing more than 3 percent of total U.S. GHG emissions in 2014.[10] Globally, U.S. aircraft GHG emissions represent 29 percent of all global aircraft GHG 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 cause or contribute finding under CAA section 231(a)(2)(A).

2. Statutory Basis for This Final Action

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."

Before the Administrator may propose and issue final standards addressing emissions of an air pollutant 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

[10] U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*, 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430-R-16-002, April 2016. Available at: www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html (last accessed June 14, 2016).

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certain classes of aircraft engines cause or contribute to this air pollution.[11] If the Administrator answers both questions in the affirmative, she must propose and issue final 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 notice summarizes the legal framework for this final action under CAA section 231. Typically, past endangerment and cause or contribute findings have been proposed and promulgated concurrently with proposed and promulgated standards under various sections of the CAA, including section 231. In those actions, public comment was taken on the proposed findings as part of the notice and comment process for the proposed 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 at 66 FR 5002 (January 18, 2001). However, there is no requirement that the Administrator propose or finalize the endangerment and cause or contribute findings concurrently with the related standards. See 74 FR 66502 (December 15, 2009). As explained in the 2009 Endangerment Finding, nothing in section 202(a) requires the EPA to propose or issue endangerment and cause or contribute findings in the same rulemaking, and Congress left the EPA discretion to choose an approach that satisfied the requirements of section

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

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202(a). See id. The same analysis applies to section 231, which is analogous to section 202(a). The EPA is choosing to finalize these findings at this time for a number of reasons, including its previous commitment to issue such findings in response to a 2007 citizens' petition.[12]

The Administrator has applied 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."[13] CAA section 307(d) provides specific procedural requirements for the EPA to follow in taking certain rulemaking actions under the CAA, that apply in lieu of the otherwise applicable provisions of the Administrative Procedure Act, 5 U.S.C. sections 553-557, and 706. *See,* CAA section 307(d)(1). 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 findings were subject to the same

[12] 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 31, 2007. Available at http://www3.epa.gov/otaq/aviation.htm (last accessed April 8, 2016). EPA, 2012: Response to the Petition for Rulemaking Under the Clean Air Act to Reduce the Emission of Air Pollutants from Aircraft that Contribute to Global Climate Change, June 14, 2012. Available at http://www3.epa.gov/otaq/aviation.htm (last accessed April 8, 2016).

[13] 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).

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rulemaking procedures and requirements, as applicable, as would have applied if they had been 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 and the environment. Cars, trucks, construction equipment, airplanes, and ships, as well as a broad range of electricity generation, industrial, commercial and other facilities, are subject to various CAA programs. Many of these programs are targeted at ensuring protection of public health and welfare with a margin of safety, others are directed at encouraging improved industrial emissions performance and use of lesser polluting technologies and processes, and some address the prevention of adverse environmental effects. Implementation of the Act over the past four decades has resulted in significant reductions in air pollution that have benefited human health and the environment. The EPA's duties regarding aircraft air pollution emissions under CAA section 231 reflect a combination of the CAA's goals to protect public health and welfare and encourage improved emissions performance. This is shown by section 231(a)(2)(A)'s directive that EPA first identify whether emissions of aircraft engine air pollutants cause or contribute to air pollution that may reasonably be anticipated to endanger public health or welfare (which is broadly defined in section 302(h) of the CAA).[14] This is also shown by section 231(b)'s subsequent

[14] Previously the EPA has made the prerequisite endangerment and cause or contribute findings under CAA section 231(A) that formed the basis to begin addressing the issue of various aircraft pollutants including NOx aircraft pollution. U.S. EPA, "Control of Air Pollution from Aircraft and Aircraft Engines, Emission Standards

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requirement that EPA's standards, which may require improved emissions performance over the *status quo*, provide sufficient time for the development and application of requisite technology to meet emission standards, after consideration of costs.

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 combined mix in the atmosphere of the six well-mixed GHGs—CO_2, methane, nitrous oxide, hydrofluorocarbons,

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and Test Procedures for Aircraft." Final Rule, 38 FR 19088 (July 17, 1973). See also section IV.B.7.d of this preamble for a discussion of previous NOx section 231(A) findings.

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perfluorocarbons, and sulfur hexafluoride—endanger the public health and welfare of current and future generations.

- **Cause or Contribute Finding:** The Administrator found that the combined emissions of the six well-mixed GHGs from new motor vehicles and new motor vehicle engines contribute to the GHG pollution which threatens public health and welfare.

The Administrator made both of these findings with respect to the six well-mixed GHGs, recognizing that CAA section 202(a) sources emit only four of the six substances. 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).[15] 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).[16] On August 29, 2012, the EPA finalized the second phase of the GHG emission standards for light-duty vehicles (2017-2025 model years), further reducing GHG emissions from light-duty vehicles.[17] In 2014, the President directed the EPA

[15] 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).
[16] U.S. EPA, 2011: *Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Final Rule,* 76 FR 57106 (September 15, 2011).
[17] 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).

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and the Department of Transportation to set standards in 2016 that further increase fuel efficiency and reduce GHG emissions from medium- and heavy-duty vehicles.[18]

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 more than 6.25 billion metric tons.[19,20]

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.[21] As part of the Climate Action Plan, the President issued a Presidential Memorandum directing the EPA to

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[18] 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: https://www.whitehouse.gov/the-press-office/2014/02/18/remarks-president-fuel-efficiency-standards-medium-and-heavy-duty-vehicl (last accessed April 27, 2016).

[19] U.S. EPA, 2012: *EPA and NHTSA Set Standards to Reduce Greenhouse Gases and Improve Fuel Economy for Model Years 2017-2025 Cars and Light Trucks*. Document No. EPA-420-F-12-051, 10 pp. Available at http://www.epa.gov/otaq/climate/documents/420f12051.pdf (last accessed April 27, 2016). See also Table 7.4-2 in U.S. EPA, 2012: *Regulatory Impact Analysis: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards and Corporation Average Fuel Economy Standards,* EPA-420-R-12-016, 555 pp. Available at: https://www3.epa.gov/otaq/climate/documents/420r12016.pdf (last accessed April 27, 2016).

[20] U.S. EPA, 2011: *Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium-and Heavy-Duty Engines and Vehicles; Final Rule,* 76 FR 57106 (September 15, 2011).

[21] Executive Office of the President, 2013: *The President's Climate Action Plan*, June 25, 21 pp. Available at: http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf (last accessed April 8, 2016).

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work expeditiously to complete carbon pollution standards for the power sector.[22] In August 2015, after notice and comment rulemaking, the EPA finalized two carbon pollution rulemakings: one for new, modified, and reconstructed electric utility generating units[23] and another for existing power plants.[24]

In the Climate Action Plan, the President also indicated that the United States 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.[25] The final 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 notice, total U.S. aircraft GHG emissions in 2014 represented 12 percent of GHG emissions from the U.S. transportation sector,[26] and in 2010, the latest year with complete global emissions data,

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[22] 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 April 8, 2016).

[23] U.S. EPA, 2015: *Standards of Performance for Greenhouse Gas Emissions From New, Modified, and Reconstructed Stationary Sources: Electric Utility Generating Units; Final Rule,* 80 FR 64510 (October 23, 2015).

[24] U.S. EPA, 2014: *Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule*, 80 FR 64661 (October 23, 2015). On February 9, 2016 the Supreme Court stayed this rule pending judicial review. The Court's stay order does not articulate a basis for the stay and does not address the merits of the rule.

[25] Executive Office of the President, 2013: *The President's Climate Action Plan, June 25, 21 pp.* Available at http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf (last accessed April 8, 2016).

[26] U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*, 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430-R-16-002, April 2016. Available at: www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html (last accessed June 14, 2016).

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U.S. aircraft GHG emissions represented 29 percent of global aircraft GHG emissions.[27, 28] U.S. aircraft GHG emissions are projected to increase by 43 percent over the next two decades.[29] See section V of this preamble for more information about the data sources that comprise the aircraft GHG emissions inventory.

2. Background on the Aircraft Petition, the 2008 Advance Notice of Proposed Rulemaking, and the 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.[30] Specifically, Petitioners

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[27] Ibid.
[28] 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.
[29] As discussed in section V.B.4.c, fuel burn growth rates for air carriers and general aviation aircraft operating on jet fuel are projected to grow by 43 percent from 2010 to 2036, and this provides a scaling factor for growth in GHG emissions which would increase at a similar rate as the fuel burn by 2030, 2036, and 2040. FAA, 2016: *FAA Aerospace Forecast Fiscal Years 2016-2036*, 94 pp. Available at https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2016-36_FAA_Aerospace_Forecast.pdf (last accessed April 8, 2016).
[30] 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*

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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 advance notice of proposed rulemaking (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, 44468-73 (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.

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

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Emissions of Air Pollutants from Aircraft the Contribute to Global Climate Change, December 5, 26 pp. Available at http://www.epa.gov/otaq/aviation.htm (last accessed April 8, 2016) and Docket EPA-HQ-OAR-2014-0828.

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whether 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 the 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 the 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 District of Columbia Circuit (also called the "D.C. Circuit" in this notice).

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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 of Appeals upheld the 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 these findings regarding aircraft engine GHG emissions as a further step toward responding to the 2007 Petition for Rulemaking.

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[31] U.S. EPA, 2012: *Memorandum in Response to Petition Regarding Greenhouse Gas Emissions from Aircraft*, June 14, 11 pp. Available at http://www.epa.gov/otaq/aviation.htm (last accessed April 8, 2016) 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.

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

The EPA and the FAA traditionally work within the standard-setting process of ICAO's Committee on Aviation Environmental Protection (CAEP or the Committee) to establish international emission standards and related requirements, which individual nations later adopt into domestic law in fulfillment of their obligations under the Convention on International Civil Aviation (Chicago Convention). Historically, under this approach, international emission standards have first been adopted by ICAO, and subsequently the EPA has initiated rulemakings under CAA section 231 to establish domestic standards that are at least as stringent as ICAO's standards. This approach has been affirmed as a reasonable way to implement the Agency's duties under CAA section 231 by the U.S. Court of Appeals for the D.C. Circuit. *Nat'l Ass'n of Clean Air Agencies (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 regulations to ensure compliance with these standards when issuing certificates under its authority under Title 49 of the United States Code. These final endangerment and cause or contribute findings for aircraft GHG emissions are in preparation for this domestic emissions standards rulemaking process.

1. International Regulations and U.S. Obligations

The EPA has worked with the FAA since 1973, and later with ICAO, to develop domestic and international standards and other recommended practices pertaining to aircraft engine emissions. ICAO is a United Nations (UN) specialized agency, established in 1944 by the Chicago Convention, "in order that international civil aviation may be developed in a safe

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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 international standards and regulations 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 United States 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 that deems it necessary to adopt regulations or practices differing in any particular respect from those established by an

[33]ICAO, 2006: *Convention on International Civil Aviation, Ninth Edition*, Document 7300/9, 114 pp. Available at: http://www.icao.int/publications/Documents/7300_9ed.pdf (last accessed April 20, 2016).
[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 website: www.icao.int (last accessed April 8, 2016).

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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. 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 GHG emissions on the global climate.

The Chicago Convention has a number of other features that govern international commerce. First, member states that wish to use aircraft in international transportation must adopt 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, the Chicago Convention indicates that member states are required to recognize the airworthiness certificates of any state whose standards are

[36] ICAO, 2006: *Doc 7300-Convention on International Civil Aviation*, *Ninth Edition,* Document 7300/9, 114 pp. Available at http://www.icao.int/publications/Documents/7300_9ed.pdf (last accessed April 8, 2016).
[37] ICAO, 2006: *Convention on International Civil Aviation*, *Article 87*, *Ninth Edition*, Document 7300/9, 114 pp. Available at http://www.icao.int/publications/Documents/7300_9ed.pdf (last accessed April 8, 2016).

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at least as stringent as ICAO's standards[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] The ICAO Council reviews and adopts the recommendations made by CAEP. It then reports to the ICAO Assembly, the highest body of the Organization, where the main policies on aviation environmental protection are adopted and translated into Assembly Resolutions. If ICAO

[38] ICAO, 2006: *Convention on International Civil Aviation*, *Article 33, Ninth Edition*, Document 7300/9, 114 pp. Available at http://www.icao.int/publications/Documents/7300_9ed.pdf (last accessed April 8, 2016).
[39]ICAO, 2006: *Convention on International Civil Aviation, Article 38*, *Ninth Edition*, Document 7300/9, 114 pp. Available at http://www.icao.int/publications/Documents/7300_9ed.pdf (last accessed April 8, 2016).
[40]ICAO: CAEP Terms of Reference. Available at http://www.icao.int/environmental-protection/Pages/Caep.aspx#ToR (last accessed April 27, 2016).

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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).[41,42]

At CAEP meetings, the United States is represented by the FAA and plays an active role.[43] 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 environmental policy matters. In turn, the FAA assists and advises the EPA on aviation environmental issues, technology and certification matters.

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 (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x). The 1981 standards applied to newly manufactured engines, which are those engines built after the

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[41] ICAO, 2008: *Aircraft Engine Emissions*, International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Third Edition, July, 110 pp. Available at http://www.icao.int/publications/catalogue/cat_2016_en.pdf (last accessed April 8, 2016). The ICAO Annex 16 Volume II is found on page 19 of the ICAO Products & Services 2016 catalog and is copyright protected; Order No. AN16-2.

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

[43] 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.

[44] ICAO, 2008: *Aircraft Engine Emissions: Foreword*, International Standards and Recommended Practices, Environmental Protection, Annex 16, Volume II, Third Edition, July, 110 pp. Available at http://www.icao.int/publications/catalogue/cat_2016_en.pdf (last accessed April 8, 2016). The ICAO Annex 16 Volume II is found on page 19 of the ICAO Products & Services 2016 catalog and is copyright protected; Order No. AN16-2.

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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

[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, 110 pp. Available at http://www.icao.int/publications/catalogue/cat_2016_en.pdf (last accessed April 8, 2016). The ICAO Annex 16 Volume II is found on page 19 of the ICAO Products & Services 2016catalog and is copyright protected; Order No. AN16-2.

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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), and ICAO approved these recommendations in 2011.[50]

2. The International Civil Aviation Organization'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] The Resolution 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 up to the year 2050, and stabilizing CO_2 emissions at 2020 levels.[52] Reducing climate impacts of international

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[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, 2014: *Aircraft Engine Emissions*, Annex 16, Volume II, Third Edition, July 2008, Amendment 8, 108 pp. CAEP/8 corresponds to Amendment 7 effective on July 18, 2011. Available at http://www.icao.int/publications/catalogue/cat_2016_en.pdf (last accessed April 8, 2016). The ICAO Annex 16 Volume II is found on page 19 of the ICAO Products & Services 2016 catalog and is copyright protected; Order No. AN16-2/E/11.
[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 2010.
[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, 2009: *Aspirational Goals and Implementation Options*, Working Paper HLM-ENV/09-WP/5, 5 pp. Available at http://www.icao.int/Meetings/AMC/MA/High%20Level%202009/hlmenv_wp005_en.pdf (last accessed April 8, 2015).

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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 lower-carbon 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. EPA's Regulation of Aircraft Emissions and the Relationship of the Final Endangerment and Cause or Contribute Findings to International Aircraft Standards

As required by the CAA, the EPA has been engaged in reducing harmful air pollution from aircraft engines for over 40 years, regulating gaseous exhaust emissions, smoke, and fuel venting from aircraft engines.[53] We have periodically revised these regulations. In a 1997 rulemaking, for example, we made our emission standards and test procedures more consistent with those of ICAO's CAEP for turbofan engines used in commercial aviation with rated thrusts greater than 26.7 kilonewtons.[54] These ICAO requirements are generally referred to as CAEP/2 standards.[55] The 1997 rulemaking included new NO_x emission

[53] U.S. EPA, 1973: *Emission Standards and Test Procedures for Aircraft; Final Rule*, 38 FR 19088 (July 17, 1973).
[54] 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).
[55] 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.

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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)[56] 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).[57] It also included a CO emission standard for in-production commercial turbofan engines.[58] In 2005, we promulgated more stringent NO_x emission standards for newly certified commercial turbofan engines.[59] 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.[60,61] The EPA's actions to regulate certain pollutants emitted

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

[57] 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.

[58] 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).

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

[60] 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).

[61] 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 CAA section 231(a)(2)(A) to include such emissions from both commercial and

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from aircraft engines come directly from the authority in section 231 of the CAA, and we have aligned the U.S. emissions requirements with those promulgated by ICAO. All of these previous emission standards have generally been considered anti-backsliding standards (most aircraft engines meet the standards), which are technology-following.

In addressing CO_2 emissions, ICAO has moved to regulating a whole aircraft. ICAO explained its decision to regulate pollutant emissions from the whole aircraft in a 2013 ICAO circular.[62] Several factors are considered when addressing whole-aircraft CO_2 emissions, as CO_2 emissions are influenced by aerodynamics, weight, and engine technology. Since the aircraft-specific characteristics of aerodynamics and weight affect fuel consumption, they ultimately affect CO_2 engine exhaust emissions. Rather than viewing CO_2 as a measurable emission from the engine alone, ICAO addresses CO_2 emissions as an aircraft-specific characteristic based on fuel consumption.

The EPA has worked diligently over the past six years within the ICAO/CAEP process on a range of technical issues regarding aircraft CO_2 emission standards. The 2015 ANPR discussed the issues arising from those international proceedings and requested public comment on a variety of issues to assist the Agency in developing its position with regard to

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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.

[62] ICAO, 2013: *CAEP/9 Agreed Certification Requirement for the Aeroplane CO_2 Emissions Standard*, Circular (Cir) 337, 40 pp, AN/192. Available at http://www.icao.int/publications/catalogue/cat_2016_en.pdf (last accessed April 8, 2016). The ICAO Circular 337 is found on page 87 of the ICAO Products & Services 2016 catalog and is copyright protected; Order No. CIR337.

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these issues, to help ensure transparency and obtain views on aircraft engine GHG emission standards that it might potentially adopt under the CAA.

As described in the 2015 ANPR, in 2013 CAEP agreed on a metric[63] to compare CO_2 emissions from aircraft. The CO_2 metric value is a comparative metric meant to differentiate between generations of aircraft and to equitably capture improvements in aerospace technology that contribute to a reduction in the airplane CO_2 emissions. The CO_2 metric is not intended for use as a direct measure of CO_2 emissions rates or operational fuel burn, rather it is a comparative measure of technology on different aircraft.

Using this metric, CAEP considered and analyzed 10 different stringency levels for both in-production and new type standards, comparing aircraft with a similar level of technology on the same stringency level. These levels were generically referred to numerically from "1" as the least stringent to "10" as the most stringent, which correspond to the upper and lower lines of constant technology, respectively, from the 2015 ANPR. The 2015 ANPR described the range of stringency levels under consideration at CAEP as falling into three categories as follows: (1) CO_2 stringency levels that could impact[64] only the oldest,

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[63]The CO2 metric is the average of three cruise test points normalized by a dimensionless parameter representing aircraft fuselage size. The units of the metric value are kilograms of fuel burned per kilometer flown. However, because the metric is a normalized value it cannot be used to estimate operational fuel burn or emission rates of aircraft. The metric value is described in detail in both ICAO Circular 337 and in section D of the 2015 ANPR. ICAO, 2013: *CAEP/9 Agreed Certification Requirement for the Aeroplane CO_2 Emissions Standard*, Circular (Cir) 337, 40 pp. , AN/192, Available at http://www.icao.int/publications/catalogue/cat_2016_en.pdf (last accessed April 27, 2016). The ICAO Circular 337 is found on page 87 of the catalog and is copyright protected; Order No. CIR337.

[64] As described in the 2015 ANPR, the aircraft shown in [Figure II.1 and II.2] are in-production and current in-development. These aircraft could be impacted by an in-production standard in that, if they were above the

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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 CO2 standards becomes effective.[65]

At its meeting in February of 2016, CAEP agreed on an initial set of international standards to regulate CO_2 emissions from aircraft.[66] It was agreed that these international standards should apply to both new type and in-production aircraft. The applicability date for the in-production standard was agreed to be later than for the new type standard. CAEP explained that this will allow manufacturers and certification authorities additional preparation time to accommodate the standards. The new type and in-production stringency levels for smaller and larger aircraft were agreed to be set at different levels to reflect the range of technology being used and the availability of new fuel burn reduction technologies that vary across aircraft of differing size and weight. Table II.1 provides a brief overview of the applicability dates and stringency levels of the standards agreed to at ICAO/CAEP. As described earlier, CAEP considered and analyzed 10 different stringency levels for both in-production and new type standards (from 1 as the least stringent to 10 as the most stringent).

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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.

[65] 80 FR at 37797.

[66] Further, the EPA anticipates that the 39th ICAO Assembly will approve these CO_2 emissions standards in October 2016, and that subsequently, ICAO will formally adopt these CO_2 emissions standards in March 2017.

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Table II.1

STRINGENCY LEVELS AND APPLICABILITY DATES FOR ICAO/CAEP CO_2 EMISSION STANDARDS

	AIRCRAFT MTOM THRESHOLDS (KG)	NEW TYPE AIRCRAFT[67] MAXIMUM PERMITTED CO_2 METRIC VALUE	IN-PRODUCTION AIRCRAFT MAXIMUM PERMITTED CO_2 METRIC VALUE
Stringency Level	>5,700 to <60,000	5 A	3 B
	Horizontal Transition[68] 60,000 to ~ 70,000	C	D
	> ~70,000	8.5 E	7 F
Applicability Date	Application for a new type certificate or a change to an existing type certificate	2020 (2023 for planes with less than 19 seats)	2023
	Production Cut Off	n/a	2028

[67] "In Development" aircraft shown in Figures II.1 and II.2 are the aircraft that were in development by manufacturers at the time the 2015 ANPR was published.
[68] Stringency lines above and below 60,000 kilograms (MTOM) are connected by a horizontal transition starting at 60,000 kilograms (MTOM) and continuing right (increasing mass) until it intersects with the next level.

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A. Equation of ICAO Stringency Option #5: $\boldsymbol{MV} =$
$$\mathbf{10}^{-2.73780+\left(0.681310*log10(MTOM)\right)+\left(-0.0277861*\left(log10(MTOM)\right)^2\right)}$$
B. Equation of ICAO Stringency Option #3: $\boldsymbol{MV} =$
$$\mathbf{10}^{-2.57535+\left(0.609766*log10(MTOM)\right)+\left(-0.0191302*\left(log10(MTOM)\right)^2\right)}$$
C. Equation of New Type transition – 60,000 to 70,395kg: $\boldsymbol{MV} = \mathbf{0.764}$
D. Equation of In-production transition – 60,000 to 70,107kg: $\boldsymbol{MV} = \mathbf{0.797}$
E. Equation of ICAO Stringency Option #8.5: $\boldsymbol{MV} =$
$$\mathbf{10}^{-2.57535+\left(0.609766*log10(MTOM)\right)+\left(-0.0191302*\left(log10(MTOM)\right)^2\right)}$$
F. Equation of ICAO Stringency Option #7: $\boldsymbol{MV} =$
$$\mathbf{10}^{-1.39353+\left(-0.020517*log10(MTOM)\right)+\left(0.0593831*\left(log10(MTOM)\right)^2\right)}$$

Figures II.1 and II.2 show a graphical depiction of both the new type and in-production standards compared against the lines of constant technology described in the 2015 ANPR and CO_2 metric value levels of current (as of February 2016) in-production and in-development[69] aircraft. The aircraft data shown were generated by the EPA using a commercially available aircraft modeling tool called PIANO.[70] It should be noted that a number of the aircraft currently shown as in-production are expected to go out of production and be replaced by known in-development aircraft prior to both the new type and the in-production CO_2 standards going into effect internationally.

[69] 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.
[70] 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 April 8, 2016). This is a commercially available aircraft design and performance software suite used across the industry and academia. This model contains non-manufacturer provided estimates of performance of various aircraft.

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FIGURE II.1

ICAO CO_2 EMISSION STANDARDS (MTOM IN KILOGRAMS)

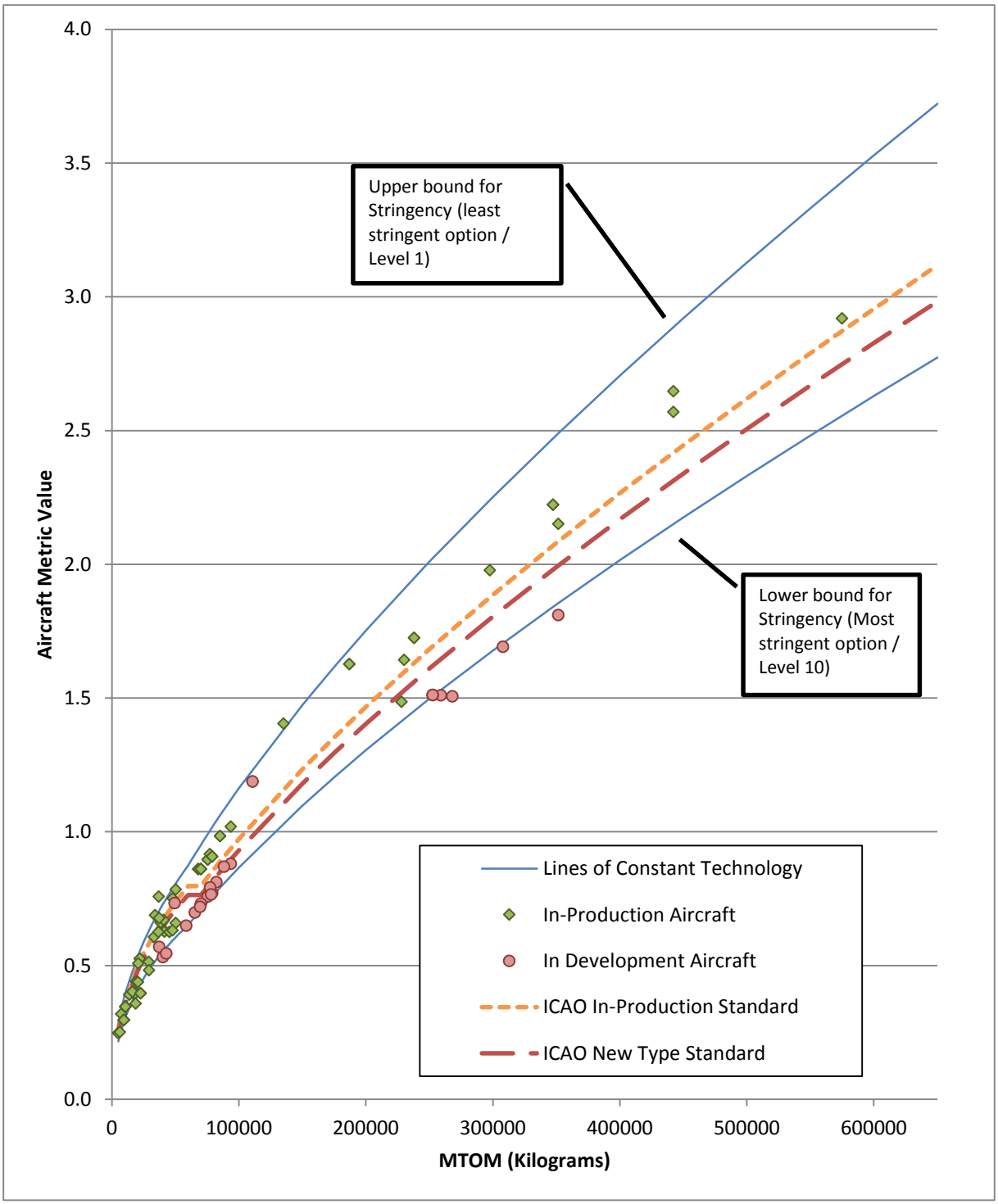

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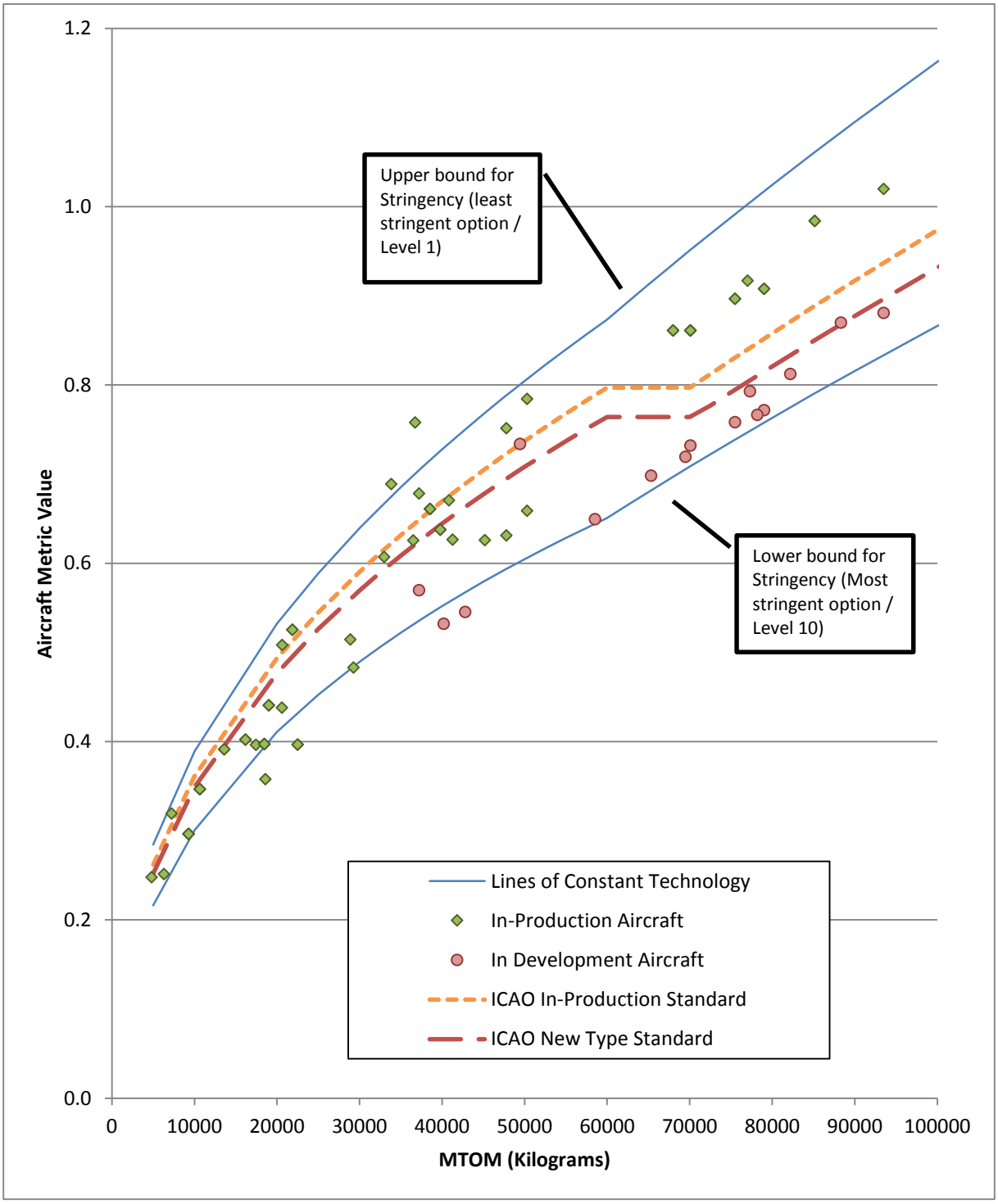
FIGURE II.2

ICAO CO_2 EMISSION STANDARDS (Zoomed to show <100,000 MTOM IN KILOGRAMS)



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In this final action, the EPA is promulgating findings under section 231(a)(2) that emissions of the six well-mixed GHGs from certain classes of engines used in covered aircraft cause or contribute to endangering air pollution. The EPA is not yet issuing proposed or final emission standards, nor is the EPA taking final action that prejudges what future standards will be. Instead, the EPA's final endangerment and cause or contribute findings for aircraft GHG emissions are in preparation for a subsequent, expected domestic rulemaking process to adopt future GHG emissions standards. If the ICAO Assembly, in October 2016, approves the final CO_2 standards and subsequently ICAO formally adopts the final CO_2 standards in March 2017, the EPA's standards will need to be at least as stringent as the ICAO CO_2 aircraft standards for the United States to meet its treaty obligations under the Chicago Convention. As a result of these positive findings, the EPA is obligated under section 231 of the CAA to set emission standards applicable to GHG emissions from the classes of aircraft engines included in the contribution finding, no matter the outcome of ICAO's future actions in October 2016 and March 2017.

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

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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

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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 finds 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 final section 231 finding.

Two provisions of the CAA govern this final action. 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, the six well-mixed GHGs—may reasonably be anticipated to endanger public health or welfare, and second, whether emissions of any air

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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.[71]

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. 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.[72]

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.[73] 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

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[71] *See CRR*, 684 F.3d at 117 (explaining two-part analysis under section 202(a)).
[72] 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 courts. As the D.C. Circuit 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).
[73] *See id.* at 121-122.

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less significant, but the likelihood high.[74] 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.[75] 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 considering only those impacts that can be traced to the amount of air pollution directly attributable to 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

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[74] *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)).
[75] See *id.* at 121-122.

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GHG emissions of aircraft. *See* 74 FR at 66542 (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.[76] 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 and welfare 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 section 231 finding, vulnerable subpopulations face serious health and welfare risks as a result of climate change.

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[76] 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.

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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." *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.'" *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 at 66506. 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 final 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.

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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 section 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 GHGs would effectively prevent EPA from doing the job that Congress gave it in [section] 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"

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clearly indicates that such emissions need not be the sole or major cause of the pollution. In addition, the absence of the term "significantly" or any other word that modifies "contribute" shows that the EPA need not find that contributing emissions cross a minimum percentage- or mass-based threshold to be cognizable. 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 at 18891; *see also* 74 FR at 66506. 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 is fully consistent with Congress' intention in crafting these provisions. See H.R. Rep. 95-294 (1977), as reprinted in 4 A Legislative History of the Clean Air Act Amendments of 1977 (1978) at 2465 (hereinafter

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LH). The committee explained that its action addressed not only section 211(c)(1)(A) but rather the entirety of the proposed legislative amendments, and stated that the committee's bill would thus apply the interpretation of section 211(c)(1)(A) in the *en banc* decision in *Ethyl Corp.* 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. As both CAA sections 231 and 202 were included in the 1977 amendments, 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. EPA's interpretation of section 231 is the same as its interpretation of the parallel language in section 202(a), which is explained in the 2009 Endangerment Finding. *See* 74 FR at 18891; *see also* 74 FR at 66506.

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.[77] 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[78]; (2) authorizes the Administrator to

[77] 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.
[78] *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").

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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.[79]

In revising the statutory language, Congress relied heavily on the *en banc* decision in *Ethyl Corp. v. EPA*, which reversed a three-judge panel opinion regarding an EPA rule restricting the content of lead in leaded gasoline.[80] 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,

[79] 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.

[80] 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).

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necessarily, a precautionary statute." *Id.* Optimally, the court found, regulatory action would not only precede, but prevent, a perceived threat. *Id.*

The court also rejected petitioners' 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."

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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"[81] 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.[82]

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[81] 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.

[82] 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.

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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 "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." This contrasts with other CAA provisions that expressly require "significant" contribution. *Compare, e.g.,* CAA sections 110(a)(2)(D)(i)(I); 111(b); 213(a)(2), (4). In the absence of specific language regarding the degree of contribution, the Administrator is to exercise her judgment in determining contribution. Congress clearly 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

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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 in this context need not be significant. 74 FR at 66542. 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" that does not meet 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*,

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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 from classes of new nonroad engines or vehicles to ozone or carbon monoxide concentrations before the EPA can regulate those engines or vehicles, while the EPA's view was that the CAA requires a finding only of contribution. *Id.* at 13. Section 213(a)(3)'s regulatory authority for specific classes of nonroad engines or vehicles, like that of section 231(a)(2)(A) for classes of aircraft engines, is triggered by a finding that certain sources "cause, or contribute to," air pollution, whereas an adjacent provision, section 213(a)(2), is triggered by a finding of a "significant" contribution from all new and existing nonroad engines and vehicles. The court looked at the "ordinary meaning of 'contribute'" when upholding the EPA's reading of section 213(a)(3). 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.[83] The court found that the bare "contribute" language in section 213(a)(3) 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.[84]

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[83] 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.

[84] 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.

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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 measureable amount of pollutant emissions to be resulting from the analyzed source category; a truly trivial or *de minimis* "contribution" might not count as such (although such a small level is not presented by the facts of today's findings). 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.[85] 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

[85] Section V discusses the evidence in this case that supports the 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.

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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) does not require some level of contribution that rises to a pre-determined numerical level or percentage- or mass-based portion of the overall endangering air pollution.

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 and weight of evidence (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 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 section 107(d) and finding it reasonable for

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the agency to apply a totality of the circumstances approach); *see also* 74 FR at 66542. Further discussion of this issue can be found in sections IV and V of this preamble.

4. Summary of Responses to Key Legal Comments on the Interpretation of the CAA Section 231(a) Endangerment and Cause or Contribute Test

Here we summarize key public comments regarding the legal interpretation of CAA section 231(a)(2)(A) that supports this finding and the Agency's response. The Response to Comments document contains the Agency's full response to comments on this topic.

Some commenters strongly supported the proposed findings. These comments stated, for example, that the proposed findings were clearly authorized under CAA section 231(a)(2)(A) and further noted that the U.S. Supreme Court had upheld EPA's authority under section 202(a) of the CAA to make an endangerment finding with regard to GHG emissions from motor vehicles and that the findings required under section 202(a)(1) are the same as the findings required under section 231(a)(2)(A). Another commenter, however, questioned the EPA's authority to make endangerment and cause or contribute findings for GHGs, stating that the EPA had not sufficiently explained its authority to address pollutants other than NAAQS under CAA section 231. This commenter made the following points in support of this view. First, the comment pointed to the use of the term "air quality control regions" in CAA sections 231(a)(1)(A) and 231(a)(3) as suggesting that Congress intended to authorize EPA to issue standards only for pollutants for which a NAAQS has been established. Second, the comment stated that the EPA should address this issue in light of a recent Supreme Court case, *Utility Air Regulatory Grp. v. EPA*, 134 S.Ct. 2427 (2014).

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After consideration of these comments, we disagree with the argument that Congress intended to only authorize the EPA to address NAAQS pollutants under section 231(a)(2)(A). That provision of the Act requires the EPA to issue 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." CAA section 231(a)(2)(A) (emphasis added). Looking to that plain language, there is nothing that limits the scope of the air pollutants that can be found to contribute to possible endangerment, and therefore which the EPA may be required to regulate, under that section to NAAQS pollutants. To the contrary, the language is clear that the EPA would be required to regulate aircraft engine emissions of "any air pollutant" as long the pre-requisite endangerment and cause or contribute findings are made. "Air pollutant" is not defined in section 231; instead, the definition under CAA section 302(g) applies, which states in relevant part that "'air pollutant' means *any* air pollutant agent or combination of such agents, including *any* physical, chemical … substance or matter which is emitted into or otherwise enters ambient air." CAA section 302(g) (emphasis added). Interpreting this provision in *Massachusetts v. EPA*, the U.S. Supreme Court observed that "[o]n its face, the definition embraces all airborne compounds of whatever stripe, and underscores that intent through the repeated use of the word 'any.'" 549 U.S. 497, 529 (2007). It further stated that "[b]ecause greenhouse gases fit well within" this "capacious definition of 'air pollutant'" the EPA has the statutory authority to regulate the emission of such gases from new motor vehicles under CAA section 202(a)(2). *Id.* at 532. As noted above, sections 231(a)(2)(A) and 202(a)(1) have parallel structures, use substantially the same language, and use the same definition of air

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pollutant. As that definition is "unambiguous" in its inclusion of GHGs, *Massachusetts*, 549 U.S. at 529, the Act clearly authorizes the EPA to make these findings for GHGs under CAA section 231(a)(2)(A). Moreover, one U.S. District Court has also ruled that the EPA has a duty to determine whether aircraft engine emissions of GHGs cause or contribute to endangerment, and that ruling was not appealed to the D.C. Circuit. *Center for Biological Diversity, et al. v. EPA*, 794 F. Supp. 2d 151 (D.D.C. 2011). Consequently, the statutory language imposing the EPA's duties under section 231(a)(2)(A), and relevant case law in the GHG context, do not support the commenter's limited reading of the EPA's authority under that language.

The commenter points to the use of the term "air quality control regions" in nearby paragraphs of CAA sections 231(a)(1)(A) and (a)(3) to support its suggestion that Congress intended to limit the EPA's analysis and regulatory authority to NAAQS pollutants in section 231(a)(2)(A). That argument is flawed for several reasons. The commenter points to section 231(a)(1), which relates to a study the EPA was to conduct of emissions of air pollutants from aircraft, and to section 231(a)(3), which requires the EPA to hold public hearings with respect to proposed standards under section 231(a)(2) in "air quality control regions … most seriously affected by aircraft emissions" to the extent practicable. These obligations are imposed in addition to those imposed by section 231(a)(2)(A), and their separate establishment does not by that fact narrow the EPA's scope of authority regarding its obligations imposed under section 231(a)(2)(A). They are additive, not subtractive, duties. Moreover, one of those added duties, to investigate the extent to which aircraft emissions affect air quality in air quality control regions under section 231(a)(1)(A), was a one-time duty that corresponded to

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NAAQS that have long-since been revised, whereas the EPA's duty to propose and promulgate aircraft emission standards is a continuing one to be conducted "from time to time" under section 231(a)(2)(A). The commenter provides no reasoning to explain why these provisions imposing additional duties should be read to limit the scope of section 231(a)(2) beyond their proximity. Sections 231(a)(1) and (a)(3) do not speak to what pollutants may be addressed under section 231(a)(2). Further, there is no incompatibility between the use of the term "air quality control regions" in those provisions to identify geographic areas where certain activities are to occur and making the endangerment and cause or contribute findings for GHGs that are finalized in this action. In fact, the EPA long ago discharged its one-time duty under CAA section 231(a)(1)(A)[86] and, after proposing new aircraft engine emission standards, could also meet its obligations to hold public hearings in the air quality control regions most seriously affected by aircraft emissions, to the extent practicable, all while meeting its obligations under section 231(a)(2)(A). Accordingly, the EPA does not interpret sections 231(a)(1) and (a)(3) to limit the scope of the duties and authority established by section 231(a)(2) to NAAQS pollutants. Further, the EPA has previously implemented section 231(a)(2) to reach air pollutants for which no NAAQS exists and has applied that provision to establish standards for non-NAAQS pollutants, such as smoke. *See, e.g.,* 40 CFR 87.21(a)-(c), (e), 87.23(a)-(c), and 87.31(a)-(c) emission standards for smoke. The EPA's regulation of non-NAAQS smoke emissions from aircraft engines has

[86] USEPA, 1973: Aircraft Emissions: Impact On Air Quality And Feasibility Of Control. U.S. Environmental Protection Agency, 102 pp. Available at http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=2000T6Z0.txt (last accessed April 26, 2016).

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never been judicially challenged. Finally, even if the Act were ambiguous, which it is not, the EPA's interpretation of section 231(a)(2) to include authority to address GHGs, is reasonable for the reasons described above.

The U.S. Supreme Court's opinion in *UARG* cited by the commenter does not change this analysis. The commenter misinterprets the *UARG* decision to mean that for purposes of determining applicability of the CAA's Prevention of Significant Deterioration (PSD) preconstruction permitting program, "air pollutant" meant only pollutants for which NAAQS had been established. The *UARG* decision, however, does not limit PSD applicability to only NAAQS pollutants. In fact, the Court recognized that such theories had been advanced during the course of that litigation but expressly declined to consider them in its decision. *See* 134 S.Ct. 2427, 2442 n.6 (2014). Rather, in *UARG*, the Court's holding pertained only to GHGs. More specifically, the Court held that the EPA may not treat GHGs as an air pollutant for the specific purpose of determining whether a source is a major source (or a modification thereof) and thus required to obtain a PSD permit or an operating permit under title V of the CAA. *Id.* at 2449.

Further, the regulatory context that was addressed in *UARG* is distinguishable from that of this action. In *UARG*, the Court explained that *Massachusetts* does not prevent an Agency from using statutory context to infer that in some provisions "air pollutant" refers only to those airborne substances that "may sensibly be encompassed within the particular regulatory program." 134 S.Ct. at 2441. However, the commenter offers no reason why GHG emissions from U.S. covered aircraft could not "sensibly be encompassed" under CAA

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section 231; nor is the EPA aware of any such reasons. In fact, *UARG* itself recognizes a distinction between the statutory scheme of the CAA permitting programs at issue in that case and the mobile source programs under Title II of the Act which were at issue in *Massachusetts*. Namely, the *UARG* opinion notes that part of the Court's reasoning in *Massachusetts* was based on its understanding that "nothing in the Act suggested that regulating greenhouse gases under [Title II] would conflict with the statutory design. Title II would not compel EPA to regulate in any way that would be 'extreme,' 'counterintuitive,' or contrary to 'common sense.' … At most, it would require EPA to take the modest step of adding greenhouse-gas standards to the roster of new-motor-vehicle emission regulations." 134 S.Ct. at 2441 (quoting *Massachusetts,* 549 U.S. at 531). Like *Massachusetts*, the statutory provisions for this action are found in Title II, and closely parallel the structure and language of the statutory program at issue in *Massachusetts*.[87] *Compare* CAA section 231(a)(2)(A) *with* 202(a)(1). Nor will reading the Title II provision section 231(a)(2)(A) to extend to GHGs result in a regulatory outcome that would be extreme, counterintuitive or contrary to common sense. Instead, as the D.C. Circuit has previously ruled, the EPA's discretion when establishing reasonable standards under section 231 is exceptionally broad. *See NACAA*, 489 F.3d at 1230–32. In short, the *UARG* opinion in no way precludes the

[87] Although this comment asserts that section 202(a) does not include mention of "air quality control region" as other provisions of section 231(a) do, that distinction is immaterial. As described above, the use of that term in other paragraphs imposing additional duties beyond those established by section 231(a)(2)(A) does not affect what pollutants may be addressed under section 231(a)(2)(A).

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EPA's interpretation that "air pollutant" as used in CAA section 231(a)(2)(A) includes GHGs, but rather supports that interpretation.

To the extent that the commenter is suggesting that the EPA should exercise its discretion to interpret CAA section 231(a)(2)(A) to exclude GHGs, the EPA declines to do so. The commenter has provided no persuasive reason for such an exclusion. Moreover, to make the threshold findings in this action, the EPA must, fundamentally, answer only two questions: Whether the particular "air pollution"—here, the six well-mixed GHGs—"may reasonably be anticipated to endanger public health or welfare," and whether emissions of those six well-mixed GHGs from U.S. covered aircraft engines "cause, or contribute to" that endangerment. *See CRR,* 648 F.3d at 117 (interpreting analogous provisions in CAA section 202(a)). Because the EPA answers both of these questions in the affirmative for emissions of the six well-mixed GHGs from U.S. covered aircraft engines—based on extensive scientific evidence and emissions information, as explained in detail in sections IV and V below—it is appropriate and reasonable to make both endangerment and cause or contribute findings under section 231(a)(2)(A) in this action.

In sum, after considering all of the relevant information, including that in public comments, the EPA interprets section 231(a)(2)(A) to include authority to address GHGs from U.S. covered aircraft engines. This interpretation is consistent with both its own and with judicial interpretations that the EPA's authority under the analogous section 202(a) unambiguously extends to GHGs.

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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). GHGs 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 term "air pollutant" for purposes of this section 231(a)(2)(A) contribution finding, which uses the same definition of air pollutant as the one 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, manmade 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.

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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 is no definition of "public health" 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 NAAQS. *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).

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IV. The Administrator's Finding under CAA Section 231 that Greenhouse Gases Endanger Public Health and Welfare

The Administrator finds, for purposes of CAA section 231(a)(2)(A), that elevated concentrations of the six well-mixed GHGs constitute air pollution that may reasonably be anticipated to endanger both the public health and welfare of current and future generations. The Administrator is making this finding specifically with regard to the same definition of the "air pollution" under CAA section 231(a)(2) as that used under CAA section 202(a)(1), namely the combined mix of CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride, which together are the root cause and best understood drivers of human-induced climate change and the resulting impacts on public health and welfare. The EPA received public comments on this definition of air pollution from the proposed findings, and summarizes responses to some of those key comments below; fuller responses to public comments can be found in EPA's Response to Comments document included in the docket. The Administrator addresses other climate-forcing agents both in the 2009 Endangerment Finding[88] and in this action; however, these substances are not included in the air pollution definition used in this action for the reasons discussed below in section IV.B.7.

Section IV.A below discusses the EPA's approach to evaluating the scientific evidence before it. Section IV.B discusses the scope and nature of the relevant air pollution

[88] 74 FR at 66519-21.

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for the endangerment finding under CAA section 231(a)(2)(A), including a discussion of other substances with climate effects that were addressed but not included in the definition of air pollution. Section IV.C summarizes the scientific evidence that the air pollution is reasonably anticipated to endanger both public health and welfare. Section IV.D summarizes the Administrator's conclusion for purposes of section 231(a)(2)(A), in light of the evidence, analysis, and conclusions that led to the 2009 Endangerment Finding as well as more recent evidence and consideration of public comments, that emissions of the six well-mixed GHGs in the atmosphere may reasonably be anticipated to endanger public health and welfare.

A. **The Science Upon Which the Agency Relied**

This finding under section 231(a)(2)(A) 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 the six well-mixed GHGs in the atmosphere may reasonably be anticipated to endanger public health and welfare. 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 for the six well-mixed GHGs under CAA section 231(a)(2)(A). While the EPA is providing a summary of newer scientific assessments below, the EPA is also relying on the same scientific and technical evidence

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discussed in the notices for the 2009 Endangerment Finding in these final findings for purposes of CAA section 231(a)(2)(A).[89]

The EPA is following the same approach toward technical and scientific information in this finding under section 231(a)(2)(A) as it used in the 2009 Endangerment Finding. More specifically, in the 2009 Endangerment Finding 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 consider the recent, major assessments by the U.S. Global Change Research Program (USGCRP), the IPCC, and the National Research Council of the National Academies of Sciences, Engineering, and Medicine (referred to interchangeably as NRC or NAS) as the primary scientific and technical basis informing the endangerment finding. 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 in terms of factors such as their objectivity, integrity, utility, and transparency, including how they have employed rigorous peer review processes. The EPA considers these assessments to represent the best available science that maintains the highest level of adherence to Agency guidelines for information quality.[90] These assessments have been adequately peer reviewed in a manner

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[89] See sections III of the 2009 Proposed Endangerment Finding and sections III and IV of the 2009 Endangerment Finding. 74 FR at 18894-18904 and 74 FR at 66510-36.

[90] Applicable guidance includes U.S. EPA 2012: *Addendum to A Summary of General Assessment Factors for Evaluating the Quality of Scientific and Technical Information*, 9 pp. Available at

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commensurate with the EPA's Peer Review Policy[91] and guidance in the EPA's Peer Review Handbook.[92]

The EPA is giving careful consideration to all of the scientific and technical information in the record. However, the Administrator considers the major scientific assessments as the primary scientific and technical basis of her endangerment decision. This provides assurance that the Administrator is basing her judgment on the best available, well-vetted science that reflects the consensus of the climate science research community. 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. The major findings of the USGCRP, IPCC, and NRC assessments support the Administrator's determination that elevated concentrations of GHGs in the atmosphere may reasonably be anticipated to endanger the

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https://www.epa.gov/risk/guidance-evaluating-and-documenting-quality-existing-scientific-and-technical-information (last accessed July 11, 2016) and U.S. EPA, 2002: *Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by the EPA*, 61 pp. Available at https://www.epa.gov/quality/guidelines-ensuring-and-maximizing-quality-objectivity-utility-and-integrity-information (last accessed July 11, 2016).

[91] U.S. EPA, 2006: *Memorandum on Peer Review and Peer Involvement at the U.S. EPA*, 4 pp. Available at https://www.epa.gov/osa/memorandum-peer-review-and-peer-involvement-epa (last accessed April 12, 2016).

[92] U.S. EPA, 2015: *EPA Peer Review Handbook, Fourth Edition*, 248 pp. Available at https://www.epa.gov/osa/peer-review-handbook-4th-edition-2015-0 (last accessed April 12, 2016). Also, 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. A copy of this letter and all other relevant EPA peer review documentation is located in the docket for today's final action (EPA-HQ-OAR-2014-0828).

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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.

The EPA reviewed ten administrative petitions for reconsideration of the 2009 Endangerment Finding in 2010.[93] 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 2009 Endangerment Finding and their objections' lack of "central relevance" to the Finding. [94] 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.[95]

The 2009 Endangerment Finding and the 2010 Reconsideration Denial were challenged in a lawsuit before the D.C. Circuit.[96] On June 26, 2012, the D.C. Circuit upheld the Endangerment Finding and the Reconsideration Denial, ruling that the Finding (including

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[93] Administrative petitions are available from www3.epa.gov/climatechange/endangerment/petitions.html (last accessed June 21, 2016), and in the docket for the 2009 Endangerment Finding: EPA-HQ-OAR-2009-0171.
[94] 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.
[95] The Response to Petitions document is available from www3.epa.gov/climatechange/endangerment/petitions.html (last accessed June 21, 2016), and in the docket for the 2009 Endangerment Finding: EPA-HQ-OAR-2009-0171.
[96] *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*).

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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 GHGs)[97] and the text and structure of the CAA, and was adequately supported by the administrative record.[98] The D.C. Circuit also agreed with the EPA that the Petitioners had "not provided substantial support for their argument that the Endangerment Finding should be revised."[99] It 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.[100] The D.C. Circuit further noted that the EPA's reliance on assessments was consistent with the methods decision-makers often use to make a science-based judgment.[101] Moreover, it 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

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[97] 549 U.S. 497 (2007).
[98] *CRR*, 684 F.3d at 117-27.
[99] *Id.* at 125.
[100] *Id.* at 120-121.
[101] *Id*. at 121.

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> scientific consensus the reports 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.[102]

In addition, the EPA's consideration of 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."[103] The D.C. Circuit subsequently noted that "the existence of some uncertainty does not, without more, warrant invalidation of an endangerment finding."[104]

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

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[102] *Id*. at 120.
[103] 74 FR at 66524.
[104] *CRR,* 684 F.3d at 121.

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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."[105] Thus, the Supreme Court did not disturb the D.C. Circuit's holding that affirmed the 2009 Endangerment Finding.

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 use 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. The EPA reviewed the following new major peer-reviewed scientific assessments:

- IPCC's 2013-2014 Fifth Assessment Report (AR5)[106]

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[105] *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.).

[106] 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,

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- IPCC's 2012 "Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" (SREX)[107]
- USGCRP's 2014 "Climate Change Impacts in the United States: the Third National Climate Assessment" (NCA3)[108]
- NRC's 2010 "Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean" (Ocean Acidification)[109]
- NRC's 2011 "Climate Change, the Indoor Environment, and Health" (Indoor Environment)[110]
- NRC's 2011 "Report on Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia" (Climate Stabilization Targets)[111]

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.

[107] 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.

[108] 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.

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

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

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

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- NRC's 2011 "National Security Implications for U.S. Naval Forces" (National Security Implications)[112]
- NRC's 2011 "Understanding Earth's Deep Past: Lessons for Our Climate Future" (Understanding Earth's Deep Past)[113]
- NRC's 2012 "Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future" (Sea Level Rise)[114]
- NRC's 2013 "Climate and Social Stress: Implications for Security Analysis" (Climate and Social Stress)[115]
- NRC's 2013 "Abrupt Impacts of Climate Change" (Abrupt Impacts)[116]
- NRC's 2014 "The Arctic in the Anthropocene: Emerging Research Questions" (Arctic)[117].

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, explained in the 2009 Endangerment Finding.

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[112] NRC, 2011: *National Security Implications of Climate Change for U.S. Naval Forces*. The National Academies Press, 226 pp.
[113] NRC, 2011: *Understanding Earth's Deep Past: Lessons for Our Climate Future*. The National Academies Press, 212 pp.
[114] NRC, 2012: *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*. The National Academies Press, 201 pp.
[115] NRC, 2013: *Climate and Social Stress: Implications for Security Analysis.* The National Academies Press, 280 pp.
[116] NRC, 2013: *Abrupt Impacts of Climate Change: Anticipating Surprises*. The National Academies Press, 250 pp.
[117] NRC, 2014: *The Arctic in the Anthropocene: Emerging Research Questions.* The National Academies Press, 220 pp.

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1. Response to Key Comments on the EPA's Approach to the Science

Here we summarize key public comments regarding the approach to the science—see the Response to Comments document for the Agency's full responses to comments. Several commenters agreed and no commenters disagreed with the EPA's approach to the science for making an endangerment decision specifically with respect to the six well-mixed GHGs (see section IV.B.7 for a summary of key public comments and our responses to commenters who argued that the science supports expanding the scope of the endangerment finding to include other climate forcers beyond the six well-mixed GHGs). They specifically mentioned their support for the EPA's approach to considering the scientific and technical information in the record of the 2009 Endangerment Finding—primarily the recent, major assessments by the USGCRP, the IPCC, and the NRC—as well as the most recent scientific assessments for additional support and justification. For the reasons stated in section IV.A above, the EPA agrees with the commenters that this approach ensures that the Administrator considers the best available scientific and technical information.

B. **The Air Pollution Consists of Six Key Well-Mixed Greenhouse Gases**

The Administrator must define the scope and nature of the relevant air pollution for the endangerment finding under CAA section 231(a)(2)(A). In this final action, the Administrator finds that the air pollution is the combined mix of six well-mixed GHGs, which together are the root cause and best understood drivers of human-induced climate change and the resulting impacts on public health and welfare. These six GHGs— CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride—are

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considered an aggregate group for purposes of this finding. The Administrator's definition of air pollution for purposes of section 231(a)(2)(A) is made in light of (1) the evidence, analysis, and conclusions that led to the 2009 Endangerment Finding; (2) more recent evidence from scientific assessments published since 2009; and (3) consideration of public comments, for which key comments and responses are summarized in sections IV.B.6 and 7 below. The Administrator considered five primary reasons in the 2009 Endangerment Finding for focusing on this aggregate group as the air pollution: (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 root cause of human-induced climate change, are the best-understood driver of climate change, and are expected to remain the primary 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).[118] After consideration of all information before her, including public comments, as explained below, the Administrator maintains her view that these five reasons for defining the scope and nature of the air pollution to be these six well-mixed

[118] 74 FR at 66517-19.

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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 as that under section 202(a)(1). The following subsections summarize the five reasons detailed in the 2009 Endangerment Finding and as appropriate, summarize additional supporting information from the recent scientific assessments published since 2009.

1. Common Physical Properties of the Six Greenhouse Gases

The six GHGs share common physical properties that are relevant to the climate change problem. They all are sufficiently long lived in the atmosphere such that, once emitted, concentrations of each gas become globally well mixed in the atmosphere.[119] A well-mixed gas has relatively uniform concentrations in the atmosphere anywhere around the globe, with little local or regional variation except immediately next to sources or sinks. A given amount of a well-mixed gas emitted anywhere will have similar impacts on global

[119] The properties "long lived" and "well mixed" used in this notice 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. Atmospheric lifetime is a measure of how long a type of molecule is likely to remain in the atmosphere before it breaks down, reacts with other gases, or is absorbed by Earth's surface. The IPCC often refers interchangeably to the six well-mixed GHGs as long-lived GHGs; however, the IPCC and others in the international climate change community, such as the United Nations Environment Programme, also refer to methane and some HFCs as "near-term climate forcers," "short-lived climate forcers," or "short-lived climate pollutants." These terms refer to those compounds whose impacts on Earth's climate occurs primarily with the first decade after their emission. According to the IPCC AR5 (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. Thus, methane and some HFCs are both short- and long-lived GHGs—*i.e.*, they have lifetimes long enough to become globally well mixed in the atmosphere, but short enough to primarily affect Earth's climate within a decade after their emission. For comparison, 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.

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concentrations regardless of the geographic location of emission. All six GHGs trap outgoing heat that would otherwise escape to space, and all are directly emitted from a source as a GHG rather than becoming a GHG in the atmosphere after emission of a precursor gas. This fundamental scientific understanding of the intrinsic physical, chemical, and atmospheric properties of the six GHGs has not changed and remains supported by the more recent climate change assessments.

2. The Six Well-Mixed Greenhouse Gases Are the Primary and Best Understood Driver of Current and Projected Climate Change

The Administrator judges that the scientific evidence is compelling that together the six well-mixed GHGs constitute the largest anthropogenic driver of climate change. In addition, the six well-mixed GHGs are the best-understood driver of climate change because they have well-understood physical properties as described above that govern their climate effect (e.g., their radiative forcing, a measure of their total net effect on the global energy balance). As explained in more detail in the 2009 Endangerment Finding,[120] the Administrator 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

[120] 74 FR at 66517-18.

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anthropogenic activities was based on multiple lines of evidence. 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). Observed increases in global average air temperatures are driving observed climate impacts like widespread melting of snow and ice and rising global average sea level. The Administrator also considered these observed changes as additional evidence of the unequivocal warming of the climate system driven primarily by elevated atmospheric GHG concentrations because the consistency of these observed changes in physical and biological systems and the observed significant warming cannot be explained entirely due to natural variability or other confounding non-climate factors.

In addition, as described in more detail in the 2009 Endangerment Finding,[121] the Administrator made the judgment that the scientific evidence is compelling that six GHGs are expected to remain the primary driver of future climate change and that, without substantial and near-term efforts to significantly reduce emissions, it can be expected that atmospheric concentrations of the six GHGs will continue to climb and thus lead to ever greater rates of climate change. Given the long atmospheric lifetime of the six well-mixed GHGs, which

[121] 74 FR at 66518-19.

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range from roughly a decade to centuries, future atmospheric GHG concentrations for the remainder of this century and beyond will be influenced not only by future emissions but indeed by present-day and near-term emissions. Consideration of future plausible scenarios, and how our current GHG emissions essentially commit present and future generations to cope with an altered atmosphere and climate, reinforces the Administrator's judgment that it is appropriate to define the combination of the six key greenhouse gases as the air pollution. Most future scenarios that assume no explicit GHG mitigation actions (beyond those already enacted) project increasing global GHG emissions over the century, which in turn result in climbing GHG concentrations. Concentrations of the six well-mixed GHGs increase even for those scenarios where annual emissions toward the end of the century are assumed to be lower than current annual emissions.

The EPA has also carefully reviewed the recent assessments of the IPCC, USGCRP, and NRC. The EPA finds that these recent assessments support and strengthen the evidence cited in the 2009 Endangerment Finding that current atmospheric GHG concentrations are now at elevated and essentially unprecedented levels primarily as a result of both historic and current anthropogenic emissions. The 2014 USGCRP NCA3 states, "Atmospheric levels measured at Mauna Loa in Hawai'i and at other sites around the world reached 400 parts per million in 2013, higher than the Earth has experienced in over a million years."[122] Such concentrations are the primary driver of observed changes in Earth's climate system, namely

[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. 739.

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increased global average temperatures that drive climate impacts like widespread melting of snow and ice and rising global average sea level (discussed in more detail in section IV.C). The recent assessments of the IPCC, USGCRP, and NRC also describe how these six well-mixed GHGs play a dominant role in future warming of the climate system. The USGCRP NCA3 makes the following finding with very high confidence: "The magnitude of climate change beyond the next few decades depends primarily on the amount of heat-trapping gases emitted globally, and how sensitive the Earth's climate is to those emissions."[123] Key findings from the recent assessments regarding global and U.S. trends are described briefly below.

a. Key Observed Trends Driven Primarily by the Six Well-Mixed GHGs

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.[124] The IPCC AR5 concludes that the increase in atmospheric GHG concentrations since 1750, plus other human activities (e.g., land use change and aerosol emissions), has had a radiative forcing

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[123] 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.20. See also p. 736: "Past emissions of heat-trapping gases have already committed the world to a certain amount of future climate change. How much more the climate will change depends on future emissions and the sensitivity of the climate system to those emissions."

[124] "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.

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effect estimated to be 2.3 Watts per square meter (W/m^2) in 2011.[125] Radiative forcing is a measure of a substance's total net effect on the global energy balance for which a positive number represents a warming effect and a negative number represents a cooling effect. The IPCC's estimate is an increase from the previous 2007 IPCC Fourth Assessment Report (AR4) total net estimate of 1.6 W/m^2 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 aerosol particles. The IPCC AR5 rates the level of confidence[126] 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 since the 2009 Endangerment Finding 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 an even 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 observed increase in anthropogenic 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

[125] Ibid.
[126] 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.

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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[127] 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 GHGs, 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."[128]

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. Short-term variability does not alter conclusions about the long-term climate trend that the IPCC AR5 finds after its review of independently verified observational records: "Each of the past three

[127] 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.
[128] 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.

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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."[129, 130]

Temperature trends at the global level have also been observed regionally and in the United States. In the Northern Hemisphere, the IPCC AR5 finds that the last 30 years were likely the warmest 30-year period of the last 1400 years. The USGCRP NCA3 states with very high confidence that "U.S. average temperature has increased by 1.3°F to 1.9°F since record keeping began in 1895; most of this increase has occurred since about 1970. The most recent decade was the nation's warmest on record."[131] The USGCRP also notes that the rate of U.S. temperature increase over the past 4 to 5 decades has been greater than the rate observed in earlier decades.

b. Key Projections Based Primarily on Future Scenarios of the Six Well-Mixed GHGs

Future temperature changes will depend on what path the world follows with respect to GHG emissions and associated levels of GHG concentrations in the atmosphere. The NRC

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[129] 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.

[130] Furthermore, we note that according to both NOAA and NASA, 2015 was the warmest year in the modern instrumental record for globally averaged surface temperature, breaking the record previously held by 2014. This now means that the last fifteen years have been fifteen of the sixteen warmest years on record. Available at http://www.ncdc.noaa.gov/sotc/global/201513 (last accessed April 11, 2016).

[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. 28.

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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."[132] A key future projection of this assessment is that by the end of the century, if no emissions reductions are made, CO_2 concentrations are projected to increase to levels that Earth has not experienced for more than 30 million years. In its high emission scenario, the IPCC AR5 projects that global temperatures by the end of the century will likely be 2.6 to 4.8 degrees Celsius (4.7 to 8.6 degrees Fahrenheit) warmer than today. Temperatures on land and in northern latitudes will likely warm even faster than the global average.

For the United States, the USGCRP NCA3 concludes, "Warming is ultimately projected for all parts of the nation during this century. In the next few decades, this warming will be roughly 2°F to 4°F in most areas. By the end of the century, U.S. warming is projected to correspond closely to the level of global emissions: roughly 3°F to 5°F under lower emissions scenarios (B1 or RCP 4.5) involving substantial reductions in emissions, and 5°F to 10°F for higher emissions scenarios (A2 or RCP 8.5) that assume continued increases

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

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in emissions; the largest temperature increases are projected for the upper Midwest and Alaska."[133]

3. The Six Well-Mixed GHGs Are Currently the Common Focus of the Climate Change Science and Policy Communities

The six well-mixed GHGs are currently the common focus of climate science and policy analyses and discussions. Grouping them is consistent with the focus of international and domestic climate science research enterprises like the IPCC and USGCRP. The IPCC and USGCRP assessment reports assess the climate change effects on health, society, and the environment as a result of human-induced climate change driven primarily by the group of six gases.

Grouping them is also consistent with the focus of climate policy. The United Nations Framework Convention on Climate Change (UNFCCC), signed and ratified by the United States in 1992, requires its signatories to "develop, periodically update, publish and make available…national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies…"[134] To date, the primary focus of UNFCCC actions and discussions has

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[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. 29.
[134] United Nations Framework Convention on Climate Change, 1992: Article 4(1)(a) of the United Nations Framework Convention on Climate Change, p. 10. Available at https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf (last accessed April 11, 2016).

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been on the six well-mixed GHGs, including the recent Paris Agreement in which Parties agreed to undertake nationally determined contributions to achieving the goal of "global peaking of GHG emissions as soon as possible" in order to reach a long-term global temperature target.[135] Domestically, the EPA has been developing standards for GHG emissions from mobile and stationary sources under the Clean Air Act since finalizing the 2009 Endangerment Finding.

4. Defining Air Pollution as the Aggregate Group of Six GHGs is Consistent with Evaluation of Risks and Impacts Due to Human-Induced Climate Change

Based on her review of the science described in detail above in section IV.B.2, the Administrator judges that the six well-mixed GHGs constitute the largest anthropogenic driver of climate change and play a dominant role in observed and projected changes in Earth's climate system. Thus, the Administrator finds, as she did in the 2009 Endangerment Finding, that because the six well-mixed GHGs are collectively the primary driver of current and projected human-induced climate change, the current and future risks (here described in section IV.C below) due to human-induced climate change—whether these risks are associated with increases in temperature, changes in precipitation, a rise in sea levels, changes in the frequency and intensity of weather events, or more directly with the elevated GHG concentrations themselves—can be associated with this definition of air pollution. Due to the

[135] United Nations Framework Convention on Climate Change, 2015: *Adoption of the Paris Agreement Conference of the Parties Twenty-first session Paris*, FCCC/CP/2015/L.9/Rev.1, 12 December 2015, Available at: https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf (last accessed April 8, 2016).

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cumulative purpose of the statutory language, even if the Administrator were to look at the atmospheric concentration of each GHG individually, she would still consider the impact of the concentration of a single GHG in combination with that caused by the other GHGs.

5. Defining Air Pollution as the Aggregate Group of Six GHGs is Consistent with Past EPA Practice

Treating the air pollution as the aggregate of the well-mixed GHGs is consistent with other provisions of the CAA and previous EPA practice under the CAA, where separate emissions from different sources but with common properties may be treated as a class (e.g., particulate matter (PM)). This approach addresses the total, cumulative effect that the elevated concentrations of the six well-mixed GHGs have on climate and, thus, on different elements of health, society, and the environment. The EPA treats, for example, PM as a common class of air pollution; PM is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles.

6. Response to Key Comments on Defining the Air Pollution as the Aggregate Group of the Six Well-Mixed Greenhouse Gases

Many commenters agreed with the EPA that the "air pollution" for purposes of the endangerment finding under section 231(a)(2)(A) of the CAA should be defined as the six well-mixed GHGs. Several commenters discussed the fact that aircraft engines emit only two of the six well-mixed GHGs. Commenters pointed out that the majority of aircraft emissions

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are CO_2, while nitrous oxide emissions are described as "nominal (<1%)" or "trace." Some commenters ultimately concluded that the EPA's approach to defining the air pollution as an aggregate group of six gases is acceptable, but that the scope of future regulations should be limited to CO_2. One commenter agreed with the Agency's evaluation of the six GHGs based on their common attributes, but questioned the EPA's decision to aggregate the six gases rather than considering them individually for purposes of making the findings. Other commenters disagreed with the EPA and requested limiting the definition of air pollution in this action to CO_2 or to CO_2 and nitrous oxide.

The EPA disagrees with comments regarding changing the definition of the air pollution to limit it to only those GHGs that are emitted from aircraft or to CO_2 only. The EPA has explained both in the 2009 Endangerment Finding and in the proposed findings under CAA section 231(a)(2)(A) that the definition of the air pollution is based on shared characteristics and common attributes relevant to climate change science and policy[136]—which is not affected by the identity of the source(s) of the emissions contributing to the air pollution. The EPA recognized in the proposed findings that aircraft emit two of the six well-mixed GHGs but stated that nonetheless it is entirely reasonable and appropriate, and in keeping with the 2009 Endangerment Finding and past EPA practice, for the Administrator to group into a single class those substances that possess shared relevant properties, even though they are not all emitted from the classes of sources before her.[137] After considering all the

[137] 80 FR at 37774, 37785 and 37787.

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comments, this continues to be the EPA's view. Moreover, this approach to defining air pollution (and air pollutant, as described below) as a grouping of many substances is not unique to GHGs but rather is common practice under the CAA, for example for particulate matter and volatile organic compounds.

The five primary reasons for grouping the six well-mixed GHGs are explained in detail above in sections IV.B.1 through IV.B.5. Because the well-mixed GHGs are collectively the primary driver of current and projected human-induced climate change, all current and future risks due to human-induced climate change can be associated with this definition of air pollution. Thus, this grouping is consistent with evaluation of the scientific issues that the EPA is required to examine in this endangerment finding, namely the risks and impacts due to human-induced climate change. As discussed above, the key scientific evidence and observations that are the basis of this finding focus on the combined six well-mixed GHGs, and did not assess risks and impacts associated with greenhouse gas-induced climate change using an individual gas approach. Accordingly, we are not undertaking a separate endangerment analysis for each of the six well-mixed gases individually.

The question of limits to the scope of future regulations is outside of the scope of this action because the EPA has neither proposed nor is finalizing in this action any such regulatory standards. This final action does not itself impose any requirements on source categories under CAA section 231. Thus, the EPA anticipates that this question could be raised and considered, as needed, in the standard-setting phase of the regulatory process, and the EPA will consider comments submitted on the issue of the appropriate form of emission

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standards in response to EPA's anticipated future notice of proposed rulemaking on standards. Although this final action establishes a duty for the EPA to promulgate standards for the GHG emissions from engines used by covered aircraft, the findings do not pre-judge the form that such standards may take.

Another commenter expressed concern about EPA's proposed endangerment finding because it does not differentiate between CO_2 emissions that result from combustion of fossil fuels and those that result from "combustion of biomass or biofuels derived from herbaceous crops or crop residues, as well as biogenic CO_2 emissions associated with the production, gathering and processing of crops or crop residues used in bio-based products including fuels."[138] The commenter argues that such crop-related biogenic CO_2 emissions should be excluded from the endangerment finding because the CO_2 released back to the atmosphere when emitted from crop-derived biogenic sources contains the same carbon that was previously removed or sequestered from CO_2 in the atmosphere and thus does not contribute to elevated atmospheric concentrations of the six well-mixed GHGs.

The EPA reiterates that the Administrator defines the relevant air pollution considered in the endangerment finding as the aggregate group of the six well-mixed GHGs based on shared physical characteristics and common attributes relevant to climate change science and policy, which is not affected by consideration of the sources of the emissions contributing to

[138] Biogenic CO_2 Coalition, 2015: Comments on EPA's 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, 80 FR 37757 (July 1, 2015). Docket ID number EPA-HQ-OAR-2014-0828-0916. Available at www.regulations.gov (last accessed April 11, 2016).

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the air pollution. In the record for the 2009 Endangerment Finding, the Agency stated that "all CO_2 emissions, regardless of source, influence radiative forcing equally once it reaches the atmosphere and therefore there is no distinction between biogenic and non-biogenic CO_2 regarding the CO_2 and the other well-mixed GHGs within the definition of air pollution that is reasonably anticipated to endanger public health and welfare."[139] The EPA continues to hold that position in these findings, which is supported by the evidence before it. First, the fact that these CO_2 emissions originate from combustion of carbon-based fuels created through different processes is not relevant to defining the air pollution that is reasonably anticipated to endanger public health and welfare. The origin and constitution of a fuel prior to its combustion and subsequent emission into the atmosphere has no bearing on the fact that CO_2 and the other well-mixed GHGs are all sufficiently long lived to become well mixed in the atmosphere, directly emitted, of well-known radiative forcing, and generally grouped and considered together in climate change scientific and policy forums as the primary driver of climate change. Moreover, as explained in section IV.C of this notice, the endangerment arises from the elevated concentrations of the six well-mixed GHGs in the atmosphere. A molecule of biogenic CO_2 has the same radiative forcing effect as a molecule of fossil-fuel derived CO_2. In other words, no matter the original source of the CO_2, the behavior of the CO_2 molecules in the atmosphere in terms of radiative forcing, chemical reactivity, and atmospheric lifetime is effectively the same. Any differential treatment of biogenic CO_2 in the context of the endangerment finding would be inconsistent with the primary scientific

[139] EPA, 2009. Response to Comments document, Volume 9: The Endangerment Finding, EPA-HQ-OAR-2009-0171-11676. Available at www.regulations.gov (last accessed April 11, 2016).

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basis for the grouping of the six well-mixed GHGs as a single class for purposes of identifying the air pollution (and air pollutant, as explained below). A more detailed response to the issues raised in this comment can be found in the Response to Comments document in the docket.

7. Other Climate Forcers Not Being Included in the Definition of Air Pollution for This Finding

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 that affect Earth's climate (referred to as climate forcers). However, as described in more detail in the 2009 Endangerment Finding and in the proposed findings under CAA section 231(a)(2)(A),[140] these substances do not fit within one or more of the five primary reasons for focusing on this aggregate group as the air pollution. As described in the following subsections, we received comments on the omission of water vapor, NOx, and aerosol particles emitted from aircraft from the proposed definition of air pollution for this finding, but not on the omission of other climate forcers. After considering public comments and additional information in the new assessments regarding the climate-relevant substances outside the group of the six well-mixed GHGs, it is the Administrator's

[140] 74 FR at 66519-21 and 80 FR at 37781-84.

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view that the reasons stated in the 2009 Endangerment Finding[141] for not including these substances in the scope of the GHG air pollution still apply at this time.

As the EPA acknowledged in the proposed findings,[142] some short-lived substances—namely water vapor, NO_x emitted at high altitude, and aerosol particles including black carbon—have physical properties that result in their having different, and often larger, climate effects when emitted at high altitudes. For example, the assessment 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. 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 GHGs—lead to more uncertainty in the scientific understanding of these short-lived substances' total effect on Earth's climate. The short-lived nature of these substances means that, unlike GHGs that are sufficiently long lived to become well mixed in the atmosphere, 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,

[141] 74 FR at 66519-21.
[142] 80 FR at 37781-84.

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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). More detail on the uncertainties relating to the climate effects of these short-lived substances is provided in the subsections below in response to public comments and in the Response to Comments document.

Overall, the state of the science as represented in the assessment literature at present continues to highlight 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 well-mixed GHGs. Given the aforementioned scientific uncertainties at present, the Agency is not including these constituents in the definition of air pollution for purposes of the endangerment finding under section 231(a)(2)(A) of the CAA.

Many public comments either supported or opposed inclusion of other substances in addition to the six well-mixed GHGs in the definition of air pollution, and some specifically suggested water vapor, NO_x, and aerosol particles as additional substances to include in that definition. The Agency's full responses to those comments can be found in the Response to Comments document; key comments and responses are summarized below.

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a. Response to Key Comments on Including Other Climate Forcers in the Definition of Air Pollution

Some commenters argued that the proposed findings under CAA section 231(a)(2)(A) did not demonstrate careful examination of the scientific issues with regard to those short-lived substances that have different climate effects when emitted at high altitudes, and that a more thorough analysis should lead the EPA to conclude that water vapor, NO_x, and black carbon also drive climate change in addition to the six well-mixed GHGs. These comments stated that the EPA should have quantified and included the effect of high-altitude water vapor, NO_x, and black carbon in the Agency's discussion of drivers of climate change. Another commenter argued that the EPA should include metal particulates (specifically lead, barium, and aluminum) in the definition of air pollution for this finding because of their role in aviation-induced cloudiness, which the commenter argues has a larger effect on climate change than the six well-mixed GHGs.

Although the EPA is not at this time taking final action to determine whether these other climate forcers should be found to represent air pollution within the meaning of CAA section 231(a)(2)(A), the EPA disagrees with these comments suggesting that the Agency did not carefully examine the scientific issues and information supporting its current endangerment finding in regard to these substances. Consistent with the approach described in the proposed findings and for the reasons discussed above, the Administrator considers the major peer-reviewed scientific assessments of the IPCC and NRC as the primary scientific and technical basis informing the endangerment finding and providing the current state of

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scientific understanding of the differential climate effects that water vapor, NO_x, and aerosols such as black carbon have when emitted at high altitudes. The EPA has 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),[143] the IPCC Special Report: Aviation and the Global Atmosphere (IPCC 1999),[144] the NRC's Advancing the Science of Climate Change (NRC 2010),[145] and the NRC's Atmospheric Effects of Aviation: A Review of NASA's Subsonic Assessment Project (NRC 1999).[146] The USGCRP assessments have not dealt specifically with emissions at high altitude.

As described previously in section IV.A of this notice, the Administrator's consideration of the major scientific assessments provides assurance that the Administrator is basing her judgment on the best available, well-vetted science that reflected the consensus of the climate science research community. These scientific 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

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[143] 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.

[144] 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.

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

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

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took part. The commenters provide no compelling arguments against this approach, which underwent judicial review and was upheld as described in section IV.A of this notice. The assessments synthesize literally thousands of individual studies to convey the consensus conclusions on what the body of scientific literature tells us, and the commenters did not provide evidence that we had missed or mischaracterized conclusions of the assessments regarding aviation impacts.

The state of the science as represented in the assessment literature supports the EPA's reasons for defining the air pollution as the aggregate group of the six well-mixed GHGs, which include their common physical properties relevant to climate change (i.e., directly emitted and sufficiently long lived to become well mixed in the atmosphere), the fact that these gases are considered the primary drivers of climate change, and the fact that these gases remain the best understood drivers of anthropogenic climate change. Water vapor, NO_x, aerosol particles, or aviation-induced cloudiness associated with metal particulates do not share these common attributes, and are each associated with substantial scientific uncertainty. Accordingly, although the EPA is not making a final determination on whether these additional substances should be found to be air pollution within the meaning of CAA section 231(a)(2)(A), the EPA is not at this time changing or expanding the definition of the air pollution to include these additional substances. The following subsections provide additional discussion of the state of the science as represented in the assessment literature regarding the climatic effects of these substances when emitted at high altitudes.

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b. Responses to Key Comments on Changes in Clouds from High Altitude Emissions of Water Vapor and Particles

Some commenters supported the EPA's summary of the scientific assessment literature and agreed that there are substantial scientific uncertainties regarding net climate effects of aviation-induced cloudiness from high altitude emissions of water vapor and particles. Other commenters disagreed and argued that there is clear scientific evidence that aviation-induced cloudiness associated with high altitude emissions of water vapor drives climate change and should be included in the definition of air pollution. One commenter disagrees and argues that, due to their effect on aviation-induced cloudiness and climate change, metal particulates should be included in the definition of air pollution.

The EPA disagrees with the comments regarding changing or expanding the definition of the air pollution employed in this endangerment finding to include these additional substances. For the reasons stated above, the Administrator considers the scientific assessment literature as the primary scientific and technical basis informing the endangerment finding and providing the state of climate science on aviation-induced cloudiness. Section IV.B.4 of the proposed findings under CAA section 231(a)(2)(A)[147] explained that 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

[147] 80 FR at 37782-83.

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climate by both reflecting solar radiation (cooling) and trapping outgoing longwave radiation (warming). Unlike the warming effects associated with GHGs that are sufficiently long lived to become well mixed in the atmosphere, the climate effects associated with changes in cloud cover are more regional and temporal in nature. The assessment literature describes three main components of aviation-induced cloudiness—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 estimated that persistent contrails increased cloudiness above the United States by two percent between 1950 and 1988, with similar results reported over Europe.[148] 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/m^2 (medium confidence and with an uncertainty range of 0.005 to 0.03 W/m^2).[149] To put both the magnitude and large uncertainty range of this number for the first of the three components of aviation-induced cloudiness into context, some examples of other IPCC AR5 best estimates

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

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for global mean radiative forcing include: 1.68 W/m^2 for CO_2 (very high confidence and with an uncertainty range of 1.33 to 2.03 W/m^2), 0.97 W/m^2 for methane (high confidence and with an uncertainty range of 0.74 to 1.20 W/m^2), and 0.17 W/m^2 for nitrous oxide (very high confidence and with an uncertainty range of .013 to 0.21 W/m^2).[150] 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 second of three main climate forcing components of aviation-induced cloudiness, 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).[151]

Particles emitted or formed in the atmosphere as a result of aircraft emissions (primarily sulfates and black carbon) may also act as ice nuclei and modify naturally forming cirrus clouds, an effect referred to as "induced cirrus." This third of three main climate

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[150] 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.

[151] 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.

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forcing components of aviation-induced cloudiness is an area of active research, and there are significant challenges in estimating the climatic impacts of cirrus cloud modification. Neither IPCC AR4 nor AR5 provided global or regional estimates related to this forcing, with the AR5 stating that "it is deemed too uncertain to be further assessed here."[152] 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.[153]

Given differences in scientific understanding of the three main components of aviation-induced cloudiness, the more recent assessments have not provided quantitative estimates of the overall net climate forcing effect of changes in clouds from high altitude emissions of water vapor and particles. Going back to the 1999 IPCC assessment's quantitative estimates, the science is characterized as "very uncertain" with a range for the best estimate between 0 to 0.040 W/m^2.[154] Thus, based on its consideration of the scientific evidence and all the comments on this issue, the EPA agrees with those commenters that indicate there are substantial scientific uncertainties regarding net effects of the three components of aviation-induced cloudiness on the climate system. These uncertainties result in the Agency's not being prepared at this time to determine whether these additional

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[152] Ibid.
[153] 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.
[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.

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substances are air pollution within the meaning of CAA section 231(a)(2)(A) and not including them within the definition of "air pollution" being employed in this endangerment finding.

c. Responses to Key Comments on Direct Radiative Forcing Effects of High Altitude Particle Emissions

Some commenters supported the EPA's summary of the scientific uncertainties regarding the net direct radiative forcing effects of aviation-induced particles including black carbon. Other commenters disagreed and argued that there is clear scientific evidence that black carbon in particular drives climate change and should be included in the definition of air pollution.

The EPA disagrees with comments regarding changing or expanding the definition of the air pollution employed in this endangerment finding to include aviation-induced particles like black carbon. For the reasons stated above, the Administrator considers the scientific assessment literature as the primary scientific and technical basis informing the endangerment finding and providing the state of climate science regarding the direct radiative forcing effects of high altitude emissions of the two primary aviation-induced particles, sulfates and black carbon. Section IV.B.4 of the proposed findings under CAA section 231(a)(2)(A)[155] explained that 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

[155] 80 FR at 37783.

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radiation, which is a negative radiative forcing that ultimately results in cooling. The more recent assessments have not identified a quantitative best estimate for this negative radiative forcing effect specifically from aviation, as it is an active area of scientific study with large uncertainties. Going back to the 1999 IPCC assessment's quantitative estimates, the direct radiative forcing 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.[156]

Similarly, the proposed findings under CAA section 231(a)(2)(A) explained that 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 (positive radiative forcing). The more recent assessments have not identified a quantitative best estimate for this effect specifically from aviation, as it is an area of active scientific study with large uncertainties. Going back to the 1999 IPCC assessment's quantitative estimates, the global mean radiative forcing of black carbon emissions from aircraft is estimated to be 0.003 W/m^2 with uncertainty spanning 0.001 to 0.009 W/m^2.[157] The IPCC 1999 assessment suggests that because the contribution of black carbon in the stratosphere (which actually contributes to cooling of the Earth's surface rather than warming) was not included in its calculations, its estimates of radiative forcing were likely to be too high.

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[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.
[157] Ibid.

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In addition, the 2009 Endangerment Finding did not include aerosols in the definition of air pollution, noting that much of the uncertainty range surrounding the best estimate of total net forcing due to all human activities was due to uncertainties about the cooling and warming effects of aerosols[158] (though from all sources, not just aircraft). The 2009 Endangerment Finding also stated that the magnitude of aerosol effects can vary immensely with location and season of emissions, noting that estimates of its total climate forcing effect have a large uncertainty range.[159] Regarding black carbon specifically, the 2009 Endangerment Finding noted that it does not share common physical and chemical attributes with the six well-mixed GHGs because it is an aerosol particle (not a gas) that has different physical, chemical, and atmospheric properties. Black carbon affects the climate differently than GHGs that are sufficiently long lived to become well mixed in the atmosphere. In contrast to its indirect warming and cooling effects via clouds, black carbon causes a direct warming effect primarily by absorbing incoming and reflected sunlight (whereas GHGs that are sufficiently long lived to become well mixed in the atmosphere cause warming by trapping outgoing, infrared heat), and by darkening bright surfaces such as snow and ice, which reduces reflectivity. Black carbon is short-lived, remaining in the atmosphere for only about a week, and does not become well-mixed in the atmosphere. There are also concerns in the international climate science and policy communities about how to treat the short-lived black carbon emissions alongside GHGs—for example, what are the appropriate metrics to compare the warming and/or climate effects of the different substances, given that, unlike

[158] 74 FR at 66517.
[159] 74 FR at 66520.

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GHGs that are sufficiently long lived to become well mixed in the atmosphere, the magnitude of aerosol effects can vary immensely with location and season of emissions.

Thus, although the EPA is not at this time prepared to make a final determination on whether black carbon should be found to be air pollution within the meaning of CAA section 231(a)(2)(A), based on its consideration of the scientific evidence and all the comments on this issue, and consistent with its conclusion in the 2009 Endangerment Finding, the EPA disagrees with commenters that ask for black carbon to be included in the definition of the air pollution as part of this endangerment finding. Because aerosols such as black carbon and sulfates are fundamentally different from and do not share the relevant properties that support grouping the six well-mixed GHGs together as a class, and scientific uncertainties remain regarding the net radiative forcing effects of these substances (whether in general or when emitted at high altitudes), the EPA is not at this time including them in the definition of air pollution employed in this finding. However, because of these uncertainties the Agency is not at this time taking final action to determine whether these additional substances should be found to represent air pollution within the meaning of CAA section 231(a)(2)(A).

d. Responses to Key Comments on Changes in Atmospheric Chemistry from High Altitude Nitrogen Oxides Emissions

Most commenters supported the EPA's summary of the scientific uncertainties regarding the changes in atmospheric chemistry from high altitude NO_x emissions. At least one commenter disagreed and argued that there is clear scientific evidence that the effects of

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NO_x emissions on ozone production have a significant climate forcing effect. They concluded that NO_x should therefore be included in an endangerment finding.

The EPA disagrees with comments to the extent that they suggest including NO_x in this endangerment finding by changing or expanding the definition of the air pollution. NO_x emissions have different, and potentially larger, climate effects when emitted at high altitudes and about 90 percent of aircraft NO_x is emitted in flight (not during landing and takeoff),[160] meaning its relevance for climate change is primarily in relation to emissions at high altitude. The atmospheric lifetime of NO_x emitted near the surface is on the order of a few hours, while in the upper troposphere, or roughly the cruise altitude for jet aircraft, it is on the order of several days.

Section IV.B.4 of the proposed findings under CAA section 231(a)(2)(A)[161] explained that 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 NO_x 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

[160] FAA, *System for Assessing Aviation's Global Emissions, Version 1.5, Global Aviation Emissions Inventories for 2000 through 2004*, FAA-EE-2005-02, September 2005, revised March 2008, available at http://www.faa.gov/about/office_org/headquarters_offices/apl/researc/models/sage/ (Last accessed April 14, 2016).
[161] 80 FR at 37783-84.

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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.

For the reasons stated above, the Administrator considers the scientific assessment literature as the primary scientific and technical basis informing the endangerment finding and providing the state of climate science regarding how emissions of NO_x affect the climate system. Quantifying these impacts is an area of active scientific 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 NO_x emissions on ozone and methane concentrations, the location of aircraft emissions is an important additional factor. Going back to the IPCC 1999 assessment since no more recent quantitative estimates are available, the globally averaged radiative forcing estimates for high-altitude aircraft emissions of NO_x in 1992 were 0.023 W/m^2 for ozone-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).[162]

The IPCC AR5 presents the impact of aviation high-altitude NO_x emissions using a different metric, global warming potential (GWP), which is a measure of the warming impact

[162] 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.

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of a pulse of 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.[163] 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.

Thus, although the EPA is not prepared to determine whether NO_x emissions at high altitude should be found to be air pollution within the meaning of CAA section 231(a)(2)(A), based on its consideration of the scientific evidence and all the comments on this issue, and consistent with its conclusion in the 2009 Endangerment Finding, the EPA disagrees with commenters that assert that NO_x should be included at this time in the definition of the air pollution for this finding. NO_x does not share the relevant properties that support grouping the six well-mixed GHGs together as a class. NO_x is not classified as a GHG because it influences the climate system indirectly through production of ozone rather than directly through trapping outgoing heat. In addition, NO_x does not have a sufficiently long atmospheric lifetime to become well-mixed in the atmosphere and significant scientific uncertainties remain regarding its net radiative forcing effects.

The Administrator notes that NO_x emissions are already regulated under the EPA's rules implementing CAA section 231, at 40 CFR part 87, due to their impacts during landing

[163] 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.

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and take-off operations (LTO). 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 LTO NO_x emissions as a precursor to ozone formation in areas that did not meet the NAAQS for ozone.[164] The continuing significant uncertainties regarding high altitude NO_x emissions, which are emitted during cruise operations rather than during LTO, as a climate forcer do not undermine the Agency's prior conclusion under CAA section 231(a)(2)(A) 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. This final finding does not revise or reopen the Agency's prior findings under CAA section 231(a)(2)(A) 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.

C. The Air Pollution is Reasonably Anticipated to Endanger Both Public Health and Welfare

The Administrator finds that elevated atmospheric concentrations of the six well-mixed GHGs may reasonably be anticipated to endanger the public health and welfare of current and future generations within the meaning of CAA section 231(a)(2)(A). This section describes the major pieces of scientific evidence supporting the Administrator's

[164] 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).

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endangerment finding, discusses both the public health and welfare aspects of the endangerment finding, and addresses a number of key issues the Administrator considered when evaluating the state of the science.

The EPA is informed by and places considerable weight 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 final finding under CAA section 231(a)(2)(A) accounts for the EPA's careful consideration of the scientific and technical record for the 2009 Endangerment Finding, of the new, major scientific assessments issued since closing the administrative record for the 2009 Endangerment Finding, and of public comments. No recent information or assessments published since late 2009 or provided by commenters 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 one the EPA reached in 2009 under CAA section 202(a). Rather, they provide further support for this final finding under section 231(a)(2)(A). In particular, the new assessments discussed in this notice provide additional detail regarding public health impacts, particularly on groups and people especially vulnerable to climate change, including children, the elderly, low-income communities and individuals, indigenous groups, and communities of color.

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Following the same decision framework and analysis that we followed for the 2009 Endangerment Finding, as detailed in section IV.B of that finding,[165] here we summarize the general approach used by the Administrator in reaching the judgment that a positive endangerment finding should be made for purposes of CAA section 231(a)(2)(A), as well as the specific rationale for finding that the GHG air pollution may reasonably be anticipated to endanger both public health and welfare. First, the Administrator finds the scientific evidence linking anthropogenic emissions and resulting elevated atmospheric concentrations of the six well-mixed GHGs to observed global and regional temperature increases and other climate changes to be sufficiently robust and compelling. The Administrator is basing her finding on the total weight of scientific evidence and what the science has to say regarding the nature and potential magnitude of the risks and impacts across all climate-sensitive elements of public health and welfare, now and projected out into the foreseeable future. The Administrator has considered the state of the science on how anthropogenic emissions and the resulting elevated atmospheric concentrations of the six well-mixed GHGs may affect each of the major risk categories, include human health, air quality, food production and agriculture, forestry, water resources, sea level rise and coastal areas, the energy sector, infrastructure and settlements, and ecosystems and wildlife. The Administrator understands that the nature and potential severity of impacts can vary across these different elements of public health and welfare, and that they can vary by region, as well as over time.

[165] 74 FR at 66523-36.

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The Administrator is therefore aware that, because human-induced climate change has the potential to be far-reaching and multi-dimensional, not all risks and potential impacts can be characterized with a uniform level of quantification or understanding, nor can they be characterized with uniform metrics. Thus, the Administrator is not necessarily placing the greatest weight on those risks and impacts which have been the subject of the most study or quantification. Rather, given this variety in not only the nature and potential magnitude of risks and impacts, but also in our ability to characterize, quantify and project into the future such impacts, the Administrator must use her judgment to weigh the threat in each of the risk categories, weigh the potential benefits where relevant, and ultimately to judge whether these risks and benefits, when viewed in total, endanger public health and/or welfare.

First, the Administrator has not established a specific threshold metric for the different categories of risk and impacts, which are referred to as impact sectors. The potential for both adverse and beneficial effects is considered, as well as the relative magnitude of such effects, to the extent that the relative magnitudes can be quantified or characterized. Furthermore, given the multiple ways in which the buildup of anthropogenic GHG emissions in the atmosphere can cause effects (*e.g.,* via elevated CO_2 concentrations, temperature increases, precipitation increases, sea level rise, and changes in extreme events), these multiple pathways are considered. The Administrator has balanced and weighed the varying risks and effects for each impact sector. She has judged whether there is a pattern across the sector that supports or does not support an endangerment finding, and if so whether the support is of more or less weight. In cases where there is a potential for both benefits and risks of harm, the Administrator has balanced these factors by determining whether there appears to be any

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directional trend in the overall evidence that would support placing more weight on one than the other, taking into consideration all that is known about the likelihood of the various risks and effects and their seriousness. In all of these cases, the judgment is largely qualitative in nature and is not reducible to precise metrics or quantification.

Regarding the timeframe for the endangerment test, it is the Administrator's view that both current and future conditions must be considered. The Administrator is thus taking the view that the endangerment period of analysis extend from the current time to the next several decades and in some cases to the end of this century. This consideration is also consistent with the timeframes used in the underlying scientific assessments. The future timeframe under consideration is consistent with the atmospheric lifetime and climate effects of the six well-mixed GHGs and also with our ability to make reasonable and plausible projections of future conditions. The Administrator acknowledges that some aspects of climate change science and the projected impacts are more certain than others. Our state of knowledge is strongest for recently observed, large-scale changes. Uncertainty tends to increase in characterizing changes at smaller (regional) scales relative to large (global) scales. Uncertainty also increases as the temporal scales move away from the present, either backward or more importantly forward in time. Nonetheless, the current state of knowledge of observed and past climate changes and their causes enables projections of plausible future changes under different scenarios of anthropogenic forcing for a range of spatial and temporal scales. The subsections below summarize the scientific information on climate change impacts to public health and welfare that inform the Administrator's judgment, as well as the

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key public comments and Agency responses. The Agency's full responses to public comments can be found in the Response to Comments document.

1. The Air Pollution is Reasonably Anticipated to Endanger Public Health

The Administrator finds under CAA section 231(a)(2)(A) that the well-mixed GHG air pollution is reasonably anticipated to endanger public health, for both current and future generations. The Administrator finds that the public health of current generations is endangered and that the threat to public health for both current and future generations will mount over time as GHGs continue to accumulate in the atmosphere and result in ever greater rates of climate change. The Administrator continues to find robust scientific evidence in the assessment literature that climate change can increase the risk of morbidity and mortality and believes that these public health impacts can and should be considered when determining endangerment to public health under CAA section 231(a)(2)(A). As described in section IV.B.1 of the 2009 Endangerment Finding, the Administrator is not limited to only considering whether there are any direct health effects such as respiratory or toxic effects associated with exposure to GHGs.

Here we summarize information from the scientific assessment literature cited in the 2009 Endangerment Finding showing that climate change resulting from anthropogenic GHG emissions threatens multiple aspects of public health.[166] In determining that the well-mixed GHG air pollution is reasonably anticipated to endanger public health for current and future

[166] 74 FR at 66524-30.

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generations under CAA section 202(a), the Administrator noted her view that climate change can increase the risk of morbidity and mortality. In making that public health determination, 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 were unlikely to be compensated for by decreases in cold-related mortality. 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 increased risk of food-, water-, and vector-borne diseases in susceptible populations. Climate change also has the potential to change aeroallergen production (for

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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 risks and impacts. The Administrator placed weight on the fact that these certain groups are most vulnerable to these climate-related health effects.

The EPA concludes that the 2009 Endangerment Finding's discussion under CAA section 202(a) is equally persuasive for purposes of CAA section 231(a)(2)(A). In addition, the EPA has carefully reviewed the key conclusions in the recent assessments regarding public health risks and the current and projected health impacts from human-induced climate change. 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, further supporting an endangerment finding under CAA section 231(a)(2)(A). These key findings are described briefly here.

The USGCRP NCA3 finds that, "Climate change threatens human health and well-being in many ways, including impacts from increased extreme weather events, wildfire, decreased air quality, threats to mental health, and illnesses transmitted by food, water, and diseases carriers such as mosquitoes and ticks. Some of these health impacts are already underway in the United States."[167] Regarding temperature effects, the USGCRP NCA3 states,

[167] 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.

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"The effects of temperature extremes on human health have been well documented for increased heat waves, which cause more deaths, hospital admissions and population vulnerability."[168] The conclusions of the assessment literature cited in the 2009 Endangerment Finding were uncertain with respect to the balance of future heat- versus cold-related mortality associated with climate change, but they 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 likely will be larger than the decreases in cold-related mortality, further supporting this endangerment finding under CAA section 231(a)(2)(A). The USGCRP NCA3 concludes, "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."[169] 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),"[170] but that, "[o]verall, we conclude that the increase in heat-related mortality by mid-century will outweigh gains due to fewer cold periods."[171]

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

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[168] Ibid at p. 252.
[169] Ibid at p. 224.
[170] 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.
[171] Ibid. at p. 721.

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associated risks in respiratory illnesses and premature death, but that the directional effect of climate change on ambient particulate matter levels was less certain. One of the more recent assessments, the USGCRP NCA3, similarly concludes, "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."[172] 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 USGCRP NCA3 states, "The effects of wildfire on human health have been well documented with increases in wildfire frequency, leading to decreased air quality and negative health impacts."[173] 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 due to 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

[172] 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.
[173] Ibid at p. 252.

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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. Each of these assessments further supports finding endangerment under CAA section 231(a)(2)(A).

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. The more recent assessments further support this conclusion for purposes of CAA section 231(a)(2)(A). The USGCRP NCA3 finds that "Heavy downpours are increasing nationally, especially over the last three to five decades. Largest increases are in the Midwest and Northeast. Increases in the frequency and intensity of extreme precipitation events are projected for all U.S. regions."[174] The USGCRP NCA3 identifies that: "Elevated waterborne disease outbreaks have been reported in the weeks following heavy rainfall, although other variables may affect these associations. Water intrusion into buildings can result in mold contamination that manifests later, leading to indoor air quality problems."[175] Other risks include mortality associated with flooding and impacts on mental health, such as anxiety and post-traumatic stress disorder. The IPCC AR5 also discusses increased risk of 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

[174] 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. 36.
[175] Ibid at p. 224-225.

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increase exposure to health risks associated with drought conditions, which includes impacts from wildfires, dust storms, extreme heat events, and flash flooding. Droughts can lead to reduced water quantity and degraded water quality, thereby increasing the risk of water-related diseases. The IPCC SREX assessment projects further increases in some extreme weather and climate events during this century, and it specifically notes that changes in extreme weather events have implications for disaster risk in the health sector.

The potential for changes in climate-sensitive diseases was also cited in the 2009 Endangerment Finding. This included an increase in the spread of several food and water-borne pathogens, which can affect susceptible populations. Also noted was 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"[176] 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,

[176] 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.

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human modification of the landscape, the diversity of animal hosts, and human behavior that affects vector-human contact, among other factors."[177] This new assessment literature further supports finding endangerment under CAA section 231(a)(2)(A).

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 definitive data or conclusions were lacking on how climate change might impact aeroallergens in the United States. Further supporting an endangerment finding under CAA section 231(a)(2)(A), the most recent assessments now express greater confidence that climate change influences the 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, there is high confidence that "warming will lead to further changes in the seasonal timing of pollen release."[178]

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[177] 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.
[178] 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, pp. 1465-1466.

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a. Health Impacts of Climate Change on Vulnerable Populations

In the 2009 Endangerment Finding, the EPA cited the assessment literature's conclusions regarding the fact that certain populations, including children, the elderly, and the poor, are most vulnerable to climate change-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 and further supports an endangerment finding under CAA section 231(a)(2)(A) 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, "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."[179] 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

[179] 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.

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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."[180] In addition, increasing

[180] 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.

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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, primarily because of physiological and developmental factors, will disproportionately suffer from the effects of heat waves, air pollution, infectious illness, and trauma resulting from extreme weather events."[181] As noted above, the IPCC AR5 finds that in North America, climate change will influence production of pollen, and that this affects asthma and other allergic respiratory diseases to which children are among those especially susceptible. The IPCC AR5 also identifies children as a susceptible population to health effects associated with heat waves, storms, and floods.

Both the USGCRP and IPCC conclude that climate change increases 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.

Accordingly, as discussed above, all of these recent assessments further support finding endangerment under CAA section 231(a)(2)(A).

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.

[181] 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.228.

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b. Responses to Key Comments on Endangerment to Public Health

Public comments supported the EPA's summary of the scientific information and finding that the well-mixed GHG air pollution is reasonably anticipated to endanger public health of current and future generations under CAA section 231(a)(2)(A). Commenters cited a number of examples of climate impacts relevant to public health including changes in outdoor and indoor air quality, extreme temperatures, floods, fires, and hurricanes. Some commenters also agreed with the EPA's summary of health impacts to certain vulnerable populations and emphasized that certain populations like the elderly, poor, very young, and indigenous groups are more vulnerable to the health impacts of climate change for various reasons. No commenters disagreed with the EPA's summary of the scientific information or with its conclusion on endangerment to public health. The EPA agrees with the commenters that this endangerment finding is well supported by the scientific assessment literature; that it covers a range of health risks associated with climate change-induced changes in air quality, increases in temperatures, changes in extreme weather events, increases in food and water borne pathogens, and changes in aeroallergens; and that certain populations are more vulnerable to climate change health risks and impacts.

2. The Air Pollution is Reasonably Anticipated to Endanger Welfare

The Administrator finds under CAA section 231(a)(2)(A) that the air pollution comprised of the six well-mixed GHGs is reasonably anticipated to endanger welfare, for both current and future generations. As with public health, the Administrator considered the multiple pathways in which the GHG air pollution and resultant climate change affect

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climate-sensitive sectors and the impact this may have on welfare. These sectors include food production and agriculture; forestry; water resources; sea level rise and coastal areas; energy, infrastructure, and settlements; and ecosystems and wildlife. The Administrator examined each climate-sensitive sector individually, informed by the scientific information in the major assessments contained in the administrative record for the 2009 Endangerment Finding as well as the newer assessments in the record for this action, and weighed the extent to which the risks and impacts within each sector support or do not support a positive endangerment finding in her judgment. The Administrator then viewed the full weight of evidence looking across all sectors to reach her decision regarding endangerment to welfare. For each of these sectors, the evidence indicates that the risk and the severity of adverse impacts on welfare are expected to increase over time, providing compelling support for a finding of endangerment to welfare. The Administrator also considered impacts on the U.S. population from climate change effects occurring outside of the United States, such as national security concerns for the United States that may arise as a result of climate change impacts in other regions of the world, and finds that this provides additional support to the finding of endangerment to welfare of current and future generations of the United States population.

The 2009 Endangerment Finding summarized information from the scientific assessment literature showing that climate change resulting from anthropogenic GHG emissions also threatens multiple aspects of welfare under CAA section 202(a).[182] In determining that the well-mixed GHG air pollution is reasonably anticipated to endanger

[182] 74 FR at 66530-36.

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welfare for current and future generations, the Administrator considered the multiple pathways by which GHG air pollution and resultant climate change affect welfare by evaluating the numerous and far-ranging risks and impacts associated with food production and agriculture; forestry; water resources; widespread snow and ice melt, sea level rise and coastal areas; energy, infrastructure, and settlements; and ocean acidification, ecosystems, and wildlife. The Administrator also considered observed and projected risks and 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. Water resources across large areas of the country are at serious risk from climate change, with effects on water supplies, water quality, and adverse effects from extreme events such as floods and droughts. The severity of risks and impacts is likely to increase over time with accumulating GHG concentrations and associated temperature increases and precipitation changes. 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 electricity production for 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. In Alaska, indigenous communities are likely to experience disruptive impacts. Climate change is also very likely to fundamentally change U.S. ecosystems over the 21st century and to lead to predominantly negative consequences for

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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 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.

The Administrator concludes that the discussion in the 2009 Endangerment Finding under CAA section 202(a) is equally compelling to support an endangerment finding under CAA section 231(a)(2)(A). In addition, the EPA has carefully reviewed the recent scientific conclusions in the assessments regarding human-induced climate change impacts on welfare.[183] The EPA finds that they further support finding endangerment under CAA section 231(a)(2)(A), as they are largely consistent with or strengthen the underlying science supporting the 2009 Endangerment Finding regarding observed and projected climate change risks and impacts to food production and agriculture; forestry; water resources; widespread snow and ice melt, sea level rise, and coastal areas; energy, infrastructure, and settlements; ocean acidification, ecosystems, and wildlife; and impacts on the U.S. population from

[183] 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.

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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, and support finding endangerment under CAA section 231(a)(2)(A). 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."[184] The IPCC AR5 concludes, "Overall yields of major crops in North America are projected to decline modestly by mid-century and more steeply by 2100 among studies that do not consider adaptation (very high confidence)."[185] The IPCC AR5 notes that in the absence of extreme events, climate

[184] 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.
[185] 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.

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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 finding endangerment under CAA section 231(a)(2)(A). 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.

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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 is expected to have adverse impacts on water quality and is likely to further constrain water 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, and therefore support an endangerment finding under CAA section 231(a)(2)(A). 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."[186] 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."[187] The IPCC AR5 states, "Throughout the eastern USA, water supply systems will be negatively impacted by lost snowpack storage, rising sea levels contributing to increased storm intensities and saltwater intrusion, possibly lower streamflows, land use and population changes, and other stresses."[188] The IPCC AR5 also synthesizes recent studies that project a range of adverse climate impacts

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[186] 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.
[187] 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, pp. 1456-1457.
[188] Ibid at p. 1457.

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in North America to surface water quality (including to the Great Lakes), 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 current and projected rates of 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, and support finding endangerment under CAA section 231(a)(2)(A). The USGCRP NCA3 finds, "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."[189]

The IPCC AR5 found that global sea levels rose 0.19 m (7.5 inches) from 1901 to 2010. Contributing to this rise was the warming of the oceans and melting of land ice from glaciers and ice sheets. It is likely that 275 gigatons per year of ice melted from land glaciers (not including ice sheets) from 1993-2009, and that the rate of loss of ice from the Greenland and Antarctic ice sheets increased substantially in recent years, to 215 gigatons per year and 147 gigatons per year respectively from 2002-2011. For context, 360 gigatons of ice melt is sufficient to cause global sea levels to rise one millimeter.

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[189] 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.

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The IPCC AR5, the USGCRP NCA3, and three of the new NRC assessments provide estimates of projected global average 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.[190] The NRC Sea Level Rise assessment projects a global average sea level rise of 0.5 to 1.4 meters by 2100. Change of this magnitude would be 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.[191] 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."[192] The NRC Climate Stabilization Targets assessment states that a global average temperature increase of 3°C will lead to a global average 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 melting ice sheets in sea level rise projections, these revised estimates are consistent with the assessments underlying the 2009 Endangerment Finding, and support finding endangerment under CAA section 231(a)(2)(A).

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[190] 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.
[191] Sea level does not rise uniformly due to changes in winds, temperature patterns, land uplift or subsidence, and other factors. Therefore, relative sea level rise along any given point on the coast can vary from the global average.
[192] NRC, 2011: *National Security Implications of Climate Change for U.S. Naval Forces*. The National Academies Press, p. 28.

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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, to support finding endangerment under CAA section 231(a)(2)(A). For example, the USGCRP NCA3 finds, "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."[193] The NRC Arctic assessment identifies threats to human infrastructure in the Arctic from increased flooding, erosion, and shoreline ice pile-up, or *ivu*, associated 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 discussed a number of impacts. These include a high confidence finding that substantial changes in the structure and functioning of terrestrial ecosystems are very likely to occur with a global warming greater than 2 to 3°C above pre-industrial levels, with predominantly negative consequences for biodiversity and the provisioning of ecosystem goods and services. In addition, climate change and ocean acidification will likely impair a

[193] 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.

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wide range of planktonic and other marine calcifiers such as corals. The recent assessments published since 2009 provide additional support for finding endangerment under CAA section 231(a)(2)(A). The USGCRP NCA3 concluded that "The oceans are currently absorbing about a quarter of the carbon dioxide emitted to the atmosphere annually and are becoming more acidic as a result, leading to concerns about intensifying impacts on marine ecosystems…Over the last 250 years, the oceans have absorbed 560 billion tons of CO2, increasing the acidity of surface waters by 30%. Although the average oceanic pH can vary on interglacial timescales, the current observed rate of change is roughly 50 times faster than known historical change."[194]

The NRC Arctic assessment states that major marine and terrestrial biomes will likely shift poleward, with significant implications for changing species composition, food web structures, and ecosystem function. The NRC Climate Stabilization Targets assessment found that coral bleaching events will likely increase in frequency and severity due warming sea surface temperatures and that ocean acidification will likely reduce coral shell and skeleton growth and increase erosion of coral reefs. 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 GHG-induced ocean acidification and warming that followed releases of GHGs 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

[194] 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. 48.

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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."[195] 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."[196] The IPCC AR5 also projects biodiversity losses in marine ecosystems, especially in the Arctic and tropics.

The IPCC AR5 found that annual mean Arctic sea ice has been declining at 3.5 to 4.1 percent per decade, and Northern Hemisphere snow cover extent has decreased at about 1.6 percent per decade for March and 11.7 percent per decade for June. The USGCRP NCA3 finds that "rising temperatures across the U.S. have reduced lake ice, sea ice, glaciers, and seasonal snow cover over the last few decades."[197] These changes are projected to continue, threatening seasonal water availability and ecosystems reliant on ice and snow cover.

a. Welfare Impacts of Climate Change on Vulnerable Populations

In general, climate change impacts related to welfare are expected to be unevenly distributed across different regions of the United States and are expected to 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

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[195] NRC, 2010: *Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean*. The National Academies Press, p. 5.
[196] Ibid.
[197] 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. 46.

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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."[198] 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."[199]

b. Other Considerations Regarding Endangerment to Welfare

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

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[198] 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.
[199] 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.

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supporting the 2009 Endangerment Finding, and further support finding endangerment under CAA section 231(a)(2)(A). 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."[200] 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

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

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disruption to the AMOC that are not expected in this century can have severe impacts if/when they happen, such as interference with the global transport of oceanic heat, salt, and carbon.

c. Responses to Key Comments on Endangerment to Welfare

Public comments supported the EPA's summary of the scientific information and finding that the well-mixed GHG air pollution is reasonably anticipated to endanger welfare under CAA section 231(a)(2)(A). Commenters cited a number of examples of climate impacts relevant to welfare including sea level rise and coastal erosion, species range changes and extinctions, and reduced water availability due to changes in snowpack and timing of snow melt. Some commenters also agreed with the EPA's summary of welfare impacts to certain vulnerable populations and emphasized that certain populations are more vulnerable to the welfare impacts of climate change, in particular tribes and indigenous groups. No commenters disagreed with the EPA's summary of the scientific information or with its conclusion on endangerment to welfare. The EPA agrees with the commenters that this finding of endangerment to welfare under CAA section 231(a)(2)(A) is well supported by the scientific assessment literature; that it covers a range of risks associated with climate change threats to food production and agriculture, forestry, water resources, sea level rise and coastal areas, energy, infrastructure, and settlements, and ecosystems and wildlife; and that certain populations are more vulnerable to climate change welfare risks and impacts.

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D. Summary of the Administrator's Endangerment Finding under CAA Section 231

In sum, the Administrator finds, 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 public health and welfare of current and future generations. In this final action under CAA section 231(a)(2)(A), the EPA is informed by and places considerable weight on the extensive scientific and technical evidence in the record supporting the 2009 Endangerment Finding under CAA section 202(a), 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 final finding under section 231(a)(2)(A) accounts for the EPA's careful consideration of the scientific and technical record for the 2009 Endangerment Finding, and of the new, major scientific assessments issued since closing the administrative record for the 2009 Endangerment Finding, and consideration of public comments. No recent information or assessments 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); instead, the new, major scientific assessments further support finding endangerment under CAA section 231(a)(2)(A). In making this finding for purposes of section 231(a)(2)(A), we are not reopening or revisiting the 2009 Endangerment Finding under CAA section 202(a). To the contrary, in light of the recent judicial decisions upholding that finding, the EPA believes the 2009 Endangerment Finding is firmly established and well

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settled.[201] Moreover, there is no need for the EPA to reopen or revisit that finding for purposes of CAA section 202(a) in order for the Administrator to rely on its analyses and conclusions, supported by more recent studies, in support of making an additional endangerment finding under section 231(a)(2)(A) of the CAA. Today's final endangerment finding, although significantly informed by the scientific information and the EPA's prior discussion of that information in the 2009 Endangerment Finding, is solely for purposes of CAA section 231(a)(2)(A).

V. The Administrator's Cause or Contribute Finding for Greenhouse Gases Emitted by Certain Classes of Engines Used by Covered Aircraft Under CAA Section 231

As noted above, the Administrator defines the air pollution for purposes of the endangerment finding under CAA section 231(a)(2)(A) to be the aggregate of six well-mixed GHGs in the atmosphere, and finds that such air pollution endangers public health and welfare of current and future generations. The second step of the two-part endangerment test for this finding is for the Administrator to determine whether the emission of any air pollutant from certain classes of aircraft engines used by certain aircraft causes or contributes to this endangering air pollution. This is referred to as the cause or contribute finding, and is the second finding by the Administrator in this action under CAA section 231(a)(2)(A).

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[201] *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).

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Section V.A of this notice describes the Administrator's reasoning for using under CAA section 231(a)(2) the same definition and scope of the GHG air pollutant that was used in the 2009 Endangerment Finding under CAA section 202(a). Section V.B puts forth the Administrator's finding that emissions of well-mixed GHGs from certain classes of aircraft engines used in covered aircraft contribute to the air pollution which endangers public health and welfare under CAA section 231(a)(2)(A). The EPA's responses to some of the most significant comments for the cause or contribute finding are provided later in section V.C. Responses to all significant issues raised by the comments on the cause or contribute finding are contained in the Response to Comments document, which is organized by subject area (found in docket EPA–HQ–OAR–2014-0828).

A. **The Air Pollutant**

1. Definition of Air Pollutant

Under section 231(a)(2)(A), 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 considered the logical 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

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contribution (e.g., the flow into the stock). See 74 FR at 66536 (similar discussion with respect to the finding for CAA section 202(a)). For purposes of section 231(a)(2)(A), the Administrator is defining the air pollutant as the same combined grouping of the six well-mixed GHGs that comprises the air pollution. Accordingly, the Administrator is using the same definition of the air pollutant that was used in the 2009 Endangerment Finding for purposes of CAA section 202(a), namely, the aggregate group of the same six well-mixed GHGs: CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. See 74 FR at 66536-37 (discussing the definition of the GHG air pollutant with respect to the finding for CAA section 202(a)). That is, as was done for the 2009 Endangerment Finding, the Administrator is defining a single air pollutant made up of these six GHGs in this action under CAA section 231(a)(2)(A).

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.[202] This collective approach to defining the air pollutant is

[202] As detailed in the 2009 Endangerment Finding proposal (74 FR at 18904) 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 notice 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). One teragram (Tg) = 1 million metric tons = 1 megatonne (Mt). 1 metric ton = 1,000 kilograms = 1.102 short tons = 2,205 lbs. The EPA's Greenhouse Gas Reporting Program (http://www.epa.gov/ghgreporting/index.html (last accessed April 8, 2016)) also reports GHG emissions on a CO_2-equivalent basis, recognizing the common and collective treatment of these six well-mixed GHGs.

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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.B, these six substances share common attributes that support their grouping to define the air pollution for purposes of the endangerment finding. These same common attributes also support the Administrator grouping these six well-mixed GHGs for purposes of defining the air pollutant for this cause or contribute finding under CAA section 231(a)(2)(A).

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 under CAA section 231(a)(2)(A) 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.[203] 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. Moreover, the reasonableness of grouping these chemicals as a single air pollutant does not turn on the particular source category. By using the definition of the air

[203] 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 at 66537.

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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.

In fact, as explained in the 2009 Endangerment Finding, Congress has given the EPA broad discretion to determine that appropriate combinations of compounds should be treated as a single air pollutant. 74 FR at 66537. Section 302(g) of the CAA defines "air pollutant" as "any air pollutant agent or combination of such agents …." Thus, it is clear that the term "air pollutant" is not limited to individual chemical compounds. Moreover, in determining that GHGs are within the scope of this definition, the Supreme Court described section 302(g) as a "sweeping" and "capacious" definition that unambiguously included GHGs, which are "unquestionably 'agents' of air pollution." *Massachusetts v. EPA*, 549 U.S. at 528, 532, 529 n. 26. Although the Court did not interpret the term "combination of" air pollution agents, there is no reason to interpret this phrase more narrowly in this context. Congress used the term "any" and did not qualify the kind of combinations that EPA could define as a single air pollutant.

2. The Definition of Air Pollutant May Include Substances Not Emitted by CAA Section 231(a)(2) Sources.

Similar to the discussion in section IV.B.6 for the definition of "air pollution" for purposes of the endangerment finding under CAA section 231(a)(2)(A), many commenters highlighted the fact that aircraft engines emit only two of the six well-mixed GHGs that together are defined as the "air pollutant" for purposes of the cause or contribute finding

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under section 231(a)(2)(A) of the CAA. Commenters point out that the majority of emissions are CO_2, while nitrous oxide emissions are described as "nominal (<1%)" or "trace." Some commenters ultimately concluded that the EPA's approach to defining the air pollutant as an aggregate group of six gases is acceptable, but that the scope of future regulations should be limited to CO_2. One commenter agreed with the Agency's evaluation of the six GHGs based on their common attributes, but questioned the EPA's decision to aggregate the six gases rather than considering them individually for purposes of making the findings. Other commenters disagreed with the EPA and requested limiting the definition of air pollutant in this action to CO_2 or to CO_2 and nitrous oxide.

The EPA disagrees with comments regarding changing the definition of the air pollutant to limit it to only those GHGs that are emitted from aircraft or to CO_2 only. The EPA has explained both in the 2009 Endangerment Finding under CAA section 202(a) and in the proposed findings under CAA section 231(a)(2)(A) that it is reasonable and appropriate for the EPA to consider the logical relationship between the GHG air pollution and air pollutant when defining the air pollutant. The purpose of this cause or contribute inquiry is to determine whether emissions of an air pollutant from certain aircraft engines cause or contribute to the endangering GHG air pollution. As described in section IV.B of this notice, the endangering GHG air pollution under consideration is defined as the aggregate group of the six well-mixed GHGs based on shared characteristics and common attributes relevant to climate change science and policy[204]—a rationale that does not take into consideration

[204] 74 FR at 66517-19; 80 FR at 37774-85.

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emission source(s). Similarly, the definition of the air pollutant in this cause or contribute inquiry establishes well-mixed GHGs as a single air pollutant comprised of six substances with common attributes. The Administrator is giving effect to the shared attributes of the six well-mixed GHGs and how they are relevant to the air pollution to which they contribute. Thus, it is also reasonable for the EPA to evaluate contribution for those gases in the aggregate, rather than individually, to ensure a like-to-like comparison of aggregate emissions contributing to an aggregate stock (atmospheric concentration) of endangering GHG air pollution.

The EPA recognized in the proposed findings that aircraft emit two of the six well-mixed GHGs, but stated that nonetheless it is entirely reasonable and appropriate, and in keeping with the 2009 Endangerment Finding under CAA section 202(a) and other past EPA practice, for the Administrator to group into a single class those substances that possess shared relevant properties, even though they are not all emitted from the classes of sources before her.[205] The fact that these six substances share these common, relevant attributes is true regardless of the source category being evaluated for contribution. After considering all the comments, this continues to be the EPA's view. Moreover, this approach to defining an air pollutant as a grouping of many substances is not unique to GHGs, but rather is common practice under the CAA. For example, the EPA has heavy-duty truck standards applicable to VOCs and PM, but it is highly unlikely that heavy-duty trucks emit every substance that is included in the group defined as VOC or PM. See 40 CFR 51.100(s) (defining volatile organic

[205] 80 FR at 37774-85, and 37787.

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compound (VOC) as "any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions"; a list of exemptions are also included in the definition); 40 CFR 51.100(oo) (defining particulate matter (PM) as "any airborne finely divided solid or liquid material with an aerodynamic diameter smaller than 100 micrometers").

Grouping these six substances as one air pollutant is just as reasonable for the contribution analysis undertaken for CAA section 231(a)(2) sources that emit one subset of the six substances as it was for the category of sources that emits another subset under CAA section 202(a). In other words, it is not necessarily the source category, motor vehicles or aircraft engines, being evaluated for contribution that determines the reasonableness of defining a group air pollutant based on the shared attributes of the group's constituent substances. Even if the EPA defined the air pollutant as the group of two compounds emitted by CAA section 231(a)(2) sources, it would not change the result. The Administrator would make the same contribution finding (as described later in section V.B.), as it would have no material effect on the emissions comparisons discussed in section V.B.

The question of limits to the scope of future regulations is outside of the scope of this action because the EPA has neither proposed nor is finalizing in this action any such regulatory standards. This final action does not itself impose any requirements on source categories under CAA section 231. Thus, the EPA anticipates that this question could be raised and considered, as needed, in the standard-setting phase of the regulatory process, and

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invites potential commenters to submit their views on this issue in response to EPA's anticipated future notice of proposed rulemaking on standards.

Another commenter expressed concern about the EPA's proposed contribution finding because it does not differentiate between CO_2 emissions that result from combustion of fossil fuels and those that result from "combustion of biomass or biofuels derived from herbaceous crops or crop residues, as well as biogenic CO_2 emissions associated with the production, gathering and processing of crops or crop residues used in bio-based products including fuels."[206] The commenter argues that such crop-related biogenic CO_2 emissions should be excluded from the contribution finding because the CO_2 released back to the atmosphere when emitted from crop-derived biogenic sources contains the same carbon that was previously removed or sequestered from CO_2 in the atmosphere, and thus does not contribute to elevated atmospheric concentrations of the six well-mixed GHGs.

Consistent with the previously discussed response to the commenter in the discussion of the definition of air pollution being used under CAA section 231(a)(2)(A), the EPA reiterates that the Administrator defines the relevant air pollutant considered in the contribution finding as the aggregate group of the six well-mixed GHGs based on shared physical characteristics and common attributes relevant to climate change science and policy, and does not include consideration of the source of the air pollutant. In the record for the 2009 Endangerment

[206] Biogenic CO_2 Coalition, 2015: Comments on EPA's 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, 80 FR 37757 (July 1, 2015). Docket ID number EPA-HQ-OAR-2014-0828-0916. Available at www.regulations.gov (last accessed April 11, 2016).

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Finding under CAA section 202(a), the Agency stated that "all CO_2 emissions, regardless of source, influence radiative forcing equally once it reaches the atmosphere and therefore there is no distinction between biogenic and non-biogenic CO_2 regarding the CO_2 and the other well-mixed GHGs within the definition of air pollution that is reasonably anticipated to endanger public health and welfare."[207] The EPA continues to hold that position in these findings under CAA section 231(a)(2)(A), which is supported by the evidence before it. First, the fact that these CO_2 emissions originate from combustion of carbon-based fuels created through different processes is not relevant to defining the air pollutant that contributes to the endangering air pollution. The origin and constitution of a fuel prior to its combustion and subsequent emission into the atmosphere has no bearing on the fact that CO_2 and the other well-mixed GHGs are all sufficiently long lived to become well mixed in the atmosphere, directly emitted, of well-known radiative forcing, and generally grouped and considered together in climate change scientific and policy forums as the primary driver of climate change. A molecule of biogenic CO_2 has the same radiative forcing effect as a molecule of fossil-fuel derived CO_2. In other words, no matter the original source of the CO_2, the behavior of the CO_2 molecules in the atmosphere in terms of radiative forcing, chemical reactivity, and atmospheric lifetime is effectively the same. Any differential treatment of biogenic CO_2 in the context of the contribution finding under CAA section 231(a)(2)(A) would be inconsistent with the primary scientific basis for the grouping of the six well-mixed GHGs as a single class for purposes of identifying the air pollutant (and air pollution, as

[207] EPA, 2009. Response to Comments document, Volume 9: The Endangerment Finding, EPA-HQ-OAR-2009-0171-11676. Available at www.regulations.gov (last accessed April 11, 2016).

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explained in section IV.B.1). A more detailed response to the issues raised in this comment can be found in the Response to Comments document in the docket.

B. The Administrator's Finding Under CAA Section 231(a)(2)(A) That Greenhouse Gas Emissions from Certain Classes of Aircraft Engines Used in Certain Aircraft Cause or Contribute to Air Pollution That May Be Reasonably Anticipated To Endanger Public Health and Welfare

Under CAA section 231(a)(2)(A), the Administrator finds that emissions of the six well-mixed GHGs 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 making a contribution finding regarding 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), or regarding the emission of other substances emitted by aircraft engines. A detailed discussion of covered aircraft and their GHG emissions data is provided below in section V.B.4.

The Administrator reached her decision after reviewing emissions data on the contribution of covered aircraft under CAA section 231(a) relative to both U.S. GHG and global GHG emissions inventories. It is the Administrator's judgment that the collective GHG emissions from the classes of engines used in U.S. covered aircraft clearly contribute to endangering GHG pollution, whether the comparison is -- as described later in Tables V.1 and

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V.3 of sections V.B.4.a and V.B.4.b respectively -- to domestic GHG inventories (10 percent of all U.S. transportation GHG emissions, representing 2.8 percent of total U.S. emissions), to global GHG inventories (26 percent of total global aircraft GHG emissions representing 2.7 percent of total global transportation emissions and 0.4 percent of all global GHG emissions), or if using a combination of domestic and global inventory comparisons. Both domestic and global comparisons, independently and jointly, support the contribution finding under CAA section 231(a)(2)(A).[208,209,210] Making this cause or contribute finding for engines used in U.S. covered aircraft results in the vast majority (89 percent) of total U.S. aircraft GHG emissions being included in this determination (as described later in Table V.1 of section V.B.4.a.). Covered U.S. aircraft GHG emissions are from aircraft that operate in and from the U.S. and thus contribute to emissions in the U.S. This includes emissions from U.S. domestic flights, and emissions from U.S. international bunker flights (emissions from the combustion of fuel used by aircraft departing the U.S., regardless of whether they are a U.S. flagged carrier – also described as emissions from combustion of U.S. international bunker fuels[211]).

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[208] U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*, 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430-R-16-002, April 2016. Available at: www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html (last accessed June 14, 2016).

[209] 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.

[210] The domestic inventory comparisons are for the year 2014, and global inventory comparisons are for the year 2010. The rationale for the different years is discussed later in section V.B.4.

[211] For example, a flight departing Los Angeles and arriving in Tokyo, regardless of whether it is a U.S. flagged carrier, is considered a U.S. international bunker flight. A flight from London to Hong Kong is not.

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In addition, the Administrator based her decision on all the information in the record for this finding, including the public comments received on the proposed finding.

1. The Administrator's Approach in Making This Finding

As it did for the 2009 Endangerment Finding under CAA section 202(a), and consistent with prior practice and current science, under this CAA section 231(a)(2)(A) contribution finding the EPA uses annual emissions as a reasonable proxy for contributions to the endangering air pollution, i.e., the elevated atmospheric concentrations of the six well-mixed GHGs. Cumulative anthropogenic emissions are primarily responsible for the observed change in GHG concentrations in the atmosphere (i.e., the fraction of a country's or an economic sector's cumulative emissions compared to global 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 GHG emissions are a reasonable proxy for annual incremental changes in atmospheric GHG concentrations.

There are a number of possible ways of assessing whether a source's emissions of air pollutants cause or contribute to the endangering air pollution, and no single approach is required or has been used exclusively in previous determinations under the CAA. Because under this CAA section 231(a)(2)(A) action the air pollution against which the contribution of air pollutant emissions is being evaluated is the six well-mixed GHGs, one reasonable starting point for a contribution analysis is a comparison of the emissions of the air pollutant from the aircraft under consideration to the total U.S. and total global emissions of these six GHGs. The Administrator recognizes that there are other valid comparisons that can be considered in

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evaluating whether emissions of the air pollutant cause or contribute to the combined concentration of these six GHGs. To inform the Administrator's assessment, section V.B.4 presents the following types of simple and straightforward comparisons of covered 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;
- 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 used metric to convert GHG emissions into standard units so they can be compared. This approach is consistent with how the EPA determined contribution for GHGs under section 202(a) of the CAA in 2009.

2. Details of the Administrator's Approach in Making this Cause or Contribute Finding

The Administrator believes that consideration of the global context is important for the cause or contribute finding under CAA section 231(a)(2)(A), 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 many decades to come. It is the Administrator's view that it is reasonable for the cause or contribute analysis

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conducted under CAA section 231(a)(2)(A) for GHGs emitted by covered U.S. aircraft engines to be consistent with the reasoning supporting the 2009 GHG cause or contribute finding under CAA section 202, as the relevant statutory provisions are parallel and as the pollutant is the same. Accordingly, the Administrator finds 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. Both domestic and global comparisons, independently and jointly, are equally important for the finding.

In the 2009 CAA section 202(a) cause or contribute finding, the Administrator considered the totality of the circumstances in order to best understand the role played by CAA section 202(a) source categories in emitting air pollutants that contribute to endangering GHG air pollution, consistent with Congress' intention for EPA to consider the cumulative impact of all emissions from sources to the endangering air pollution. In that context, the global nature of the air pollution problem and the breadth of countries and sources emitting GHGs meant that no single country or source category dominated contribution to the endangering air pollution on the global scale.[212] As was the case in 2009, it is still true that no single country or GHG source category dominates contribution to the collective stock of endangering GHG air pollution on the global scale, and contributions from individual GHG source categories may appear small in comparison to the total stock, when, in fact, they are very important contributors in terms of both absolute emissions or in comparison to GHG

[212] 74 FR at 66538.

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emissions from other source categories, globally or within the United States. That is, because climate change is a global problem that results from global GHG emissions, it is more the result of numerous and varied sources each emitting what may seem to be smaller percentages of GHG pollutants compared to the total stock of GHG pollution, than typically might be encountered when tackling solely regional or local environmental issues for different kinds of pollutants that may have more of a direct impact on receptors located in the relative vicinity of the polluting sources (such as emissions of lead, for example, or sulfur dioxide without consideration of its role as possible precursor to particulate matter). It is reasonable for the Administrator to take these circumstances into account in making a contribution determination regarding emissions from sources of GHGs, as the impacts from GHGs are not spatially or temporally limited.[213] Therefore, in order to address the risks associated with global climate change, it is less likely that a single "majority" contributing source category could be identified and controlled such that the risks could be eliminated, without the need to consider contributions to the endangering stock of air pollution from "minority" source categories that may present smaller percentages of contribution than may sometimes be encountered when tackling regional or local environmental threats presented by a single or limited set of dominant sources. Thus, in addressing GHG risks, it will be, as the Supreme Court suggested in *Massachusetts v. EPA*, necessary for agencies to take an incremental approach to resolving the larger GHG endangerment issue, as "[a]gencies, like legislatures, do not generally resolve massive problems in one fell regulatory swoop. … They instead whittle

[213] 74 FR at 66543.

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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 the unique, global aspects of the climate change problem—including that from a percentage perspective there are no dominating sources or countries for GHG emissions contributing to the endangering GHG air pollution and that the global problem is due more to the GHG emissions contributed from numerous and varied sources—justify consideration of contribution to the endangering air pollution at lower percentage levels than the EPA typically might encounter when analyzing contribution towards a more localized air pollution problem. This is not to suggest, however, that all or even most local or regional air pollution problems are due to a single or small set of sources. For example, regional haze and ambient concentrations of concern for ozone, carbon monoxide, and particulate matter are commonly the result of a variety and great number of contributing sources, and the EPA has frequently approached such problems by incrementally regulating a set of sources that, in isolation, is not contributing the dominant share of air pollutants to the stock of air pollution, but is contributing a meaningful share. This approach has been affirmed by reviewing courts as reasonable and lawful under the CAA. *See, e.g.*, *Bluewater Network v. EPA*, 370 F.3d 1 (D.C. Cir. 2004). Thus, the Administrator, similar to the approach taken in the 2009 GHG cause or contribute finding under CAA section 202(a), is under CAA section 231(a)(2)(A) placing weight on the fact that engines used in U.S. covered aircraft, as discussed in detail in sections V.B.4.a of this notice, contribute the single largest share of GHG emissions from transportation sources in the United States that have not yet

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been regulated for GHG emissions, and that such GHG emissions from U.S. covered aircraft are a meaningful contribution to total U.S. and total global GHG emissions inventories.

3. Additional Considerations

The Administrator also considered information that showed 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, in making her contribution finding under CAA section 231(a)(2)(A). Given the projected growth in aircraft emissions compared to other sectors, it is reasonable for the Administrator to consider future emissions projections as further supporting her assessment of historical annual emissions (recent emissions from the current fleet) and informing her contribution determination. As described with further detail later in section V.B.4.c, recent FAA projections reveal that by 2036 GHG emissions from all aircraft and from U.S. covered aircraft are likely to increase by 43 percent (from 191 Tg CO_2eq to 272 Tg CO_2eq for the years 2010 to 2036).[214] By contrast, it is estimated that by 2036 the light-duty vehicle sector is projected to see a 25 percent reduction in GHG emissions (1,133 Tg CO_2eq to 844 Tg CO_2eq) from the 2010 baseline, while the freight trucks sector is projected to experience a 23 percent increase in GHG emissions (390 Tg CO_2eq to 478 Tg CO_2eq) from

[214] As discussed in section V.B.4.c, fuel burn growth rates for air carriers and general aviation aircraft operating on jet fuel are projected to grow by 43 percent from 2010 to 2036 and this provides a scaling factor for growth in projected GHG emissions, which are projected to increase at a similar rate as the fuel burn by 2030, 2036, and 2040.
FAA, 2016: *FAA Aerospace Forecast Fiscal Years 2016-2036*, 94 pp. Available at https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2016-36_FAA_Aerospace_Forecast.pdf (last accessed March 29, 2016).

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the 2010 baseline (this projected increase does not reflect the impact of GHG reductions on the freight trucks sector anticipated from the Phase 2 heavy-duty GHG standards that have not yet been promulgated). In addition, by 2036 the rail sector is projected to experience a 3 percent reduction in GHG emissions (44 Tg CO_2eq to 43 Tg CO2eq) from the 2010 baseline.[215] Because the projected growth in aircraft engine GHG emissions from U.S. covered aircraft through 2036 is more than 80 Tg CO2eq, ,[216] this consideration of projected future emissions adds further support to the Administrator's finding under CAA section 231(a)(2)(A) that emissions of the six well-mixed greenhouse gases from classes of engines used in U.S. covered aircraft contribute to the GHG air pollution that endangers public health and welfare.[217]

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[215] U.S. Energy Information Administration (EIA), 2015: *Annual Energy Outlook (AEO) 2015 with projections to 2040*, DOE/EIA-0383, 154 pp. For the years 2010 to 2014, the baseline emissions for each sector are from the 2016 *Inventory of U.S. Greenhouse Gas Emissions and Sinks Report*, and after 2014 we utilize projections from the 2015 EIA AEO report. Available at http://www.eia.gov/forecasts/aeo/ (last accessed May 12, 2015).

[216] In addition, we expect aircraft engine GHG emissions from U.S. covered aircraft to continue contributing to the endangering pollution in the future and to be a bigger percentage of transportation emissions, since these emission are projected to increase at a faster rate than other transportation sources.

[217] In 2010, U.S covered aircraft were responsible for 10 percent of U.S. transportation sector GHG emissions, and in 2036, U.S. covered aircraft are projected to be the source of 15 percent of U.S. transportation GHG emissions. In 2010, light-duty vehicles were responsible for 58 percent of U.S. transportation GHG emissions, and in 2036 they are projected to be the source of 46 percent of such emissions. In 2010, heavy-duty vehicles emitted 20 percent of U.S. transportation GHG emissions, and in 2036, they are projected to emit 26 percent (this projection does not reflect the impact from the Phase 2 heavy-duty GHG standards that have not yet been promulgated). In 2010, the rail sector contributed 2 percent of U.S. transportation GHG emissions, and in 2036, they are projected to contribute the same percentage.

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4. 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.[218] This is the unambiguous result of human-activity emissions of these gases. See section IV.B.2 for more information on elevated atmospheric GHG concentrations and anthropogenic drivers of climate change. Global emissions of well-mixed GHGs have been increasing, and are projected to continue increasing for the foreseeable future. According to the IPCC AR5, total global (when using inventories from all anthropogenic emitting sources including forestry and other land use) emissions of GHGs in 2010 were 49,000 Tg CO_2eq.[219] This represents an increase in global GHG emissions of 29 percent since 1990 and of 23 percent since 2000. In 2010, total U.S. GHG emissions were responsible for 13 percent of global GHG emissions (when comparing inventories from all anthropogenic emitting sources including forestry and other land use).[220]

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[218] 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.

[219] 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.

[220] 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, 351-411 pp.

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We are also providing 2012 estimates from other widely used and recognized global datasets, the World Resources Institute's (WRI) Climate Analysis Indicators Tool (CAIT) and the International Energy Agency (IEA).[221] We are providing these data for several reasons; first, there is value in looking at multiple data sources to see if estimates are generally in line with one another. Second, there are more recent data available in the WRI/CAIT and IEA datasets (2010 IPCC data vs. 2012 WRI/CAIT and IEA data). Third and finally, these other datasets provide additional utility for examining different disaggregations of the data (by country, sector, and with or without forestry and other land use emissions). Unless otherwise noted, we are presenting data points from these other datasets without including data regarding forestry and other land use inventories to enable straightforward comparisons of gross emission estimates from transportation sources specifically. The total global GHG emissions in 2012 from WRI/CAIT were 44,816 Tg of CO_2eq, representing an increase in global GHG emissions of 47 percent since 1990 and 32 percent since 2000. In comparison, WRI/CAIT's estimate of total global GHG emissions in 2012 when including forestry and other land use inventories were 47,599 Tg of CO_2eq (representing an increase in global GHG emissions of 40 percent since 1990 and 30 percent since 2000). In past years, WRI/CAIT estimates have generally been consistent with those of IPCC. In 2012, WRI/CAIT data indicate that total U.S. GHG emissions were responsible for 15 percent of global emissions, which is also generally in line with the percentages using IPCC's 2010 estimate described

[221] World Resources Institute (WRI) Climate Analysis Indicators Tool (CAIT) Data Explorer (Version 2.0). Available at http://cait.wri.org (last accessed January 19, 2016). International Energy Agency, Data Services. Available at http://data.iea.org (last accessed January 21, 2016).

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above. According to WRI/CAIT, current U.S. GHG emissions rank only behind China's, and China was responsible for 24 percent of total global GHG emissions.

As described earlier in section IV.A, in the proposed finding and this final finding, the Administrator considers the recent, major scientific assessments of the IPCC, USGCRP, and the NRC as the primary scientific and technical basis informing her judgment. Thus, the Administrator is informed by and places considerable weight upon the IPCC's data on global GHG emissions. She also considers but places less emphasis on the WRI/CAIT and IEA emissions data, which in comparison have a different aggregation of underlying data but are available for more recent years (2010 IPCC data vs. 2012 WRI/CAIT and IEA data).

The approach of considering the major scientific assessments, including IPCC's assessment, provides assurance that the Administrator's judgment is informed by the best available, well-vetted science that reflects the consensus of the climate science research community. The major findings of the assessments, including IPCC's assessment, support the Administrator's findings in this action. While the EPA uses the IPCC data as the primary data source for informing this contribution finding, it has reasonably used additional data sources from widely used and recognized global datasets to provide context and information from more recent years. These additional data supplement and confirm the IPCC data, as they are generally in line with IPCC. Comparing their 2010 total global GHG emissions, IPCC data are 49,000 Tg CO_2eq, and WRI/CAIT data indicates 42,968 Tg CO_2eq (a 12 percent

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difference).[222] Also, comparing their 2010 global aircraft GHG emissions estimates, IPCC data are 743 Tg CO_2eq, and IEA data indicate 749 Tg CO_2eq (a 1 percent difference).[223] Ultimately, whether the Agency utilizes the IPCC data alone or the WRI/CAIT dataset (and IEA data) alone, or both datasets together, it would have no material effect on the emissions comparisons discussed in section V.B and the Administrator would make the same contribution finding.

The *Inventory of U.S. Greenhouse Gas Emissions and Sinks Report*[224] (hereinafter "U.S. Inventory"), in which 2014 is the most recent year for which data are available, indicates that total U.S. GHG emissions increased by 7.3 percent from 1990 to 2014 (or by 7.8 percent when using inventories that include forestry and other land use), and emissions increased from 2013 to 2014 by 1.1 percent.[225] This 2013 to 2014 increase was attributable to

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[222] Comparing their 2010 total global GHG emissions, IPCC data are 49,000 Tg CO_2eq, and WRI/CAIT data, including forestry and land use inventories, indicates 45,748 Tg CO_2eq (a 7 percent difference).

[223] Comparing 2012 WRI/CAIT to 2010 IPCC data, WRI/CAIT data for total global GHG emissions indicates 44,816 Tg CO_2eq for 2012 (a 9 percent difference), and including forestry and land use inventories WRI/CAIT data indicates 47,599 Tg CO_2eq for 2012 (a 3 percent difference). Comparing 2012 IEA data to 2010 IPCC data, IEA data for global aircraft GHG emissions indicates 775 Tg CO_2eq for 2012 (a 4 percent difference).

[224] U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*, 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430-R-16-002, April 2016. Available at: www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html (last accessed June 14, 2016). The EPA has determined that the U.S. Inventory has been adequately reviewed in accordance with the EPA's Peer Review Handbook. For the presentation of emissions inventory information in this contribution finding, the EPA disaggregated the existing data in one area of the U.S. Inventory (for the General Aviation Jet Fuel Category) and had the disaggregation methodology 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 final action (EPA-HQ-OAR-2014-0828).

[225] As described later in detail, 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.

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multiple factors including an increase in vehicle miles traveled and vehicle fuel use, a colder winter resulting in an increased demand for heating fuel, and an increase in industrial production across multiple sectors. The U.S. Inventory also shows that while overall U.S. GHG emissions grew between 1990 and 2014, transportation GHG emissions grew at a significantly higher rate, 16 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 (U.S. covered aircraft GHG emissions grew by 15 percent between 1990 and 2014, and total U.S. aircraft GHG emissions decreased by 3 percent over this same time period).[226]

Section V.B.4.a which follows describes U.S. aircraft GHG emissions within the domestic context, while section V.B.4.b describes these same GHG emissions in the global context. Section V.B.4.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 total U.S. aircraft GHG emission and U.S. covered 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 portion

[226] As described later in detail, total U.S. GHG emissions, U.S. transportation GHG emissions, total U.S. aircraft GHG emissions, and U.S. covered aircraft GHG emissions include emissions from combustion of U.S. international bunker fuels. More specifically, total U.S. aircraft GHG emissions include international bunker fuel emissions from both commercial and military aviation. U.S. covered aircraft GHG emissions include international bunker fuel emissions from only commercial aviation.

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of the air pollution that is endangering by causing climate change. We are providing information about total U.S. aircraft GHG emissions for purposes of giving context for the discussion of GHG emissions from U.S. covered aircraft, which are included in this contribution finding under CAA section 231(a)(2)(A). As explained in more detail below, the contribution finding under CAA section 231(a)(2)(A) in this action does not include GHG emissions from all aircraft that operate in and from the U.S and thus emit GHGs in the U.S.

In 2014, total U.S. GHG emissions from all sources were 6,975 Tg CO_2eq. As stated above, total U.S. GHG emissions have increased by 7.3 percent between 1990 and 2014, while U.S. transportation GHG emissions from all categories have grown 16 percent since 1990. The U.S. transportation sector was the second largest GHG-emitting sector (behind electricity generation), contributing 1,919 Tg CO_2eq or 28 percent of total U.S. GHG emissions in 2014. 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. Following the IPCC guidelines for common and consistent accounting and reporting of GHGs, the UNFCCC requires countries to report both total national GHG emissions and international bunker fuel emissions (aviation and marine international bunker fuel emissions), and though these emissions are reported separately, both are assigned to the reporting country. In meeting the UNFCCC reporting requirements, the U.S. Inventory calculates international bunker fuel GHG emissions in a consistent manner with domestic GHG emissions. In this final contribution finding, the EPA maintains its approach used in the proposed findings to include aviation international bunker fuel emissions attributable to the United States with the

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national emissions number from the U.S. Inventory as reported to the UNFCCC. It is the EPA's view that it is reasonable and appropriate for the analysis in the contribution finding to reflect the full contribution of U.S. emissions from certain classes of aircraft engines, including those from domestic flights of U.S. aircraft and those associated with international aviation bunker fuel emissions. 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 used by aircraft departing from the United States, regardless of whether they are a U.S. flagged carrier. Total U.S. aircraft GHG emissions (which include emissions from international commercial and military aviation bunker fuels) clearly are included in the U.S. transportation sector's GHG emissions, accounting for 222 Tg CO_2eq or 12 percent of such emissions (see Table V.1). In 2014, total U.S. aircraft GHG emissions (222 Tg CO_2eq) were the third largest transportation source of GHGs within the United States, behind GHG emissions from light-duty vehicles and medium- and heavy-duty trucks (totaling 1,508 Tg CO_2eq).

For purposes of making this cause or contribute finding, the EPA includes 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 agreed to by ICAO. These emissions are from what we have previously described as "covered aircraft" (which include emissions from international commercial aviation bunker fuels).

As mentioned earlier in section II.D, traditionally the U.S. government (EPA and FAA) participates at ICAO in the development of international standards, and then where

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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 was agreed to in February 2016, and we expect to proceed with proposing emissions standards of at least equivalent stringency domestically as soon as is practicable. The thresholds of applicability for the international CO_2 emissions standard are based on 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.[227] Applying these weight thresholds, our contribution finding applies to GHG emissions from classes of engines used in covered aircraft that meet these MTOM criteria. For purposes of the contribution finding, examples of covered aircraft include smaller jet aircraft such as the Cessna Citation CJ3+ and the Embraer E170, up to the largest commercial jet aircraft—the Airbus A380 and the Boeing 747. Other examples of covered aircraft include larger turboprop aircraft, such as the ATR 72 and the Bombardier Q400. The scope of the contribution finding corresponds to the aircraft engine GHG emissions that are from aircraft that match the applicability thresholds for the international aircraft CO_2 standard. We have also identified aircraft that are not covered aircraft for purposes of this 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

[227] ICAO, 2013: *CAEP/9 Agreed Certification Requirement for the Aeroplane CO_2 Emissions Standard*, Circular (Cir) 337, 40 pp., AN/192, Available at http://www.icao.int/publications/catalogue/cat_2016_en.pdf (last accessed April 8, 2016). The ICAO Circular 337 is found on page 87 of the ICAO Products & Services 2016 catalog and is copyright protected; Order No. CIR337.

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as the Cessna Citation M2. In addition, ICAO (with U.S. participation) has agreed to exclude "piston-engine aircraft," "helicopters," and "military aircraft"[228] from the types of aircraft that will be subject to the ICAO standards.[229] As these aircraft will not be subject to the ICAO standards, in this contribution finding we are also not including GHG emissions from classes of engines used in these types of aircraft. We stress that our exclusion of these aircraft does not reflect a final scientific or technical determination regarding their GHG emissions. Rather, consistent with how the endangerment finding does not include various other climate forcers within the scope of the "air pollution" defined in this final action, we are not prepared to make final decisions regarding the GHG emissions from these excluded aircraft.

The majority of the GHG emissions from all classes of aircraft engines are within the scope of this contribution finding, which corresponds to that agreed to by ICAO. Below we describe the contribution of these U.S. covered aircraft GHG emissions to U.S. GHG emissions, and later in section V.B.4.b we discuss the contribution of these U.S. covered aircraft emissions to global GHG emissions, in support of our conclusion that GHG emissions from engines used by U.S. covered aircraft contribute to endangering GHG air pollution.

In 2014, GHG emissions from U.S. covered aircraft (197 Tg CO_2eq), which includes non-military GHG emissions from combustion of U.S. international aviation bunker fuels,[230]

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[228] ICAO regulations only apply to civil aviation (aircraft and aircraft engines); consequently, ICAO regulations do not apply to military aircraft.
[229] The applicability of the international CO_2 standard is limited to subsonic aircraft, and does not extend to supersonic aircraft.
[230] U.S. covered aircraft does not include military aircraft that use U.S. international bunker fuels.

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comprised 89 percent of total U.S. aircraft GHG emissions[231] (222 Tg CO_2eq) and 10 percent of total U.S. transportation sector GHG emissions (1,919 Tg CO_2eq) (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 (totaling 1,508 Tg CO_2eq),[232] which is the same ranking as total U.S. aircraft.[233] The U.S. covered aircraft also represent 2.8 percent of total U.S. GHG emissions (6,975 Tg CO_2eq), which is approximately equal to the contribution from total U.S. aircraft of 3.2 percent (Table V.1).[234] Also, in Table V.2 for background information and context, we provide similar information, but excluding GHG emissions from aviation combustion of U.S. international bunker fuels.[235]

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[231] Eastern Research Group, Incorporated (ERG), 2015: *U.S. Jet Fuel Use and CO_2 Emissions Inventory for Aircraft Below ICAO CO_2 Standard Thresholds*, Final Report, EPA Contract Number EP-D-11-006, 38 pp.

[232] In 2014, the U.S. light-duty vehicle (passenger cars and light-duty trucks) GHG emissions were 1,101 Tg CO_2eq and the medium- and heavy-duty truck GHG emissions were 407 Tg CO_2eq.

[233] 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. transportation sector, behind only light-duty vehicle and medium- and heavy-duty truck sectors.

[234] Total U.S. aircraft GHG emissions and U.S. covered aircraft GHG emissions were from 12 to 31 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 15 percent greater in 2000 and 2005 than in 2014. 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, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*, 558 pp. Available at http://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2016-Main-Text.pdf (last accessed April 22, 2016)).

[235] For Table V.2, total U.S. aircraft GHG emissions and U.S. covered aircraft GHG emissions exclude emissions from aviation combustion of U.S. international bunker fuels. The U.S. transportation sector GHG emissions and

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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.[236] CO_2 represents 99 percent of all GHGs from both total U.S. aircraft (220 Tg CO_2eq) and U.S. covered aircraft (195 Tg CO_2eq), and nitrous oxide represents 1 percent from total aircraft (2.1 Tg CO_2eq) and covered aircraft (1.9 Tg CO_2eq). Modern aircraft do not emit methane,[237] and hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are not products of aircraft engine combustion.

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total U.S. GHG emissions (in Table V.2) exclude emissions from both aviation and marine combustion of U.S. international bunker fuels.

[236] U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*, 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430-R-16-002, April 2016. Available at: www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html (last accessed June 14, 2016).

[237] 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 https://www3.epa.gov/otaq/regs/nonroad/aviation/420r09901.pdf (last accessed April 22, 2016)). 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).

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Table V.1[238,239]

COMPARISONS OF U.S. AIRCRAFT GHG EMISSIONS TO TOTAL U.S. TRANSPORTATION AND TOTAL U.S. GHG EMISSIONS

	1990	2000	2005	2010	2012	2013	2014
Total U.S. Aircraft GHG emissions (Tg CO_2eq) Share of U.S. Transportation Share of total U.S. Inventory	228 14% 3.5%	262 13% 3.6%	254 12% 3.4%	216 11% 3%	212 11% 3.1%	216 11% 3.1%	222 12% 3.2%
U.S. Covered Aircraft GHG emissions (Tg CO_2eq) Share of U.S. aircraft GHG emissions Share of U.S. Transportation Share of total U.S. Inventory	171 75% 10% 2.6%	223 85% 11% 3%	218 86% 10% 2.9%	191 88% 9.8% 2.7%	190 90% 10% 2.8%	195 90% 10% 2.8%	197 89% 10% 2.8%
U.S. Transportation GHG emissions (Tg CO_2eq) Share of total U.S. Inventory	1,659 26%	2,029 28%	2,119 28%	1,950 28%	1,891 28%	1,895 28%	1,919 28%
Total U.S. GHG emissions *(Tg CO_2eq)*	6,502	7,362	7,493	7,104	6,750	6,901	6,975

Table V.2[240,241]

COMPARISONS OF U.S. AIRCRAFT GHG EMISSIONS TO TOTAL U.S. TRANSPORTATION AND TOTAL U.S. GHG EMISSIONS - EXCLUDING U.S. INTERNATIONAL BUNKER FUELS[242]

	1990	2000	2005	2010	2012	2013	2014

[238] U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*, 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430-R-16-002, April 2016. Available at: www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html (last accessed June 14, 2016).
[239] ERG, 2015: *U.S. Jet Fuel Use and CO_2 Emissions Inventory for Aircraft Below ICAO CO_2 Standard Thresholds*, Final Report, EPA Contract Number EP-D-11-006, 38 pp.
[240] U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*, 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430-R-16-002, April 2016. Available at: www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html (last accessed June 14, 2016).
[241] ERG, 2015: *U.S. Jet Fuel Use and CO_2 Emissions Inventory for Aircraft Below ICAO CO_2 Standard Thresholds*, Final Report, EPA Contract Number EP-D-11-006, 38 pp.
[242] International bunker fuels emissions are emissions resulting from the combustion of fuels used for international transport activities, which includes aviation and marine. U.S. international bunker fuels includes aviation and marine bunker fuels allocated to the U.S. The U.S. international aviation bunker fuels category includes emissions from combustion of fuel used by aircraft departing from the United States, regardless of whether they are a U.S. flagged carrier. The U.S. international marine bunker fuels category includes emissions from the combustion of fuel used by vessels of all flags (that are engaged in international water-borne navigation) departing from the United States.

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Total U.S. Aircraft GHG emissions (Tg CO_2eq) Share of U.S. Transportation Share of total U.S. Inventory	190 12% 3%	200 10% 2.8%	194 9.7% 2.6%	155 8.5% 2.2%	147 8.2% 2.2%	151 8.4% 2.2%	152 8.4% 2.2%
U.S. Covered Aircraft GHG emissions (Tg CO_2eq) Share of U.S. aircraft GHG emissions Share of U.S. Transportation Share of total U.S. Inventory	141 74% 9% 2.2%	166 83% 8.6% 2.3%	162 84% 8.1% 2.2%	133 86% 7.3% 1.9%	128 87% 7.2% 1.9%	132 88% 7.4% 1.9%	130 86% 7.2% 1.9%
U.S. Transportation GHG emissions (Tg CO_2eq) Share of total U.S. Inventory	1,554 24%	1,927 27%	2,004 27%	1,832 26%	1,784 27%	1,794 26%	1,815 26%
Total U.S. GHG emissions *(Tg CO_2eq)*	6,397	7,259	7,379	6,986	6,643	6,800	6,871

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 portion 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 covered by the 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 portion of the air pollution that is causing climate change. As in the preceding section, we present comparisons from both total U.S. aircraft GHG emissions and U.S. covered aircraft GHG emissions.

According to IPCC AR5, global aircraft GHG emissions in 2010 were 11 percent of global transport GHG emissions and 1.5 percent of total global GHG emissions. Data from ICAO's 2013 Environmental Report indicate that the vast majority of global emissions from

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the aircraft sector are emitted by the types of aircraft that are covered by the ICAO CO_2 standard ("ICAO covered aircraft"), which was agreed to in February 2016.[243] When compared to global data from IPCC AR5, worldwide GHG emissions from ICAO covered aircraft represented 93 percent (688 Tg CO_2eq) of global aircraft GHG emissions,[244] 9.8 percent of global transport GHG emissions, and 1.4 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 29 percent of global aircraft GHG emissions, 3.1 percent of global transport GHG emissions, and 0.5 percent of total global GHG emissions in 2010 (see Table V.3). U.S. covered aircraft in 2010 GHG emissions represented 26 percent of global aircraft GHG emissions, 2.7 percent of global transport GHG emissions, and 0.4 percent of total global GHG emissions (see Table V.3).[245] For reasons described above in section V.B.4, we also made comparisons using 2012 estimates from WRI/CAIT and the IEA and found that they yield very similar results.[246] Also, in Table V.4 for background information and context

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[243] ICAO CAEP, 2013: *ICAO Environmental Report 2013, Aviation and Climate Change*, 224 pp. Available at http://cfapp.icao.int/Environmental-Report-2013/ (last accessed April 8, 2016).

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

[245] We are providing information about total U.S. aircraft GHG emissions for purposes of giving context for the discussion of GHG emissions from U.S. covered aircraft, which are included in this contribution finding under CAA section 231(a)(2)(A). As explained in more detail below, the contribution finding under CAA section 231(a)(2)(A) in this action does not include GHG emissions from all aircraft that operate in and from the U.S and thus emit GHGs in the U.S.

[246] Data from WRI/CAIT (that excludes forestry and other land use inventories) and IEA show that, in 2012, total U.S. aircraft emissions represented 27 percent of global aircraft GHG emissions, 2.9 percent of global transport GHG emissions, and 0.5 percent of total global GHG emissions. U.S. covered aircraft represented 25 percent of global aircraft GHG emissions, 2.6 percent of global transport GHG emissions, and 0.4 percent of total global GHG emissions in 2012.

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in regard to the global GHG inventory, we provide similar information, but excluding aviation GHG emissions from combustion of U.S. international bunker fuels.

Table V.3[247]

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 (%)[248]	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	0.4	1.5

Table V.4[249]

COMPARISONS OF U.S.AIRCRAFT GHG EMISSIONS TO TOTAL GLOBAL GREENHOUSE GAS EMISSIONS IN 2010 - EXCLUDING AVIATION GHG EMISSIONS FROM COMBUSTION OF U.S. INTERNATIONAL BUNKER FUELS FROM THE U.S. AIRCRAFT GHG EMISSIONS

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[247] 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.
U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*, 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430-R-16-002, April 2016. Available at: www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html (last accessed June 14, 2016).
[248] ERG, 2015: *U.S. Jet Fuel Use and CO_2 Emissions Inventory for Aircraft Below ICAO CO_2 Standard Thresholds*, Final Report, EPA Contract Number EP-D-11-006, 38 pp.
[249] 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.
U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*, 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430-R-16-002, April 2016. Available at: www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html (last accessed June 14, 2016).

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	2010 (Tg CO_2 eq)	**Total U.S. Aircraft Share (%)**	**U.S. Covered Aircraft Share (%)[250]**	**Global Aircraft Share (%)**
Global Aircraft GHG emissions	743	21	18	--
Global Transport GHG emissions	7,000	2.2	1.9	11
Total Global GHG emissions	49,000	0.4	0.3	1.5

For additional background information and context, we used 2012 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 2012 ranked 8th overall, behind only China, United States, India, Russian Federation, Japan, Brazil, and Germany, and ahead of about 177 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 6 times higher than aircraft GHG emissions from China, which globally is the second ranked country for aircraft GHG emissions, and about 4 times higher than aircraft GHG emissions from all of Asia. U.S. covered aircraft GHG emissions are about 5 times more than total aircraft GHG emissions from China, and about 4 times more than total aircraft GHG emissions from all of Asia. If U.S. covered aircraft emissions of GHGs were ranked against total GHG emissions for entire countries, these covered aircraft emissions would rank ahead

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

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of Belgium, Czech Republic, Ireland, Sweden, Switzerland and about 150 other countries in the world.

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

Global and U.S. covered aircraft GHG emissions have increased between 1990 and 2010, and are predicted to continue to increase in future years. While overall GHG emissions from U.S. covered aircraft increased by 12 percent from 1990 to 2010, the portion attributable to combustion of U.S. international aviation bunker fuels[251] increased by 91 percent.[252] During this same time period, global aircraft GHG emissions grew by 40 percent, and the portion attributable to combustion of global international aviation bunker fuels increased by 80 percent.[253,254] Notwithstanding the substantial growth in GHG emissions from combustion

[251] The U.S. international aviation bunker fuels category includes emissions from combustion of fuel 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 171 to 191 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 171 to 193 Tg CO2eq (13 percent), and GHG emissions from the portion attributable to U.S. international aviation bunker fuels grew from 30 to 62 Tg CO2eq (110 percent). From 1990 to 2012, GHG emissions from U.S. covered aircraft increased from 171 to 190 Tg CO2eq (11 percent), and GHG emissions from the portion attributable to U.S. international aviation bunker fuels grew from 30 to 62 Tg CO2eq (110 percent).

[252] U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*, 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430-R-16-002, April 2016. Available at: www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html (last accessed June 14, 2016).

[253] 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.

[254] According to IEA, from 1990 to 2012, global aircraft GHG emissions grew by 53 percent, and global international aviation bunker fuels increased by 86 percent. International Energy Agency Data Services, Available at http://data.iea.org (last accessed January 21, 2016).

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of U.S. international aviation bunker fuels, U.S. covered aircraft emissions have not increased as much as global aircraft emissions from 1990 to 2010, 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.[255] In fact, U.S. covered aircraft emissions decreased from 2000 to 2010 (13 percent), but then have increased from 2010 to 2014 (3 percent).[256] 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.[257] 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.[258]

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[255] According to the *FAA Aerospace Forecast 2014-2034,* these shocks include the September 11, 2001, terror attacks, significant increases in fuel prices, debt restructuring in Europe and U.S., and a global recession. FAA, 2014: *FAA Aerospace Forecast Fiscal Years 2014-2034*, 129 pp. Available at http://www.faa.gov/data_research/aviation/aerospace_forecasts/media/2014_faa_aerospace_forecast.pdf (last accessed April 8, 2016).

[256] U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*, 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430-R-16-002, April 2016. Available at: www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html (last accessed June 14, 2016).

[257] According to the *FAA Aerospace Forecast 2016-2036*, in 2015 U.S. air carriers were profitable for the sixth consecutive year.
FAA, 2016: *FAA Aerospace Forecast Fiscal Years 2016-2036*, 94 pp. Available at https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2016-36_FAA_Aerospace_Forecast.pdf (last accessed March 29, 2016).

[258] 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

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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,[259] 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).[260] The FAA projects that the fuel consumption from U.S. air carriers and general aviation aircraft operating on jet fuel will grow by 43 percent from 2010 to 2036, corresponding to an average annual increase rate in fuel consumption of 1.4 percent.[261] 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 contribution 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 will increase at a similar rate as the fuel burn by 2030, 2036, and 2040.

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cumulative operating profits (with nine years out of ten posting gains) and net profits (with six years out of ten posting gains).

[259] FAA, 2016: *FAA Aerospace Forecast Fiscal Years 2016-2036*, 94 pp. Available at https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2016-36_FAA_Aerospace_Forecast.pdf (last accessed March 29, 2016).

ICAO CAEP, 2013: *ICAO Environmental Report 2013, Aviation and Climate Change*, 224 pp. Available at http://cfapp.icao.int/Environmental-Report-2013/ (last accessed April 8, 2016).

[260] ICAO CAEP, 2013: *ICAO Environmental Report 2013, Aviation and Climate Change*, 224 pp. Available at http://cfapp.icao.int/Environmental-Report-2013/ (last accessed April 8, 2016).

[261] FAA, 2016: *FAA Aerospace Forecast Fiscal Years 2016-2036*, 94 pp. Available at https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2016-36_FAA_Aerospace_Forecast.pdf (last accessed March 29, 2016).

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C. Response to Key Comments on the Administrator's Cause or Contribute Finding

EPA received numerous comments regarding the Administrator's proposed cause or contribute finding. Below is a brief discussion of some of the key comments. Responses to comments on this topic (and further details for the key comments) are also contained in the Response to Comments document.

1. The Administrator Reasonably Defined the Scope of the Cause or Contribute Finding

a. Applicability Weight Thresholds Match Those of International CO_2 Standard.

Several commenters stated that the EPA should undertake another cause or contribute finding for a broader range of aircraft not covered in our proposed finding, including smaller turboprop aircraft (such as the Beechcraft King Air 350i), smaller jet aircraft (such as the Cessna Citation M2), piston-engine aircraft, and helicopters. These commenters stated, however, that this comment did not affect the validity of the conclusions in the proposed finding. Numerous commenters stated their support for our proposed finding's scope matching the applicability (weight or MTOM) thresholds of the international CO_2 standard.

As described earlier, at this time and for the purposes of this cause or contribute finding under CAA section 231(a)(2)(A), the EPA is including emissions of the six well-mixed greenhouse gases 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

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kilograms. We are not at this time taking final action with respect to the GHG emissions from aircraft other than those included in the scope of this finding.[262] The cause or contribute finding is a prerequisite under CAA section 231 for EPA to adopt standards that are of at least equivalent stringency to those set by ICAO. Accordingly, in this finding, the EPA is focusing on matching the scope of our contribution finding to the applicability thresholds of the international standard. The covered aircraft match the applicability (or MTOM) thresholds of the international aircraft CO_2 standard. This is a reasonable approach for this first finding regarding the contribution of aircraft GHG emissions to the endangering air pollution, as the vast majority of U.S. emissions from all classes of aircraft engines (89 percent of U.S. aircraft GHG emissions) will be covered by this scope of applicability, which corresponds to 26 percent of global aircraft GHG emissions. This approach is also consistent with our past practice in promulgating aircraft engine NOx standards. In ruling on a petition for judicial review of the 2005 rule for further stringency of aircraft engine NOx standards,[263] the D.C. Circuit held that the EPA's approach in that action of tracking the applicability criteria of 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

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[262] Consequently, this final action does not restrict the EPA's future discretion to address GHG emissions from aircraft that are not included in the scope of this finding, or prejudge how the Agency would respond to a petition to address those GHG emissions should one be submitted in the future.

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

In 2005, we promulgated more stringent NO_x emission standards for newly certified commercial turbofan engines. That final rule brought the U.S. standards closer to alignment with ICAO CAEP/4 requirements that became effective in 2004.

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determines are reasonable. *Id.*) Also, by using the phrase "any class or classes of aircraft engines which in [her] judgment causes, or contributes to," the endangering air pollution, section 231(a)(2)(A) gives the EPA discretion to determine which class or classes of aircraft engines to evaluate in making a cause or contribute finding, and whether to focus on a single class or multiple classes of aircraft engines in satisfying the requirements of section 231(a)(2)(A).

In response to the commenters who asked the EPA to undertake an additional cause and contribute finding regarding GHG emissions from non-covered U.S. aircraft, the Agency will take that request under advisement and consideration among its other duties and priorities, but is not prepared at this time to either reject or grant that request. At this point, given the nearly complete process for ICAO's adoption of an international standard, which will under the Chicago Convention trigger the duties of the U.S. and other member states to adopt domestically standards that are of at least equal stringency, it is most important for the EPA to prepare for having to meet that nearly certain duty by expeditious completion of the pre-requisite endangerment and cause or contribute findings, without possibly delaying final action to consider the possibility of proposing a broader cause or contribute finding before taking final action.

b. The Administrator Reasonably Defined U.S. Covered Aircraft

A commenter stated that they understand that the scope of the finding corresponds to the aircraft engine GHG emissions that are from aircraft that match the applicability thresholds (or MTOM thresholds) for the international aircraft CO2 standard; however, they

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requested clarification on the difference between "U.S. covered aircraft" and non-U.S. covered aircraft. This commenter requested clarification on whether U.S. covered aircraft means aircraft made in the U.S., registered in the U.S., operated by an entity holding an air carrier certificate issued by the U.S., operated by an air carrier in the National Air Space, or operated by anyone in the U.S. (National) Air Space. The commenter expressed that the EPA must explain the basis for its definition, and its claimed authority to regulate U.S. covered aircraft.

As described earlier in section V.B.4, U.S. covered aircraft for this cause or contribute finding refers to aircraft that are a subset of all aircraft that meet the applicability thresholds of the international aircraft CO2 standard, namely those that fly domestically with starting and ending points within the U.S. and those that depart the U.S. for international destinations. U.S. covered aircraft include aircraft that operate in the U.S., and thus contribute to GHG emissions in the U.S. This includes emissions from U.S. domestic flights of these aircraft. In addition, the scope of this finding reaches GHG emissions from non-military aircraft combusting U.S. international bunker fuels departing the U.S., regardless of whether they are a U.S. flagged carrier—also described as emissions from combustion of U.S. international bunker fuels.[264] Similar to statements earlier in section V.B.4, in defining U.S. covered aircraft for this specific contribution finding, in advance of needing to meet the expected duties imposed by the ICAO standards, the EPA is focused on the GHG emissions that the

[264] For example, a flight departing Los Angeles and arriving in Tokyo—regardless of whether it is a U.S. flagged carrier—is considered a U.S. international bunker flight. A flight from London to Hong Kong is not.

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atmosphere receives as a result of aviation activities occurring inside the U.S. and originating from the U.S., in order to capture the full contribution of covered aircraft to U.S. GHG emissions, consistent with the scope of the ICAO international standard. It is important for the EPA's finding to reach the subset of aircraft that meet the definition of U.S. covered aircraft, and that subset will not necessarily be covered by any other member state with responsibilities to meet the ICAO standard under the Chicago Convention. For U.S. covered aircraft, the EPA has chosen to combine GHG emissions from all flights both domestic and those reflected in international bunker fuel inventories to determine the contribution of U.S. covered aircraft GHG emissions to the endangering air pollution. We additionally note that the IPCC and UNFCCC guidance states that for an international bunker flight the entire flight's emissions are calculated and reported (for the country from where the flight departed), and the GHG emission calculation methodologies are the same for both domestic and international aviation bunker fuel flights. We have followed this guidance in our calculation methodologies for this contribution finding.[265] Ultimately, GHG emissions inventories from U.S. covered aircraft with or without GHG emissions from combustion of U.S. international

[265] As described earlier, following the IPCC guidelines for common and consistent accounting and reporting of GHGs, the UNFCCC requires countries to report both total national GHG emissions and international bunker fuel emissions (aviation and marine international bunker fuel emissions), and though these emissions are reported separately, both are assigned to the reporting country. In meeting the UNFCCC reporting requirements, the U.S. Inventory calculates international bunker fuel GHG emissions in a consistent manner with domestic GHG emissions. In this final contribution finding, the EPA maintains its approach used in the proposed findings to include aviation international bunker fuel emissions attributable to the United States with the national emissions number from the U.S. Inventory as reported to the UNFCCC. It is the EPA's view that it is reasonable and appropriate for the analysis in the contribution finding to reflect the full contribution of U.S. emissions from certain classes of aircraft engines, including those from domestic flights of U.S. aircraft and those associated with international aviation bunker fuel emissions. 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 used by aircraft departing from the United States, regardless of whether they are a U.S. flagged carrier.

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aviation bunker fuels are sufficient to support the Administrator's cause or contribute finding in this action, whether we consider the inventories both together, or just the inventory from domestic flights of U.S. covered aircraft.

In response to the comment that EPA must explain its claimed authority to regulate U.S. covered aircraft, as described earlier, the endangerment and cause or contribute findings are a prerequisite under CAA section 231(a)(2)(A) for EPA to adopt standards (that are of at least equivalent stringency to those set by ICAO). If the Administrator makes these findings in the affirmative, she must issue standards under section 231(a)(2)(A).

c. It Is Reasonable for the Administrator to Limit the Contribution Finding to U.S. Covered Aircraft

Some commenters stated that the EPA should issue a broader contribution finding and wait until the standard setting phase to exercise discretion as to what classes of aircraft engines should be covered by standards. These commenters stated that the EPA has authority to set aircraft engine GHG emission standards, following a cause or contribute finding, that do not impose requirements on every engine or class of aircraft engine within the scope of that finding. They also argued that in this instance there does not seem to be a sufficiently reasoned basis for EPA to exclude the non-covered aircraft for purposes of making the cause or contribute finding.

As described earlier in section III, the endangerment and contribution findings for aircraft GHG emissions under section 231(a)(2)(A) of the CAA are a necessary first step to

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begin to address GHG emissions from the aviation sector, the highest-emitting category of transportation GHG sources that the EPA has not yet addressed. As presented in more detail in section V.B.4 of this preamble, covered U.S. aircraft GHG emissions in 2014 represented 10 percent of GHG emissions from the U.S. transportation sector,[266] and in 2010, the latest year with complete global emissions data, U.S. covered aircraft GHG emissions represented 26 percent of global aircraft GHG emissions.[267, 268] U.S. covered aircraft GHG emissions are projected to increase by 43 percent over the next two decades.[269]

Section III of this preamble summarizes the legal framework for this proposed action under CAA section 231. As discussed there, 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." Before the Administrator may issue standards addressing

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[266] U.S. EPA, 2016: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*, 1,052 pp., U.S. EPA Office of Air and Radiation, EPA 430-R-16-002, April 2016. Available at: www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html (last accessed June 14, 2016).
[267] Ibid.
[268] 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, 599-670 pp.
[269] As discussed in section V.B.4.c, fuel burn growth rates for air carriers and general aviation aircraft operating on jet fuel are projected to grow by 43 percent from 2010 to 2036, and this provides a scaling factor for growth in GHG emissions which would increase at a similar rate as the fuel burn by 2030, 2036, and 2040. FAA, 2016: *FAA Aerospace Forecast Fiscal Years 2016-2036*, 94 pp. Available at https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2016-36_FAA_Aerospace_Forecast.pdf (last accessed March 29, 2016).

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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 the classes of aircraft engines under consideration cause or contribute to this air pollution.[270] If the Administrator answers both questions in the affirmative, she must issue standards under section 231. While we agree that the EPA has significant discretion in the standard-setting phase, we disagree with the comment to the extent that it suggests the standard-setting phase is the only appropriate place for the EPA to exercise discretion as to the scope of covered aircraft engine classes in this first instance of findings regarding aircraft GHG emissions. By using the phrase "any class or classes of aircraft engines which in [her] judgment causes, or contributes to," the endangering air pollution, section 231(a)(2)(A) gives the EPA discretion to determine which class or classes of aircraft engines to evaluate in making a cause or contribute finding, and whether to focus on a single class or multiple classes of aircraft engines in satisfying the requirements of section 231(a)(2)(A). Because the scope of the first international CO_2 standard adopted by ICAO is limited to aircraft over the specified MTOM levels, and the U.S. will have a duty to set domestic standards in order to meet its obligations under the Chicago Convention, it is reasonable in this case to similarly limit the scope of and issue this first aircraft GHG contribution finding and not delay this determination in order to

[270] 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.

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possibly additionally consider and re-propose our finding to reach a broader scope. We do not necessarily disagree with the commenters who suggested that we could issue a broader contribution finding and then narrow the scope of future standards at that stage, but doing so in this action would require further analysis and development of an additional proposed finding, which could impede expeditious final issuance of the finding we proposed and thereby possibly impede prompt development of domestic standards that are of at least equivalent stringency as ICAO's. We expect to proceed with promulgating a domestic CO_2 standard (or GHG standard) of at least equivalent stringency to the international CO_2 standard as soon as it is practicable, and to begin to take action along this expected path, we are exercising our discretion in matching the applicability thresholds of the international CO_2 standard. The majority of the GHG emissions from all classes of aircraft engines would be covered by these applicability thresholds. We are not making either positive or negative contribution findings regarding GHG emissions from engines used in non-covered aircraft at this time, but nothing prevents us from doing so in the future.

2. The Administrator's Cause or Contribute Analysis Is Reasonable

a. It Is Reasonable to Include GHG Emissions from Combustion of International Aviation Bunker Fuels in the U.S. Aircraft GHG Inventory

Some commenters stated that the EPA's choice of data for the cause or contribute analysis was selective and biased. They contended that emissions resulting from combustion of the international aviation bunker fuels should not be part of the U.S. covered aircraft GHG inventory or of the total U.S. aircraft GHG inventory, since the EPA's own U.S. inventory for

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UNFCCC reporting purposes does not include emissions from combustion of these fuels in the national GHG totals and reports them separately to the UNFCCC, pursuant to UNFCCC inventory reporting guidelines.[271] Consequently, they asserted that the total emissions from domestic commercial aircraft accounts for less than 2 percent (1.7%) of total U.S. aircraft GHG emissions. Because of this, commenters believe that EPA inappropriately specified that the U.S. covered aircraft GHG emissions represent 3 percent of the total U.S. GHG emissions.

The EPA disagrees with this comment. As stated earlier in this section, U.S. covered aircraft GHG emissions[272] (and total U.S. aircraft GHG emissions) in this cause or contribute finding include those GHG emissions resulting from combustion of international aviation bunker fuel because we want to capture the full contribution of GHG emissions from aircraft that are attributable to covered aircraft activity in or originating from the U.S. In tracking aircraft GHG emissions, the EPA is focused on the U.S.'s contributions from this sector to the atmosphere. Accordingly, the EPA includes GHG emissions for all aircraft departing from U.S. airports in a calendar year (domestic and international flights) in determining total U.S. GHG emissions and total U.S. aircraft GHG emissions. Thus, consistent with that practice, for assessing GHG emissions from U.S. covered aircraft, EPA has chosen to combine all flights, both those with domestic takeoff and landing points, and those with domestic takeoff points and international landing points. In addition, guidance from the IPCC and UNFCCC

[271] EPA GHG Emissions Inventory at A-31 (reporting and methods) is available at: http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2015-Annex-2-Emissions-Fossil-Fuel-Combustion.pdf (last accessed April 8, 2016).

[272] As described earlier in section V.B.4, U.S. covered aircraft do not include military aircraft that use U.S. international aviation bunker fuels.

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states that for an international bunker fuel-combusting flight the entire flight's emissions are calculated and reported, and the GHG emission calculation methodologies are the same for both domestic and international bunker fuel-combusting flights. The U.S. calculates and reports emissions resulting from combustion of international bunker fuels in accordance with this guidance. However, pursuant to UNFCCC reporting guidelines, emissions from combustion of international bunker fuels are reported separately from other aircraft emissions in the U.S. Inventory, in order to meet the reporting commitments under the UNFCCC. We follow the IPCC and UNFCC guidance in our calculation and reporting methodologies. [273]

b. The Administrator Does Not Need to Find Significant Contribution, or Establish a Bright Line

One comment letter stated that aircraft GHG emissions are extremely small relative to both domestic and global GHG emissions in the aggregate, and questioned whether there is a reasoned basis for EPA to find that GHG emissions from U.S. aircraft cause or contribute to air pollution that endangers public health and welfare when assessed not only relative to

[273] As described earlier, following the IPCC guidelines for common and consistent accounting and reporting of GHGs, the UNFCCC requires countries to report both total national GHG emissions and international bunker fuel emissions (aviation and marine international bunker fuel emissions), and though these emissions are reported separately, both are assigned to the reporting country. In meeting the UNFCCC reporting requirements, the U.S. Inventory calculates international bunker fuel GHG emissions in a consistent manner with domestic GHG emissions. In this final contribution finding, the EPA maintains its approach used in the proposed findings to include aviation international bunker fuel emissions attributable to the United States with the national emissions number from the U.S. Inventory as reported to the UNFCCC. It is the EPA's view that it is reasonable and appropriate for the analysis in the contribution finding to reflect the full contribution of U.S. emissions from certain classes of aircraft engines, including those from domestic flights of U.S. aircraft and those associated with international aviation bunker fuel emissions. 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 used by aircraft departing from the United States, regardless of whether they are a U.S. flagged carrier.

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contributions from other sectors, but also relative to climate impacts. For example, this commenter indicated the EPA estimates that total U.S. aircraft GHG emissions accounted for about 0.5 percent of total global GHG emissions in 2010. Thus, the commenter stated that the total U.S. aircraft GHG emission contributions from the U.S. aviation sector are extremely small relative to total global GHG emissions, or negligible as a percentage of total global GHG emissions.

The EPA disagrees with this comment and has fully explained the reasoning for this contribution finding in section V.B. In addition, the Administrator interprets CAA section 231(a)(2)(A) to require some level of contribution that, while more than *de minimis* or trivial, does not need to rise to the level of significance to support a contribution finding. By its terms, section 231(a)(2)(A) does not contain a modifier on its use of the term "contribute," which contrasts with some other provisions of the CAA, such as sections 213(a)(2) and (4), and 110(a)(2)(D)(i)(I) , that expressly require a "significant" contribution. The Administrator's interpretation is consistent with the interpretation of parallel language in CAA section 202(a), which was described in the 2009 Findings[274], and is also supported by past court decisions. For example, the D.C. Circuit's opinion in *Catawba County* v. *EPA*, 571 F.3d 20 (D.C. Cir. 2009), discusses the concept of contribution in the area designations context under section 107(d)(1)(A), which, like section 231(a)(2)(A), does not include the term "significant" to modify "contribute." This decision, along with others, supports the Administrator's interpretation that CAA section 231(a)(2)(A) does not require a significant

[274] 74 FR at 66541-42.

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contribution, but rather, in the absence of specific language regarding the degree of contribution, provides the EPA discretion such that a positive finding may be based on a determination that the air pollutant emissions from the relevant class or classes of aircraft engines merely "contribute to" the air pollution which may reasonably be anticipated to endanger public health or welfare. In addition, similar to the interpretation of section 202(a) described in the 2009 Findings, the Administrator is not required under section 231(a)(2)(A) to establish a bright-line, objective test for contribution, but is to exercise her judgment in determining contribution..[275] As explained above, and similar to the approach used in the 2009 Findings, when exercising her judgment under section 231(a)(2)(A), in this context the Administrator considers both the cumulative impact and also the totality of the circumstances. It is reasonable for the Administrator to apply a "'totality-of-the-circumstances test to implement a statute that confers broad discretionary authority, even if the test lacks a definite 'threshold' or 'clear line of demarcation to define an open-ended term.'" *Id.* at 39 (citations omitted).

In *Catawba County* the D.C. Circuit upheld the EPA's $PM_{2.5}$ area designation decisions and analyzed CAA section 107(d), which requires the EPA to designate an area as nonattainment if it "contributes to ambient air quality in a nearby area" not meeting the national ambient air quality standards. *Id.* at 35. CAA section 107(d)(1), as mentioned above, like section 231(a)(2)(A), does not use the term "significant" in establishing this duty, or set forth any other bright-line benchmark that must be met for the EPA to find "contribution."

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[275] 74 FR at 66542.

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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 D.C. Circuit 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 court again noted that the term is ambiguous, leaving it to the 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 decision in *Bluewater Network* v. *EPA,* 370 F.3d 1 (D.C. Cir. 2004), in which the court, in evaluating EPA's judgment that emissions from a specific class or category of nonroad engines contribute to air pollution for which findings of "significant" contribution had already been made with respect to nonroad engines' emissions in the aggregate, noted that the term "contribute" in CAA section 213(a)(3) "[s]tanding alone,…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. In that context, the court found that the bare term "contribute" invests the Administrator with discretion to exercise judgment regarding what constitutes a sufficient contribution for the purpose of making a contribution finding. *Id.* at 14.

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Finally, in *Catawba County,* the D.C. Circuit also rejected "petitioners' argument that the EPA violated the statute by failing to articulate a quantified amount of contribution that would trigger" the regulatory action. 571 F.3d at 39. Although petitioners preferred that the EPA establish a bright-line test, the court recognized that the statute did not require that EPA "quantify a uniform amount of contribution." *Id.*

Given this context, it is entirely reasonable for the Administrator to interpret CAA section 231(a)(2)(A) to require some level of contribution that, while more than *de minimis* or trivial, need not be significant. It is also reasonable for the EPA to find contribution without establishing a "bright-line 'objective' test of contribution." 571 F.3d at 39. As in the 2009 Endangerment Finding, when exercising her judgment under CAA section 231(a)(2)(A), 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 of source category, the number of sources in the source category, and the number and type of other source categories that may emit the air pollutant) when determining whether the emissions justify regulation under the CAA. *See id.* (finding it reasonable for an agency to adopt a totality-of-the-circumstances test under similar circumstances). In the context of GHG emissions, which come from many different sectors no single one of which is primarily responsible as their source, and which aggregate together into a common pollution stock that itself impacts public health and welfare, it is particularly reasonable to address those emissions from contributing sectors, even if looked at individually a sector may not be considered dominant. Therefore, in the specific context of making a contribution finding regarding GHG emissions from aircraft engines under CAA section 231, it is reasonable for

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the EPA to interpret that provision to not require some level of contribution that rises to a pre-determined numerical level or percentage- or mass-based portion of the overall endangering GHG air pollution.

In addition, the EPA disagrees with the assertion that we do not have a reasoned basis to make this contribution finding. As described earlier in section V.B.4, the collective GHG emissions from the classes of engines used in U.S. covered aircraft (197 Tg CO2eq) clearly contribute to the endangering GHG air pollution, whether the comparison is domestic (89 percent of total U.S. aircraft GHG emissions, 10 percent of all U.S. transportation GHG emissions, representing 2.8 percent of total U.S. GHG emissions), global (26 percent of total global aircraft GHG emissions representing 2.7 percent of total global transportation GHG emissions and 0.4 percent of all global GHG emissions), or a combination of domestic and global. Both domestic and global comparisons, independently and jointly, support the finding. Moreover, these comparisons also support the finding even if GHG emissions from combustion of U.S. international aviation bunker fuels are excluded. Making this cause or contribute finding for engines used in U.S. covered aircraft will result in the vast majority of total U.S. aircraft GHG emissions being included in this determination.

Also, even if the EPA were required to determine that a contribution met or exceeded a level of significance to make a contribution finding, for the reasons discussed above, the EPA would find that the contribution to the U.S. and global stocks of GHG air pollution from GHG emissions from classes of engines used in U.S. covered aircraft is significant. As discussed in more detail above, their GHG emissions are larger than those from the great

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majority of emitting countries, they are larger than those of several major emitting countries, and they constitute one of the largest remaining unregulated contributing parts of the U.S. GHG emissions inventory.

Finally, in response to the suggestion in the comments that a positive contribution finding is not supportable unless the EPA finds that GHG emissions from covered aircraft themselves cause climate impacts, without consideration of the impacts caused by the larger aggregate stock of GHG air pollution, we stress that the comment conflates the endangerment and contribution steps of the analysis. In making the contribution finding, the EPA need not additionally and separately find whether the contribution alone causes endangerment. That endangerment finding has already been made with respect to the stock of GHG air pollution to which covered aircraft GHG emissions contribute. The only remaining issue at the second step of the analysis is whether the analyzed GHG source sector in fact emits GHG air pollutants that contribute to the air pollution that has already been found to endanger public health and welfare. The covered aircraft, as we have shown and explained, clearly do emit GHG air pollutants that measurably contribute to that stock.

c. The Administrator Reasonably Provided Context in Comparing Aircraft GHG Emissions to Other Sector GHG Emissions

Some commenters asserted that the EPA did not show important context in comparing covered aircraft GHG emissions to other mobile source categories' GHG emissions. The EPA does not describe the very low level of aircraft emissions in general relative to emissions from other sources. The commenters assert that, for example, the EPA does not point out that

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the growth in emissions from U.S. medium-duty and heavy-duty trucks since 1990 is 53 percent greater than the GHG emissions from the U.S. commercial aircraft sector today, and 18 percent higher than the total U.S. aircraft (or entire U.S. aviation sector) GHG emissions today.

In the proposed finding and this final finding, the EPA provides context for covered aircraft GHG emissions relative to other sectors' GHG emissions, including other categories within the transportation sector. As described earlier in section V.B.4, from a national perspective, the EPA provided tables to compare total U.S. aircraft and U.S. covered aircraft GHG emissions to U.S. transportation and total U.S. inventory GHG emissions, over an extended timeframe (1990-2014). We also noted that 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 sector and medium- and heavy-duty truck sectors. This is the same ranking as total U.S. aircraft, if U.S. covered aircraft and total U.S. aircraft are compared to the other transportation sectors independent of one another. Finally, we note that the U.S. inventory also shows that while overall U.S. GHG emissions grew between 1990 and 2014, transportation GHG emissions grew at a notably higher rate, 16 percent, more rapidly than any other U.S. sector. U.S. covered aircraft GHG emissions grew by 15 percent in this time period.[276] Within the transportation sector, aircraft remain the single largest source of GHG emissions not yet subject to any GHG standards.

[276] Total U.S. aircraft GHG emissions decreased by 3 percent from 1990 to 2014. U.S. non-covered aircraft GHG emissions decreased by 56 percent in this same time period.

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In our proposal and again in this finding in section V.B.4, the Administrator also stated her concern that recent projections indicate that by 2036 GHG emissions both from all aircraft and from U.S. covered aircraft are likely to increase by 43 percent (from 191 Tg CO_2eq to 272 Tg CO_2eq for the years 2010 to 2036).[277] This was contrasted with projections of GHG emissions changes in other transportation sectors in the same timeframe. For example, projections estimate that by 2036 the light-duty vehicle sector is projected to see a 25 percent reduction in GHG emissions (from 1,133 Tg CO_2eq to 844 Tg CO_2eq) from the 2010 baseline, while the freight trucks sector is projected to experience a 23 percent increase in GHG emissions (from 390 Tg CO_2eq to 478 Tg CO_2eq) from the 2010 baseline. (However, this projected increase does not reflect the impact of GHG reductions on the freight trucks sector anticipated from the Phase 2 heavy-duty GHG standards that have not yet been promulgated.) In addition, by 2036 the rail sector is projected to experience a 3 percent reduction in GHG emissions (44 Tg CO_2eq to 43 Tg CO2eq) from the 2010 baseline.[278]

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[277] As discussed in section V.B.4.c, fuel burn growth rates for air carriers and general aviation aircraft operating on jet fuel are projected to grow by 43 percent from 2010 to 2036 and this provides a scaling factor for growth in GHG emissions which would increase at a similar rate as the fuel burn by 2030, 2036, and 2040.
FAA, 2016: *FAA Aerospace Forecast Fiscal Years 2016-2036*, 94 pp. Available at https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2016-36_FAA_Aerospace_Forecast.pdf (last accessed March 29, 2016).

[278] U.S. Energy Information Administration (EIA), 2015: *Annual Energy Outlook (AEO) 2015 with projections to 2040*, DOE/EIA-0383, 154 pp. For the years 2010 to 2014, the baseline emissions for each sector are from the 2016 *Inventory of U.S. Greenhouse Gas Emissions and Sinks Report*, and after 2014 we utilize projections from the 2015 EIA AEO report. Available at http://www.eia.gov/forecasts/aeo/ (last accessed April 8, 2016).

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Therefore, in the context of projected growth it appears that U.S. covered aircraft GHG emissions through 2036 are estimated to increase by more than 80 Tg CO2eq.[279,280]

Also, the EPA provided a global perspective by showing how total U.S. aircraft and U.S. covered aircraft GHG emissions compare to global aircraft, global transport, and total global GHG emissions. In addition, the EPA shows the ranking of the total U.S. aircraft and U.S. covered GHG emissions relative to other global transportation sectors and entire country GHG emissions.

One commenter stated that it is inappropriate and misleading to compare U.S. aircraft GHG emissions with those of other, individual countries. They indicated that to fairly compare the U.S. airlines' GHG emissions contribution, EPA should analyze, as ICAO does, contributions from other world regions with comparable land masses and levels of economic activity. (In terms of landmass, the U.S. ranks third globally, behind only Russia and Canada.) The EPA disagrees with this comment. The language of CAA section 231(a)(2)(A) is silent regarding how the Administrator is to make her contribution analysis. While it requires that the Administrator assess whether emissions of an air pollutant cause or

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[279] As described earlier in section V.B.3, in 2010, U.S. covered aircraft were 10 percent of U.S. transportation sector GHG emissions, and in 2036, U.S. covered aircraft are projected to be 15 percent of U.S. transportation GHG emissions. In 2010, light-duty vehicles were 58 percent of U.S. transportation GHG emissions, and in 2036 they are projected to be 46 percent. In 2010, heavy-duty vehicles were 20 percent of U.S. transportation GHG emissions, and in 2036, they are projected to be 26 percent (does not reflect the impact from the Phase 2 heavy-duty GHG standards that have not been promulgated). In 2010, the rail sector was 2 percent of U.S. transportation GHG emissions, and in 2036, they are projected to be the same percentage.

[280] Some commenters stated that section 231(a)(2)(A) of the CAA does not give the EPA the authority to legally base the contribution finding on future emission projections. As described earlier in section V.B, the EPA considered future emission projections as information to further support our assessment of annual actual emissions (recent emissions from the current fleet) for the contribution finding.

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contribute to air pollution which may reasonable be anticipated to endanger public health or welfare, it does not limit how she may undertake that assessment. It surely is reasonable that the Administrator look at how total U.S. aircraft GHG emissions and U.S. covered aircraft GHG emissions compare to U.S. and global GHG emissions on an absolute and relative basis, including ranking compared to other transportation sectors and entire country emissions. It is entirely appropriate for the Administrator to decide that part of understanding how a U.S. source category emitting GHGs fits into the bigger picture of global climate change is to determine how that source category fits into the contribution from the United States as a whole (including U.S. transportation and total U.S. inventory GHG emissions), where the United States as a country is a major emitter of GHGs. Knowing how total U.S. aircraft GHG emissions and U.S. covered aircraft GHG emissions rank compared to entire country GHG emissions is relevant to understanding what role they play in the global problem and hence whether they "contribute" to the global problem. Moreover, the Administrator is looking at these emissions comparisons as appropriate under the applicable science, facts, and law. Therefore, the EPA appropriately compared and provided sufficient context for total U.S. aircraft GHG emissions and U.S. covered aircraft GHG emissions.

d. The Administrator Reasonably Utilized Multiple Databases for Global GHG Emissions

Some commenters stated that the mix of data from different years utilizing emissions data from IPCC, WRI/CAIT, and IEA was confusing and potentially misleading. The EPA

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acknowledges that we presented data from a variety of sources, but the EPA does not agree that the analysis and presentation was misleading. We note that the global analysis for this covered aircraft contribution finding is consistent with the analytical approach originally developed and used in the 2009 Endangerment Finding. As described earlier in section IV.A, in the proposed finding and this final finding, the Administrator considers the recent, major scientific assessments of the IPCC, USGCRP, and the NRC as the primary scientific and technical basis informing her judgment. Thus, the Administrator is informed by and places considerable weight upon the IPCC's data on global GHG emissions. She places less emphasis on the WRI/CAIT and IEA emissions data, which in comparison have a different aggregation of underlying data but are available for more recent years (in comparison to the IPCC data). As described earlier in section V.B.4, the WRI/CAIT data are generally in line with the IPCC data. For 2010 total global GHG emissions, IPCC data are 49,000 Tg CO_2eq, and WRI/CAIT indicates 42,968 Tg CO_2eq (a 12 percent difference).[281] Also, for 2010 global aircraft GHG emissions, IPCC data are 743 Tg CO_2eq, and IEA data indicate 749 Tg CO_2eq (a 1 percent difference).[282]

The approach of considering the major scientific assessments, including IPCC's assessment, provides assurance that the Administrator's judgment is informed by the best available, well-vetted science that reflects the consensus of the climate science research

[281] Comparing their 2010 total global GHG emissions, IPCC data are 49,000 Tg CO_2eq, and WRI/CAIT data, including forestry and land use inventories, indicates 45,748 Tg CO_2eq (a 7 percent difference).
[282] Comparing 2012 WRI/CAIT to 2010 IPCC data, WRI/CAIT data for total global GHG emissions indicates 44,816 Tg CO_2eq for 2012 (a 9 percent difference), and including forestry and land use inventories WRI/CAIT data indicates 47,599 Tg CO_2eq for 2012 (a 3 percent difference). Comparing 2012 IEA data to 2010 IPCC data, IEA data for global aircraft GHG emissions indicates 775 Tg CO_2eq for 2012 (a 4 percent difference).

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community. The major findings of the assessments, including IPCC's assessment, support the Administrator's findings in this action. While the EPA uses the IPCC data as the primary data source for this contribution finding, it has reasonably used additional data sources from widely used and recognized global datasets to provide context and information from more recent years. These additional data supplement and confirm the IPCC data. Ultimately, whether the Agency utilizes the IPCC data alone or the WRI/CAIT dataset (and IEA data) alone, or both datasets together, it would have no material effect on the emissions comparisons discussed in section V.B and the Administrator would make the same contribution finding.

VI. 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 finalizes a finding that GHG emissions from aircraft cause or contribute to air pollution that may be reasonably anticipated to endanger public health and welfare. Any changes made in response to OMB recommendations have been documented in the docket for this action.

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B. Paperwork Reduction Act (PRA)

This action does not impose an information collection burden under the PRA. The endangerment and cause or contribute findings under CAA section 231(a)(2)(A) 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 endangerment and cause or contribute findings under CAA section 231(a)(2)(A) do not in-and-of-themselves impose any new requirements but rather set forth the Administrator's 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 findings.

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.

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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 final endangerment and cause or contribute findings under CAA section 231(a)(2)(A) do not in-and-of-themselves impose any new requirements but rather set forth the Administrator's 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 the endangerment and cause or contribute findings under CAA section 231(a)(2)(A). 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

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children is contained in sections IV.C.1.a of the preamble. 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 endangerment and cause or contribute findings under section 231(a)(2)(A) do not in-and-of themselves impose any new requirements but rather set forth the Administrator's 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

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health or the environment. The Administrator considered climate change risks to minority, low-income, and indigenous populations as part of these endangerment and cause or contribute findings under CAA section 231(a)(2)(A). This action's discussion of climate change impacts on public health and welfare is found in section IV.C of the preamble. Specific discussion with regard to minority, low-income, and indigenous populations are found in sections IV.C.1.a and IV.C.2.a of this preamble. 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. Congressional Review Act (CRA)

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

L. 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).

VII. Statutory Provisions and Legal Authority

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

List of Subjects in 40 CFR Part 87

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

List of Subjects in 40 CFR Part 1068

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

Dated:

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Gina McCarthy,

Administrator.