CLIMATE CHANGE AND THE CLEAN AIR ACT OF 1970 PART I: THE SCIENTIFIC BASIS

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Abstract

In *Massachusetts v. EPA*, the Supreme Court held that the 1970 Clean Air Act granted the Environmental Protection Agency (EPA) the authority, and attendant responsibility, to regulate greenhouse gases as air pollution. But, while the Court found the Act to "confer the flexibility necessary" to respond to "changing circumstances," the Justices expressed skepticism that legislators in 1970 would have been familiar with the climate-altering effects of CO_2 and other heat-trapping gases. At the time of the Clean

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Air Act's passage, the Court wrote, "the study of climate change was in its infancy." That statement was misleading. By the late 1960s, scientists knew that greenhouse gases, derived from fossil fuel combustion, could alter the global climate with potentially serious and deleterious ensuing effects. They also recognized that addressing the problem could have broad economic implications, including on energy production and the automobile industry. These insights led to a wide-ranging conversation between leading scientists, high-level administrators at federal agencies, members of Congress, White House staff under Presidents Lyndon Johnson and Richard Nixon, the Council on Environmental Quality, and the President's Science Advisory Committee. It specifically included architects of the Clean Air Act, including Maine Senator Edmund Muskie, Tennessee Senator Howard Baker, Jr., and West Virginia Senator Jennings Randolph. Existing literature understates the breadth and depth of relevant discussions, as well as the specific connection between 1950s and 1960s–era climate science and air pollution research and regulation.

This Article reviews this history and its role in the passage of the Clean Air Act of 1970. We demonstrate (1) that scientists had by 1970 established the concern that greenhouse gases emitted into the atmosphere as a waste product of burning fossil fuel — in other words, as a pollutant — could alter the global climate with potentially destructive effects; (2) that this concern was extensively communicated to both the executive and legislative branches of the U.S. federal government; and (3) that it was specifically and explicitly discussed in hearings pursuant to consideration and passage of the Clean Air Act.

This history has important implications for the scope of EPA's authority under the Clean Air Act in light of the Court's fortification of the major questions doctrine in *West Virginia v. EPA*. By requiring a threshold determination of clear congressional intent to delegate authority in areas of "vast economic and political significance," the new major questions doctrine begets a novel type of legal-historical methodology that is distinct from both that of the era of strong purposivism and its textualist successor. We advance a template for the kind of historical analysis that may need to become standard in a post-West Virginia world.

Introduction

On July 16, 1970, Nixon aide John C. Whitaker received a set of documents from the newly created Council on Environmental Quality. One item specifically caught his attention. "Man's Inadvertent Modification of Weather and Climate" presented what Whitaker called a "particularly hairy" problem: the capacity for humans to alter the long-

term trajectory of the earth's climate.[2] By trapping heat in the atmosphere, the report warned, "carbon dioxide pollution" would alter the balance of the "atmosphere's energy which determines weather and climate."[3] Pollution from a gas produced by daily activities — burning coal in power plants to produce electricity, burning gasoline to run cars — could raise the surface temperature of the planet and reshape the world's geography.

Three and a half decades later, in *Massachusetts v. EPA,*[4] the Supreme Court held that the 1970 Clean Air Act granted EPA the authority, and responsibility, to regulate CO_2 as air pollution.[5] The Court found the definition of air pollution to be "capacious," and the Act as a whole to "confer the flexibility necessary" to respond to "changing circumstances" in the rapidly evolving scientific study of air pollution and its control.[6] Nevertheless, the Justices expressed skepticism that legislators in 1970 would have been familiar with the climate-altering effects of CO_2. At the time of the Clean Air Act's passage, the Court wrote, "the study of climate change was in its infancy."[7]

That statement was misleading. As early as the 1950s, scientists referred to CO_2

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[2] John C. Whitaker to William M. Magruder, July 20, 1970, John C. Whitaker papers (WHCF:SMOF), b. 43, f. Annual Report-CEQ 1 of 2, Richard Nixon Presidential Library, Yorba Linda, California [*hereinafter* RNPL].
[3] Council on Environmental Quality First Annual Report (Draft), July 14, 1970, John C. Whitaker papers (WHCF:SMOF), b.12, f. 2 of 6, Presidential State of the Union/Environmental Message 1/6 Draft of the First Annual Report of the CEQ, RNPL.
[4] *Massachusetts v. EPA*, 549 U.S. 497 (2007).
[5] *Id*. at 532.
[6] *Id.*
[7] *Id.* at 507. Justice Stevens may have been inspired by the 1970 CEQ Report itself, which stated that the "science and technology of weather modification are only in their infancies." COUNCIL ON ENVIRONMENTAL QUALITY, FIRST ANNUAL REPORT OF THE COUNCIL ON ENVIRONMENTAL QUALITY 93 (August 1970). But this was in reference to the idea of using science for purposes of deliberate weather modification, the efficacy of which was highly contested.

as "industrial pollution," and compared it with other industrial pollutants including particulate matter and sulfur dioxide.[8] Many members of the federal government, including legislators involved in the passage of the Clean Air Act, were aware of the potential for CO_2 to alter both local weather and global climate in adverse ways.[9] While much more would be learned in the decades to come, already by the late 1960s scientists knew that greenhouse gases, derived from fossil fuel combustion, could alter the global climate with potentially serious and deleterious ensuing effects. They also recognized that addressing the problem could have wide-ranging economic implications, including on energy production and automobiles. These insights led to a wide-ranging conversation between leading scientists, high-level administrators at federal agencies, members of Congress, White House staff under Presidents Lyndon Johnson and Richard Nixon, the Council on Environmental Quality, and the President's Science Advisory Committee. It specifically included architects of the Clean Air Act, including Maine Senator Edmund Muskie, Tennessee Senator Howard Baker, Jr., and West Virginia Senator Jennings Randolph.

Discussion of CO_2 and climate also appeared in reports and congressional hearings on environmental problems more broadly, including in relation to intentional

[8] E. WENDALL HEWSON, SCI. REP. NO. 1: SOME ASPECTS OF THE DISPERSION OF POLLENS AND INDUSTRIAL CONTAMINANTS IN RELATION TO MICROMETEOROLOGY 39 (October 1953) (Project 2160, Geophysics Research Division, Air Force Cambridge Research Center, Contract No. AF 19(604)-792).

[9] *See, e.g.*, 116 Cong. Rec. 32,901 (1970) (statement of Sen. Edmund Muskie) (warning that air pollution, if not controlled, would "threaten irreversible atmospheric and climatic changes"); *Report of the Council on Environmental Quality: Hearing Before the Senate Subcom. on Air and Water Pollution of the S. Comm. On Pub. Works*, 91st Cong., 2nd Sess. 5 (1970) (statement of Russell Train, Chairman, Council of Environmental Quality) (testifying that the "international dimensions of the air pollution problem should not be overlooked . . . [as] discharge of particulates and carbon dioxide to the atmosphere could have dramatic and long-term effects on the world's temperature with many major consequences").

weather modification, nuclear energy, the development of supersonic aviation, and space exploration. CO_2, climate, and the greenhouse effect were discussed in scores of Congressional hearings, including those specifically related to the consideration and drafting of the 1970 Clean Air Act (CAA). The impact of CO_2 on climate was a major subject in the first report of the Council on Environmental Quality, released in draft form in 1969 and entered into Congressional testimony as part of the hearings for the 1970 Act.[10] The topic was the subject of a wide variety of scientific papers and reports, several of which were transmitted to the Executive Branch and communicated to Congress in the 1960s and in 1970, particularly but not only in the context of urban air pollution.[11] Concern about CO_2 pollution also made its way into film and television, including during an interview with President Nixon's Science Advisor on *Meet the Press* in 1969.[12]

This history has important implications for the scope of EPA's authority under the Clean Air Act. The Court's new articulation of the major questions doctrine in *West Virginia v. EPA*[13] sets up what is essentially an historical inquiry: in those "extraordinary cases" in which an agency asserts control over issues of "vast economic and political significance,"[14] the Court must closely scrutinize the extent to which Congress delegated

[10] *See* COUNCIL ON ENV'T QUALITY, FIRST ANNUAL REPORT OF THE COUNCIL ON ENVIRONMENTAL QUALITY (August 1970); 91 Cong. Rec. 32,908–17 (Sept. 21, 1970).
[11] *See, e.g.*, ENV'T POLLUTION PANEL OF THE PRESIDENT'S SCI. ADVISORY COMM., RESTORING THE QUALITY OF OUR ENVIRONMENT 113 (1965); NAT'L SCI. FOUND., WEATHER MODIFICATION: TENTH ANNUAL REPORT, 1968 (1969); PRESIDENT'S TASK FORCE ON AIR POLLUTION, CLEANER AIR FOR THE NATION (1970); STUDY OF MAN'S IMPACT ON CLIMATE, INADVERTENT CLIMATE MODIFICATION: REPORT OF THE STUDY OF MAN'S IMPACT ON CLIMATE (1971).
[12] *Meet the Press* (NBC television broadcast Dec. 28, 1969) (interview with Lee A. DuBridge, Director, Office of Science and Technology).
[13] *West Virginia v. EPA*, No. 20–1530 (June 30, 2022).
[14] *Id.* at 11 (quoting *Utility Air Regulatory Grp. v. EPA*, 573 U.S. 302, 324 (2014)).

its legislative authority.[15] Significant greenhouse gas regulations pose one such major question, and the answer the Court requires now comes in the form of a clear statement from Congress in the statutory text. What counts as clarity, however, depends on both "context"[16] and "history."[17] A major-questions-doctrine inflected interpretation of terms in the 1970 Act such as "weather and climate"[18] and "best system of emissions reduction"[19] thus involves recourse to the historical record to glean a "practical understanding of legislative intent."[20]

Yet, neither the majority nor the dissent in *West Virginia* seriously engaged with the historical understanding of global climate change at the time of the 1970 Clean Air Act's passage. The majority used history primarily to argue that EPA had only rarely invoked the main statutory provision at issue in the case; the dissent conceded that in 1970 climate change was a problem that Congress "knew it couldn't then know."[21] The majority's historical analysis is largely irrelevant, and the dissent's is incorrect. Scientists and government officials knew a great deal about global climate change in the 1960s and 1970s, and the architects of the Clean Air Act understood the "vast economic and political significance" of the legislation they were constructing and the task with which they entrusted the EPA in its inaugural year. When Senator Muskie, the Act's preeminent advocate, introduced the 1970 amendments on the floor of the US Senate, he warned his

[15] *Id.* at 17 (quoting *Brown & Williamson Tobacco Corp*. v. FDA, 529 U.S. 120, 159 (2000)).
[16] *Id.* at 16 (quoting *Davis v. Michigan Dept. of Treasury*, 489 US. 803, 809 (1989)).
[17] *Id.* at 17 (quoting *Brown & Williamson*, 529 U.S. at 159).
[18] 42 U.S.C. § 7602(h).
[19] 42. U.S.C. § 7411(a)(1).
[20] *West Virginia v. EPA*, No. 20–1530 (June 30, 2022) at 19.
[21] *Id.* at 27 (Kagan, J., dissenting).

colleagues that air pollution, if unchecked, would continue to "threaten irreversible atmospheric and climatic changes."[22] The evidence collected in this Article shows that Senator Muskie's words were not mere offhand remarks. They formed part of a broader narrative that extended beyond the formal legislative history of the 1970 Clean Air Act and that helps to define the original public meaning of "weather and climate" as used in the amendments themselves.

Historians have studied the early history of climate science, but there has been relatively little work on scientific communications with government in this early history.[23] Historian Joshua Howe has identified the early 1960s as a period when scientists were gaining an understanding of the potential adverse effect of increased atmospheric CO_2[24]; Paul Edwards has documented the rise of computer modeling beginning in the late 1960s as a key tool of climate research.[25] Highlighting a 1963 meeting convened by the Conservation Foundation, Spencer Weart notes that in the 1960s increased atmospheric CO_2 was explicitly framed as an environmental problem requiring attention.[26]

Scholars have also examined connections between climate science in the 1950s and 1960s and nuclear weapons research, the emergence of global atmospheric

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[22] 116 Cong. Rec. 32901 (1970) (statement of Sen. Edmund Muskie).
[23] *See generally* JAMES R. FLEMING, HISTORICAL PERSPECTIVES ON CLIMATE CHANGE (1998); SPENCER WEART, THE DISCOVERY OF GLOBAL WARMING (Revised and Expanded Edition 2008); PAUL N. EDWARDS, A VAST MACHINE: COMPUTER MODELS, CLIMATE DATA, AND THE POLITICS OF GLOBAL WARMING (2013); DEBORAH R. COEN, CLIMATE IN MOTION: SCIENCE, EMPIRE, AND THE PROBLEM OF SCALE (2018); NAOMI ORESKES, SCIENCE ON A MISSION: HOW MILITARY FUNDING SHAPED WHAT WE DO AND DON'T KNOW ABOUT THE OCEAN (2021).
[24] *See generally* JOSHUA HOWE, BEHIND THE CURVE: SCIENCE AND THE POLITICS OF GLOBAL WARMING (2014).
[25] *See generally* EDWARDS, *supra* note 22.
[26] WEART, *supra* note 22.

monitoring, and applied research in weather modification.[27] They have also linked developments in climate science to the rise of the global environmental movement in the late 1960s and early 1970s, particularly in the context of the 1972 UN Conference on the Human Environment in Stockholm. Political scientist David Hart has examined early climate knowledge in the federal government, including discussions in certain congressional debates from the 1950s through the 1970s.[28]

Existing literature, however, understates the breadth and depth of relevant discussions, as well as the specific connection between 1950s and 1960s-era climate science and air pollution research and regulation. To the extent lawyers and legal scholars have acknowledged a connection between climate science, air pollution, and the 1970 Clean Air Act, they have tended to either focus on scant data or begin their analysis later in the 1970s.[29] A recent retrospective masterfully chronicles the legislative machinations and political climate that spawned the 1970 Act, but makes hardly any mention of climate

[27] On nuclear power, see Paul N. Edwards, *Entangled Histories: Climate Science and Nuclear Weapons Research*, 68 BULLETIN OF THE ATOMIC SCIENTISTS 28 (2012). On weather modification and prediction, see KC HARPER, MAKE IT RAIN: STATE CONTROL OF THE ATMOSPHERE IN TWENTIETH CENTURY AMERICA (2017).

[28] David Hart, *Strategies of Research Policy Advocacy: Anthropogenic Climatic Change Research, 1957-1974*, Discussion Paper 92-08, Center for Science and International Affairs at Harvard's Kennedy School of Government (1992).

[29] For example, Christopher Ahlers examined papers published in a 1968 issue of the Arizona Law Review on the issue of air pollution and characterized a statement about the long-term possibility of overloading the earth's atmosphere with CO_2 and radioactive materials as "an avant garde observation for students of global warming." Christopher D. Ahlers, *Origins of the Clean Air Act: A New Interpretation*, 45 ENV'T L. 125, 125 n.391 (2015). To say that such a statement was "avant garde," however, overlooks the robust published scientific literature and political debate of the time. Professor James Speth dives deeper into the extent of early governmental knowledge of climate change, but he largely begins his story in the Carter Administration. JAMES GUSTAVE SPETH, THEY KNEW: THE US FEDERAL GOVERNMENT'S FIFTY-YEAR ROLE IN CAUSING THE CLIMATE CRISIS (2021). Our question is what the U.S. government knew in 1970, at the time the Act was written and passed.

change.[30] In one of the few papers to address the question in depth, Professor Richard Revesz has studied many of the legislative materials surrounding the Clean Air Act's passage in 1970 and concluded that members of Congress were "aware of and concerned about the adverse impact of air pollutants, particularly greenhouse gases like carbon dioxide, on global warming and climate change."[31] We agree with Revesz's interpretation of these materials and with his argument that the careful study of history should "definitively resolve" the question of whether greenhouse gases are within the ambit of the Clean Air Act.[32] Yet, absent an understanding of the broader historical context within which to situate these congressional materials, the door may still be left open for unfounded doubts about the original meaning of the statutory text.

The question becomes acute in the context of *West Virginia v. EPA*, where the primary statutory question was not whether the Clean Air Act covers carbon dioxide, but rather whether a "best system of emissions reduction" could include a cap-and-trade style regulation for greenhouse gases. In holding that Congress had not spoken with sufficient

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[30] *See generally* Brigham Daniels et al., *The Making of the Clean Air Act*, 71 HASTINGS L.J. 901 (2020). For further iterations of what Professor Daniels et al. refer to as the "told history" of the Clean Air Act, see generally CHRISTOPHER J. BAILEY, CONGRESS AND AIR POLLUTION: ENVIRONMENTAL POLICIES IN THE USA (1998); RICHARD J. LAZARUS, THE MAKING OF ENVIRONMENTAL LAW (2004); RICHARD N.L. ANDREWS, MANAGING THE ENVIRONMENT, MANAGING OURSELVES (3d Ed. 2020); E. Donald Elliott et al., *Toward a Theory of Statutory Evolution: The Federalization of Environmental Law*, 1 J.L. ECON. & ORG. 313 (1985); Jody Freeman & David B. Spence, *Old Statutes, New Problems*, 163 U. PA. L. REV. 1 (2014); Richard J. Lazarus, *Senator Edmund Muskie's Enduring Legacy in the Courts*, 67 ME. L. REV. 240 (2015); Robert V. Percival, *Environmental Federalism: Historical Roots and Contemporary Model*s, 54 MD. L. REV. 1141 (1995); Joseph L. Sax, *Environmental Law at the Turn of the Century: A Reportorial Fragment of Contemporary History*, 88 CALIF. L. REV. 2375 (2000); Russell E. Train, *The Environmental Record of the Nixon Administration,* 26 PRESIDENTIAL STUD. Q. 185 (1996). On the history of the 1970 Act's 1963 predecessor, see generally Adam D. Orford, *The Clean Air Act of 1963: Postwar Environmental Politics and the Debate over Federal Power*, 27 HASTINGS ENV'T L.J. 1 (2021).

[31] Richard L. Revesz*, Bostock and the End of the Climate Change Double Standard*, 46 COLUM. J. ENV'T L. 1, 33 (2020).

[32] *Id.* at 6.

clarity to authorize such broad-based regulation, the Court argued that EPA's development of an economy-wide "system" to address greenhouse gas pollution stretched the statutory authorization beyond any "practical understanding of legislative intent."[33] The Court is certainly correct to note that word-for-word authorization of a cap-and-trade program for greenhouse gases does not exist in the Clean Air Act. Indeed, scientists and policymakers of the early 1970s could not have anticipated the precise developments in climate science over the past fifty years. They did, however, understand the key problems in the field and anticipated the increasing concern over climate modification that has materialized over the last half century.

Our claim in this Article is that the history of climate science and the Clean Air Act complicates the major questions analysis in *West Virginia*, rendering it far more difficult than either the majority or dissent recognized. We also advance a template for the kind of historical analysis that may need to become standard in a post-*West Virginia* world. The new major questions doctrine begets a novel type of legal-historical methodology that is distinct from both that of the bygone era of legislative history[34] and that of the new textualism.[35] Its implications are still being fully understood. Further, we express no normative view about the administrative state — our aim is to understand the Clean Air Act and the precise form of delegation that Congress envisioned when it passed the Act in 1970. What becomes clear is that global climate change was far more closely

[33] *West Virginia v. EPA*, No. 20–1530, at 19 (June 30, 2022).
[34] *See, e.g.*, William N. Eskridge, Jr., *Legislative History Values*, 66 CHICAGO-KENT L. REV. 365 (1990).
[35] *See, e.g.*, John F. Manning, *Second-Generation Textualism*, 98 CALIF. L. REV. 1287 (2010); John F. Manning, *What Divides Textualists from Purposivists?*, 106 COLUM. L. REV. 70 (2006); William N. Eskridge, Jr. *The New Textualism*, 37 UCLA L. REV. 621 (1990).

linked to the original legislation than the Court in *West Virginia* appreciated.

Our review of the historical evidence demonstrates (1) that scientists had by 1970 established the concern that greenhouse gases emitted into the atmosphere as a waste product of burning fossil fuel—in other words, as a pollutant--could alter the global climate with potentially serious and deleterious effects; (2) that this concern was extensively communicated to both the executive and legislative branches of the U.S. federal government; and (3) that it was specifically and explicitly discussed in hearings pursuant to consideration and passage of the Act. In this Article, we document the extent of scientific knowledge of global climate change in the decades leading up to the passage of the Clean Air Act. In a subsequent Article, we will further analyze the through-lines between this scientific understanding and specific debates in Congress over air pollution and the linked environmental crises the Clean Air Act was meant to solve. Scientists in the 1960s and early 1970s understood the "vast economic and political significance" of their work; interpretation of the Clean Air Act cannot be unbundled from these prevailing considerations.

Part I provides a critical overview of the history of climate science since John Tyndall and Svante Arrhenius theorized and quantified the greenhouse effect. We show that robust discussions of carbon dioxide, the greenhouse effect, and global warming were undertaken by prominent scientists and were not an obscure scientific backwater. Part II focuses on the articulation of the "Carbon Dioxide Problem" by scientists and policymakers in the 1960s, centering on several key collaborative ventures across research and policy. Part III analyzes the emergent designation of carbon dioxide as a

form of "air pollution" and its legal significance. Crucial to this Part are the ways in which industry scientists contributed to early understandings of climate change and worked extensively with their governmental counterparts. Parts II and III together establish how academic, governmental, and industry-based scientists conceptualized global climate change in the 1950s and 1960s, and their premonitions of its "vast economic and political significance." Part IV turns to international efforts to address global environmental crises and reveals the extent to which CO_2 as air pollution figured in events such as the preparations for the 1972 UN Stockholm Conference on the Human Environment and several high-profile academic-governmental reports. Finally, Part V presents the little-known cultural uptake of climate issues in the 1950s and 1960s, including a film by Frank Capra and televised interview with Allen Ginsberg. Climate change was an object of scientific study, political discourse, and societal interest — to a lesser extent than today, but to a degree that is often forgotten. The precise legal significance of this information may be debated, but the historical record is clear: any suggestion that Congress did not—or worse, could not—have known in 1970 about CO_2, the greenhouse effect, and anthropogenic climate change is demonstrably false.

I. A Century of Climate Science

"Man as a geological agent"

Scientists have known since the mid 19th century that carbon dioxide (CO_2) is a "greenhouse gas," meaning that it is highly transparent to visible light but relatively

opaque to infrared radiation.[36] The "greenhouse effect" refers to the fact that sunlight reaching the Earth penetrates the atmosphere and warms the planet, but when that warmth is re-radiated back to space, some of it is trapped by greenhouse gases, the most important of which are atmospheric water vapor and CO_2. The physical basis of the greenhouse effect was established in 1859 by Irish physicist John Tyndall.[37] Tyndall noted the implications of this discovery to climatic changes and, following this work, scientists deduced that changing atmospheric CO_2 concentrations could alter the planetary climate. In the late nineteenth century, America's most famous geologist, T. C. Chamberlin (1843-1928), invoked changing CO_2 from natural causes to explain the ice ages.[38] (More CO_2 would warm the planet; less would cool it.) Around the same time, the Nobel Laureate Svante Arrhenius—one of the founders of the science of chemical thermodynamics—suggested that there was an additional factor to consider: changing atmospheric CO_2 concentration might also occur from unnatural causes, specifically burning fossil fuels.[39] Such combustion—at the time primarily from coal—added CO_2 to the atmosphere, which would have a net warming effect.

Arrhenius produced the first quantitative estimate of the effect of increased CO_2,

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[36] *See generally*, WEART, FLEMING *supra* note 22.
[37] John Tyndall, *The Bakerian Lecture—On the Absorption and Radiation of Heat by Gases and Vapours, and on the Physical Connexion of Radiation, Absorption, and Conduction*, 151 PHIL. TRANS. 1 (1861).
[38] *See generally,* T.C. Chamberlin, *A Group of Hypotheses Bearing on Climatic Change*, 5 J. GEO 653 (1897); T.C. Chamberlin, *The Influence of Great Epochs of Limestone Formation upon the Constitution of the Atmosphere*, 6 J. GEO 609 (1898); T.C. Chamberlin, *An Attempt to Frame a Working Hypothesis of the Cause of Glacial Periods on the Atmospheric Basis,* 7 J. GEO. 545 (1899).
[39] Svante Arrhenius, *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground*, 5 PHIL. MAG. & J. OF SCI. 237 (1896); Svante Arrhenius, *Über die wärmeabsportion Durch Kohlensäure,* 58 FOR. SVEN. VETEN. 25 (1901); Svante Arrhenius, *Über die wärmeabsorption durch kohlensäure*, 309 ANNAL. DER PHY. 690 (1901). Svante Arrhenius, LEHRBUCH DER KOMISCHEN PHYSIK 2 (1903). Both Chamberlain and Arrhenius were prominent, distinguished scientists, whose ideas were widely circulated, and in 1903 Arrhenius won the Nobel Prize. *See also generally,* WEART, *supra* note 22.

finding that doubling the atmospheric concentration would heat the planet by 1.5-4.5 º C (2.7-8.1 F).[40] In other words: the planetary climate was highly sensitive to changes in CO_2. The effect of doubling its concentration (once the climate system had had time to equilibrate with the new conditions) would come to be called the "equilibrium climate sensitivity."[41] In 1896, Arrhenius did not necessarily think that planetary warming would be detrimental. Moreover, at prevailing combustion rates the effects would not be discernible for several millennia (although a decade later rates had increased enough for him to revise that to centuries).[42]

In 1900, fellow Swedish scientist Knut Ångström published findings that challenged Arrhenius' central assertions. Ångström's research on solar radiation was pioneering in the field of spectroscopy: the study of how gases absorb and emit heat and light at specific wavelengths known as spectral absorption bands. In a simple laboratory experiment, he determined that only a small amount of CO_2 appeared sufficient to saturate its heat absorption bands, so further additions would have little or no effect. Moreover, infrared radiation is also absorbed by water vapor, and the CO_2 absorption bands appeared to overlap with those of water vapor. Since there is far more water vapor in Earth's atmosphere than there is CO_2, Ångström argued that any effect of small changes in CO_2 would be overwhelmed by the much larger effect of water vapor, and so

[40] Arrhenius, *supra* note 38 at 237.
[41] *Id. See also generally* WEART, *supra* note 22 at 5-6.
[42] WEART, *supra* note 22, at 5-8; Luke Skinner, *A Long View on Climate Sensitivity*, 337 SCIENCE 917 (2012).

climate change from burning fossil fuels was unlikely to be significant and increased atmospheric CO_2 would not be a problem.[43]

The following year, Arrhenius published a lengthy refutation of Ångström's paper, claiming the latter had treated the atmosphere as it if were homogenous, when in fact it is layered. He argued that if the upper atmosphere was very dry—as meteorological work suggested it was—then additional CO_2 there could have an impact. It became evident that more work was needed to understand the structure of the atmosphere and distribution of heat-absorbing gases in it.[44]

Arrhenius' theories largely fell out of favor following the Ångström refutation, but his work was replicated in 1930 by U.S. Naval Research Lab physicist E.O. Hulburt, who concluded that the temperature effect of increased CO_2 was sufficiently great as to offer a plausible mechanism of major planetary climatic change. Hulburt noted that "an increase or decrease in world-wide average atmospheric temperatures of a few degrees would give rise to other changes," including increasing atmospheric water vapor, which would further increase the greenhouse effect, affecting vegetation, snow fields, and the CO_2 content of the ocean.[45] However, he shared Angström's concern about the spectral overlap with water vapor. He presented data that suggested the spectral overlap was only partial, but concluded more work was needed, as well as on the question of how much

[43] Knut Ångström, *Über die bedeutung des wasserdampfes und der kohlensaüres bei der absorption der erdatmosphäre*, 308 ANNAL. DER PHY. 720 (1900); WEART, *supra* note 22 at 7-8.
[44] Svante Arrhenius, *Über die wärmeabsorption durch kohlensäure*, 309 ANNAL. DER PHY. 690 (1901); James Fleming, *T.C. Chamberlin, Climate Change, and Cosmogony*, 31 STUD. HIST. PHIL. MOD. PHYS. 293, 299-300 (2000).
[45] E.O. Hulburt, *The Temperature of the Lower Atmosphere of the Earth*, 38 PHYS. REV. 1876, 1890 (1931)

CO_2 would be absorbed by the oceans or taken up by plants.[46]

By the turn of the century there was scientific support for the idea that increased atmospheric CO_2 would impact the earth's temperature—but debates continued over what the effects would be and when they would occur. In 1923, British geologist R. L. Sherlock published *Man as a Geological Agent*. The book's thesis was that humans were changing the planetary environment on a scale that rivalled geological processes. He discussed a wide variety of human impacts, including afforestation and deforestation, farming, erosion, mining and quarrying, dams and harbors, and climate change. Drawing on Chamberlin and Arrhenius, Sherlock devoted his final chapter to CO_2-induced climate change. Chamberlin had theorized that CO_2 removal from the atmosphere by natural causes could have caused the Permian glaciation; if this were true, then a "reversal of the process" by unnatural (i.e. human) causes—as suggested by Arrhenius—could lead to global warming.[47] Sherlock summarized: "Arrhenius thought that if the amount of carbon dioxide in the air were increased three-fold, the temperature of the Arctic regions would rise by 8 or 9^{o} C."[48]

In the 1930s, the topic was taken up by British engineer Guy Stewart Callendar. Compiling existing data on atmospheric CO_2 and global temperatures, Callendar concluded that coal combustion was adding CO_2 to the atmosphere and that a modest

[46] *Id.*
[47] R. L. SHERLOCK, MAN AS GEOLOGICAL AGENT: AN ACCOUNT OF HIS ACTION ON INANIMATE NATURE 302-305 (1922)
[48] *Id.* at 302.

warming trend was already underway.[49] In a 1940 paper he noted the observed CO_2 increase—about 30 ppm since the late 19th century—was consistent with the known amount of coal and oil burned, about 50,000 million tons.[50] This suggested that the oceans had not absorbed much of the CO_2 released to the atmosphere; he attributed this to the slow rate of vertical ocean circulation and concluded that it would "doubtless take many centuries" before ocean CO_2 absorption would have an appreciable mitigating effect.[51] For the present, the CO_2 released to the atmosphere appeared mostly or entirely to stay in the atmosphere, where it would have a warming effect. [52] In the coming years, the relationship between CO_2 on climate was often called the "Callendar question," and the impact of CO_2 on climate "the Callendar effect."[53]

Post-War Work at the Ford Motor Company, the Scripps Institution of Oceanography, & the Oak Ridge National Laboratory

American scientists turned to the Callendar question in the 1950s when increased post-war funding for both basic and applied research made it possible to address the question in a sustained and rigorous way. A key figure in advancing understanding of CO_2 and climate was Gilbert Plass, because his work resolved the dispute between

[49] G. S. Callendar, *The Artificial Production of Carbon Dioxide and its Influence on Temperature*, 64 Q. J. ROY. MET. SOC. 223 (1938); G.S. Callendar, *Can Carbon Dioxide Influence Climate?*, 4 WEATHER 310 (1949).
[50] G.S. Callendar, *Variations of the amount of carbon dioxide in different air currents*, 66 Q. J. ROY. MET. SOC. 395, 399 (1940).
[51] *Id. at* 400.
[52] *Id. at* 395. Callendar continued publishing on this topic for the next decade: a paper on the spectral absorption issue, a 1942 note on the relation of air temperature and the growth and retreat of glaciers, and a 1945 paper on variation in winter temperatures.
[53] JAMES ROGER FLEMING, THE CALLENDAR EFFECT: THE LIFE AND WORK OF GUY STEWART CALLENDAR (1898-1964) xiii-xv (2007).

Arrhenius and Angström over spectral absorption and established that increased atmospheric CO_2 would, in time, warm the planet with potentially serious adverse effects.[54]

Plass was a Harvard trained physicist who began his career working for the Manhattan Project at the University of Chicago from 1942-1945, after which he took an instructor position at Johns Hopkins, and received his PhD in physics from Princeton in 1947.[55] His specialty was infrared radiation; while at Johns Hopkins his work was funded by the U.S. Office of Naval Research.[56]

Infrared radiation was of interest to the defense industry for its significance to weather forecasting, imaging in the infrared spectrum, and heat-seeking missiles, and so both the US military and the aerospace industry actively sought to understand CO_2 theory. In 1955 Plass left academia for industry—first, as a staff scientist at Lockheed Aircraft Corporation and then as a member of the advanced research staff at the Aeronutronic division for Ford Motor Company. By 1960, Plass was the manager of the theoretical physics research group at Ford, where he had the laboratory facilities to continue his work on infrared physics, carbon dioxide theory, and computer modelling.[57]

In a set of papers published in the mid 1950s, Plass replicated Arrhenius and

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[54] WEART, *supra* note 22, at 23-24.
[55] *Gilbert Plass,* ATOMIC HERITAGE FOUNDATION, https://www.atomicheritage.org/profile/gilbert-plass (last visited June 1, 2022).
[56] WEART, *supra* note 22, at 22.
[57] James Rodger Fleming, Gavin Schmidt, and Gilbert Plass, *Carbon Dioxide and the Climate*, 98 AM. SCI. 58 (2010). Plass was not the only scientist in the 1950s to study CO_2 absorption bands. *See* L.D. Kaplan and D.F. Eggers Jr., *Intensity and Line-Width of the 15-Micron CO_2 Band, Determined by a Curve-of-Growth Method*, 25 J. CHEM. PHYS. 876 (1956); H.J. Kostkowski and L.D. Kaplan, *Absolute Intensities of the 721 and 742 cm^{-1} Bands of CO_2,* 26 J. CHEM. PHYS. 1252 (1959); and H.J. Kostkowskil, J. Overend, M.J. Youngquist, and E.C. Curtis, *Vibrational Intensities. XI. CO_2 and the Wilson-Wells Method*, 30 J. CHEM. PHYS. 532 (1959).

Hulburt's calculations and found that doubling CO_2 would warm the planet by 3.6 º C, a magnitude sufficient to explain past ice ages.[58] He noted a key difference between past planetary changes, which were oscillatory, and the present steadily warming trend caused by human activity the Earth was now experiencing: "The extra CO_2 released into the atmosphere by industrial processes and other human activities may have caused the temperature rise during the present century. In contrast with other theories of climate, the CO_2 theory predicts that this warming trend will continue, at least for several centuries."[59] A temperature change of "perhaps only four degrees" would be sufficient to "bring a tropical climate to most of the Earth's surface."[60] While Plass was unclear on whether or not industrial CO_2 had already had an effect, he concluded there was "no doubt" that it would in time have a "profound influence on our climate."[61] Unless something changed dramatically in the future, CO_2-driven climate change was a matter of when, not if.[62]

Crucially, Plass resolved the dispute between Arrhenius and Angström over the potential effect of added CO_2 in the atmosphere. Advances in spectroscopy permitted him to resolve the spectral lines to a fine greater degree than previously achieved and show

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[58] Gilbert Plass, *A Method for the Determination of Atmospheric Transmission Functions from Laboratory Absorption Measurements*, 42 J. OPT. SOC. AM. 677 (1952); Gilbert Plass, *Parallel-Beam and Diffuse Radiation in the Atmosphere*, 9 J. Atmo. Sci. 429 (1952); Gilbert Plass and D.I. Fivel, *Influence of Doppler Effect and Damping on Line-Absorption Coefficient and Atmospheric Radiation Transfer* 117 ASTROPHYS. J. 225 (1953); Gilbert Plass, *Regions of Validity of Various Absorption-Coefficient Approximations*, 11 J. MET. 163 (1954); Gilbert Plass and D.I. Fivel, *The Influence of Variable Mixing Ratio and Temperature on the Radiation Flux,* 81 Q. J ROY. MET. SOC. 48 (1955); Gilbert Plass, *The Influence of the 9.6 Micron Ozone Band on the Atmospheric Infra-red Cooling Rate*, 82 Q. J. ROY. MET. SOC. 30 (1956).
[59] Gilbert Plass, *The Carbon Dioxide Theory of Climatic Change,* 8 TELLUS 140 (1956)
[60] Gilbert Plass, *Carbon Dioxide and the Climate*, 44 AMERICAN SCIENTIST 302, 305 (1956).
[61] *Id.* at 312.
[62] Plass wrote a popular version of this work, Gilbert Plass, Carbon Dioxide and Climate, 201 SCIENTIFIC AMERICAN 41 (1959).

that the spectral overlap was not complete. That meant that Angström's objection was wrong: increased CO_2 would almost certainly warm the planet. The question was how much and how soon?

Plass's work—and its link to industrial activity—was picked up by the *New York Times* in an article entitled "How Industry May Change Climate."[63] In the coming years, Plass communicated his work in both specialist and popular scientific journals, including *American Scientist* and *Scientific American*.[64] In 1959 in *Scientific American*, he explained that humans had burned enough fossil fuel to add about 360 billion tons of CO_2 to the atmosphere, which the theory predicted should warm the planet by one degree Fahrenheit. "This is almost exactly the average increase recorded all over the world during the past century!"[65] Plass specifically called the heating effect of CO_2 "the greenhouse effect," and reiterated that the effect would not be negated by water vapor.[66] As Sherlock had earlier, Plass argued that humans were now acting as a "new geological force...by burning fossil fuels," and it was possible to predict quantitatively what impact this would have: "If fuel consumption continues to increase at the present rate, we will have sent more than a trillion tons of carbon dioxide into the air by the year 2000. This should raise the earth's average temperature 3.6 degrees [F]."[67] The evidence suggested

[63] W. K, *How Industry May Change Climate*, NEW YORK TIMES, May 24, 1953, at E11.
[64] Gilbert Plass, *supra* note 61.
[65] *Id.* at 46 (1959).
[66] *Id.* at 41, itals added.
[67] *Id*. at 46. Plass also notes the possibility of ocean acidification, but discounts it, one the grounds of the large volume of water in the ocean: "Meanwhile the carbon dioxide content of the oceans will have doubled. This raises an incidental question about the welfare of sea organisms. We know that an increase in carbon dioxide concentration increases the acidity of water, and that many marine animals are extremely sensitive to changes in acidity. However, if the carbon dioxide content of the air were to increase sevenfold, the acidity (pH) of sea water would not rise more than .5 above its present value. Thus, changes in carbon

that that the oceans took up at most "about half of any carbon dioxide added to the air.[68] The oceans would slow global warming, but they would not stop it.

At the Scripps Institution of Oceanography, oceanographer Roger Revelle and physicist Hans Suess—a pioneer in carbon-14 dating—were also analyzing the link between CO_2, climate, and fossil fuel combustion. Building on Suess' previous work on C-14, they confirmed Plass's estimate that about half the CO_2 released from burning fossil fuels since the industrial revolution was now in the oceans.[69] But that meant that the other half was accumulating in the atmosphere or taken up by plants that would return the CO_2 when they died. In other words, the buildup of atmospheric CO_2 was happening very quickly—on the scale of years to decades. This dramatically contrasting with the amount of time it had taken to accumulate the source carbon in fossil fuels. Revelle and Suess thus observed that by "returning to the atmosphere and oceans the concentrated organic carbon stored in sedimentary rocks over hundreds of millions of years," humans were performing "a large scale geophysical experiment" on the planet. Revelle did not think the results of this experiment were likely to be good.[70] According to an interview in TIME magazine he believed that the added carbon dioxide pollution from burning fossil fuels could have "a violent effect on earth's climate."[71]

Revelle's concern was shared by the director of Oak Ridge National Laboratory,

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dioxide concentration, which have such a profound effect on climate, will probably not disturb future marine life. Perhaps only man will be uncomfortable" (at 47).

[68] *Id.* at 46, itals added

[69] Roger Revelle and Hans E. Suess, *Carbon Dioxide Exchange Between Atmosphere and Ocean and the Question of an Increase of Atmospheric CO2 during the Past Decades*, 9 TELLUS 18, 19 (1957).

[70] *Id.*

[71] *Science: One Big Greenhouse*, TIME, May 28, 1956. See also, Lloyd Norman, *Fumes Seen Warming Arctic Seas,* THE WASHINGTON POST AND TIMES HERALD, March 19, 1956, at 3.

Alvin Weinberg. The two worked together on the President's Scientific Advisory Council (PSAC) panel, *Scientific Progress, the Universities, and the Federal Government* in 1959-1960,[72] and the following year, Weinberg gave an after-dinner talk at the Ninth Southern Appalachian Science Fair at the University of Tennessee entitled *The Problem of Big Problems.* He defined these as problems "on whose solution the entire future of the human race depends." After discussing urban air pollution—newly labelled smog—he continued:

> An even more fundamental problem is the deterioration of our atmosphere by the accumulation of CO_2. As we burn more and more coal and oil, we throw more and more CO_2 into the atmosphere. Now CO_2 effectively absorbs infra-red energy. Its presence in the atmosphere converts the earth into an enormous greenhouse; the sun's energy remains partially trapped; and the temperature of the earth increases. It is estimated that, as a result of the current burden of CO_2 in the atmosphere, the average temperature of the earth is increasing about 1° C per century. This is enough to melt the ice caps in a fairly short time with the result that the sea would rise and flood many inhabited areas.[73]

By 1962, the topic was being so widely discussed that, in a letter to Plass, Guy Callendar complained that the subject of global warming was so widespread that "everyone likes to 'have a go."[74] The same year, the International Panel of the PSAC—on which Roger Revelle, among others, served—drafted a report recognizing that the "alteration of our environment has reached the point of requiring intensive study and understanding on an urgent basis." In particular, they said, "never before has man had the power he now has to

[72] PRESIDENT'S SCI. ADVISORY COMM., SCIENTIFIC PROGRESS, THE UNIVERSITIES, AND THE FEDERAL GOVERNMENT, (1960).
[73] "Problem of big problems" after-dinner talk, Ninth Southern Appalachian Science Fair banquet, Alvin Weinberg Papers, MPA.0332, University of Tennessee Libraries, Knoxville, Special Collections.
[74] Letter, G.S. Callendar to Gilbert Plass, Feb 5, 1962, Niels Bohr Library & Archives, American Institute of Physics, One Physics Ellipse, College Park, MD 20740.

bring about changes, some of them irreversible, on a scale that can affect people in all parts of the world and that can cause major but indeterminate environmental changes."[75] Among the examples provided was the continuous release of CO_2 into the atmosphere from the burning of fossil fuels.

The Air Force and Air Pollution

At the Cambridge Air Force Research Center (AFCRC) in the 1950s, the Geophysics Research Division studied the effects of CO_2 within the context of meteorology, military preparedness, and human health. In 1951 they commissioned the American Meteorological Society to publish a *Compendium of Meteorology* appraising the state of the field.[76] The compendium was organized by a committee that included Helmut Landsberg, a geophysicist at the AFCRC and expert on cloud formation who would later do important work on air pollution and health, and Harry Wexler, the chief scientist of the U.S. Weather Bureau and a developer of TIROS-1, the world's first weather satellite. The highly influential compendium was edited by Thomas Malone, at the time an assistant professor at MIT and later a scientific leader in the establishment of the National Center for Atmospheric Research (NCAR).[77] Several chapters of this 1951

[75] E.B. Skolnikoff, International Panel of the President's Sci. Advisory Comm, Draft: The Problem of Large-Scale Experimentation with Possible Environmental Effects, 3 (September 20, 1962), b. 46, f. 4, I. I. Rabi Papers, Manuscript Division, Library of Congress, Washington, DC, cited in Audrey Lara Loetscher, A History of Unsustainability: The U.S. Government, the Fossil Fuel Industry, and Climate Change (1957-1993)" (2002) (PhD Thesis, Université de Lausanne) (on file with author). Lloyd Bernker, one of the main architects of the IGY, was also on the panel.

[76] The 1300-page assessment included 102 international authors. COMPENDIUM OF METEOROLOGY (Thomas F. Malone, ed., 1951).

[77] W. W. VAUGHAN, COMPENDIUM OF METEOROLOGY: SCIENTIFIC ISSUES OF 1950 STILL OUTSTANDING, NASA Ref. Pub. 1167 (1986). In 1958, Malone helped prepare and write the "Blue Book" agenda for

compendium discuss CO_2. Two of these— "The Composition of Atmospheric Air" and "Geological and Historical Aspects of Climatic Change"—directly discuss planetary climatic change and CO_2.[78]

E. Wendell Hewson, an engineering professor at the University of Michigan, contributed a chapter on air pollution that did not discuss CO_2, but two years later he submitted a follow-up report produced under contract to the AFCRC that did. Hewson began his "Scientific Report No 1" with a discussion of "pollution and climate" and the "radiational effects [of] carbon dioxide," which placed CO_2 in the context of substances that were unequivocally understood as air pollutants. Moreover, he situated that concern in the context of air pollution's harmful effects on human health.

Drawing on Callendar's 1940 paper, Hewson included a table summarizing CO_2 levels from 1866 to 1935 and observed that there "seems to be no doubt that surface concentrations of CO_2 have increased significantly since the beginning of the present century."[79] While he debated the source of that carbon dioxide—noting that the correlation between a rise in atmospheric CO_2 and industrial production did not prove causation—he concluded that changes in atmospheric CO_2 levels could "modify the climate in various ways."[80] In the third section of the report, Hewson compared CO_2 to other kinds of air pollution including pollen, smoke, dust, sulfur dioxide (SO_2) and their

NCAR, and later served as one of its trustees. DAVID T. MALONE, THOMAS F. MALONE, 1917–2013, (NAS BIOGRAPHICAL MEMOIRS, 2014). On the Blue Book *see generally* Howe, *supra* note 23 at 31-32.
[78] E. Glueckauf, *The Composition of Atmospheric Air, in* COMPENDIUM OF METEOROLOGY 3 (Thomas F. Malone, ed., 1951) and C. E. P. Brooks, *Geological and Historical Aspects of Climatic Change*, *in* COMPENDIUM OF METEOROLOGY 1004 (Thomas F. Malone, ed., 1951)
[79] Hewson, *supra* note 7 at 3.
[80] *Id.* at 4-5. Sadly the rest of p.5 is missing.

relations to pneumonia, bronchitis, asthma, cancer, and other diseases. Unlike these conventionally understood forms of pollution, which did not remain in the atmosphere for long, he noted that the "evidence was clear" that carbon dioxide was removed from the atmosphere slowly and that, if atmospheric CO_2 levels were indeed tied to industrial releases, we could anticipate continued warming "concurrent" with those releases.[81] His conclusion echoed this concern: "Industrial pollution of the atmosphere by CO_2 may be modifying world climate, causing a temperature rise."[82]

In 1953, Landsberg recruited the German physicist Christian Junge, one of the world's leading atmospheric scientists, to the AFCRC.[83] Over the next eight years, Junge's research at the AFCRC focused on aerosols—mixtures of gases and particles in the atmosphere that could affect both local weather and global climate. In 1958, his article "Atmospheric Chemistry" in *Advances in Geophysics* addressed conventional pollutants such as sulfur dioxide, nitrogen oxides, ozone, and carbon monoxide, and included an entire section on carbon dioxide. Junge argued CO_2 was important because of its "increase during the last fifty years," and its role "in the heat budget of our atmosphere." The observed increase in CO_2 should "raise the average temperature of the atmosphere by a small, though measurable, amount," and such a "phenomenon has actually been observed in various parts of the world; the problem of a CO_2 increase,

[81] *Id.* at 28-29.
[82] *Id.* at 39. In his acknowledgments, Hewson also thanked Gilbert Plass.
[83] Robert A. Duce et. al., *Christian Junge—a Pioneer in Global Atmospheric Chemistry*, J. ATMOS. CHEM. (2022). From 1953 to 1961, Junge worked for the AFCRC, before returning returned to Germany to become a Professor of Meteorology at the University of Mainz and later the Director of the Max Planck Institute for Chemistry. In 1960, he discovered the Junge layer, a zone of aerosol particles, which, by screening sunlight, has a major impact on planetary heat balance.

therefore, is of basic importance for meteorology."[84] Two years later Junge presented a paper at the U.S. Public Health Service-sponsored Third Air Pollution Research Seminar in which he argued that "the concentrations of two atmospheric constituents, carbon dioxide and sulfur dioxide, have increased on a global scale as a result of human activity," and that the fluctuations in atmospheric CO_2 would have a "profound influence on world climate." [85]

IGY and the Establishment of Mauna Loa CO_2 Measurements

The International Geophysical Year (IGY) was a massive, international collaborative scientific effort to collect geophysical data from around the globe. It was also widely publicized, inspiring countless newspaper and magazine articles, film and televisions series, and even a pop song. [86] The "year" lasted for eighteen months, from 1957-1958, and one of its scientific leaders was Roger Revelle, who arranged for atmospheric CO_2 measurement to be an IGY project.[87]

Revelle wanted this scientific work to answer two questions: Was atmospheric CO_2 increasing, and if so, was the increase having a discernible impact on the global climate? The systematic measurement of atmospheric CO_2 became the life work of Revelle's colleague, geochemist (and 2001 National Medal of Science winner) Charles

[84] Christian E. Junge, *Atmospheric Chemistry*, 4 ADV. IN GEOPHYS. 1, 45 (1958.)
[85] *Research in Air Pollution: Conference Report,* 75 PUB. HEALTH REP. 1173 (1960). Junge later participated in the 1971 SMIC Report on Inadvertent Climate Modification (see below).
[86] Fae L. Korsmo, *Shaping Up Planet Earth: The International Geophysical Year (1957-1958) and Communicating Science Through Print and Film Media*, 26 SCI. COMM. 162 (2004).
[87] Walter H. Munk, *Tribute to Roger Revelle and his Contribution to Studies of Carbon Dioxide and Climate Change*, 94 PNAS 8275 (1997).

David Keeling.[88] In 1958, Keeling established an observatory at Mauna Loa, Hawaii, to make precise daily measurements; within a year, Keeling had demonstrated that accurate, systematic measurement was possible.[89] By 1965, he had the answer to the first question: CO_2 was increasing, and his analysis confirmed that about half of the released CO_2 was "missing" and presumed absorbed into the oceans or taken up by plants. The remainder was in the atmosphere, where its concentration was on an upward march[90] This led scientists to focus on the second question: was this increase affecting the planetary climate?

Studies of Weather Modification

A major area of interest in CO_2 and climate appeared in the context of deliberate or purposeful weather modification.[91] Shortly after World War II, the U.S. government funded projects to study techniques of weather modification, including cloud seeding and hurricane weakening (Projects Cirrus and Stormfury). Much of this work was undertaken by a research group at the General Electric Corporation, led by Nobel Laureate Irving

[88] Charles D. Keeling, *Rewards and Penalties*, 23 ANN. REV. ENER. & ENV. 25 (1998); *Scientists, Engineers Honored with National Medals*, 55 PHYS. TOD. 71 (2002).
[89] *See generally* HOWE, *supra* note 23, particularly *Introduction* and *Chapter 1*.
[90] J.C. Pales and C.D. Keeling, *The Concentration of Atmospheric Carbon Dioxide in Hawaii*, 70 J. GEOPHYS. RES. 6053, 6062 (1965); C.W. Brown and C.D. Keeling, *The concentration of atmospheric carbon dioxide in Antarctica*, 70 J. GEOPHYS RES. 6077 (1965); Charles D. Keeling, *Is Carbon Dioxide Fossil Fuel Changing Man's Environment*, 114 PROC. AM. PHIL. SOCI. 10 (1970). In hindsight, the increase is visible even in the first year, but it is in the mid 1960s that Keeling and Revelle begin to speak publicly about the results.
[91] *See generally* HOWE, *supra* note 23 at 25-27; WEART *supra* note 22 at 20-22; EDWARDS, *supra* note 22 at 359-361; Chunglin Kwa, *The Rise and Fall of Weather Modification: Changes in American Attitudes Toward Technology, Nature, and Society*, *in* CHANGING THE ATMOSPHERE: EXPERT KNOWLEDGE AND ENVIRONMENTAL GOVERNANCE 135 (Clark A. Miller and Paul N. Edwards, eds. 2001).

Langmuir, Vincent Schaefer, and Bernard Vonnegut (brother of novelist Kurt).[92] Study reports from this domain contained discussions of a concept their authors termed "inadvertent weather modification"—what scientists today would call anthropogenic (human-caused) climate change.[93] During the Cold War, many scientists argued that purposeful weather modification was possible: Hewson mentioned weather modification in the introduction to his 1953 report; Schaefer induced cloud seeding in a small-scale laboratory experiment using dry ice; and the U.S. military was intensely interested in the prospects of deliberate weather modification in warfare.[94] Discussions and research into the effects of atmospheric pollutants like carbon dioxide led some scientists to assert that accidental alterations of weather and climate might already be occurring. But others doubted that any systematic effects would occur either purposefully or accidentally.

In 1958, President John F. Kennedy approved PL 85-510, which authorized government funding of weather modification research through the National Science Foundation (NSF). In the early-to-mid 1960s the NSF reviewed the existing scientific research projects on weather modification, and then released annual reports (ten in total) in accordance with that funding.[95] In 1964 the NSF director announced the creation of a

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[92] JAMES R. FLEMING, FIXING THE SKY: THE CHECKERED HISTORY OF WEATHER AND CLIMATE CONTROL, 137-157, 165-187 (2012).

[93] Vincent R. Schaefer, *Inadvertent Modification of the Atmosphere by Air Pollution,* 50 BULLETIN AM. MET. SOC. 199 (1969). For recent use of this terminology, *see* Philip B. Duffy et al., *Strengthened Scientific Support for the Endangerment Finding for Atmospheric Greenhouse Gases*, 363 SCIENCE 597 (2019) ("One area of scientific progress since the [Endangerment Finding] is the attribution of extreme weather events . . . to human-caused climate change.")

[94] Hewson, *supra* note 7; FLEMING, *supra* note 93 at 142-144, 170-188.

[95] National Science Foundation Act of 1950, Pub. L. No. 85-510, 72 Stat. 353 (1958). This amendment to the National Science Foundation Act of 1950 made NSF the official coordinating agency for weather modification research projects and required that the agency report annually. For a summary of federal laws governing US federal weather modification programs, *see* Rachel Hauser, *Using Twentieth-Century U.S.*

Special Commission on Weather Modification to review the state of knowledge, and respond to a 1963 request from the federal government Council for Science and Technology to analyze potential purposes of weather modification and control. The commission was chaired by Colorado State University Dean A.R. Chamberlain; their final report was issued in 1965. The Committee discussed CO_2 and the problem of "inadvertent" climate change, which might be either "transient or permanent," local or global, and desirable or undesirable. Significantly, the report discussed weather and climate modification—whether deliberate or accidental—as *already underway and not merely as a local effect*.

> Weather and climate modification is becoming a reality.... [T]he inadvertent modification of the weather and climate by such influences as the products of urban development, surface modification for agriculture and silviculture, [and] compositional changes through the combustion of fossil fuels and other exhausts are becoming of sufficient consequence to affect the weather and climate of large areas and ultimately the entire planet.[96]

The report called for further research "to understand the factors involved in climatic change and thus to be able to predict inadvertent changes in weather and climate produced by present and future activities of man. Some beginnings in this direction are . . . an attempt to assess consequences of the increasing carbon dioxide content of the atmosphere caused by the burning of fossil fuels.... 'the implications of this upon tropospheric stability cannot be ignored.'" Nothing less than "the future welfare of

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Weather Modification Policy to Gain Insight into Global Climate Remediation Governance Issues, 5 WTHR. CLIM. & SOC. 180 (2013).

[96] NATIONAL SCIENCE FOUNDATION SPECIAL COMMISSION ON WEATHER MODIFICATION, WEATHER AND CLIMATE MODIFICATION 8 (1965).

mankind" was at stake. [97]

The U.S. National Academy of Sciences National Research Council (NAS-NRC) also addressed the issue. In 1963, the Academy created a panel on weather and climate modification "to undertake a deliberate and thoughtful review of the present status and activities in this field, and of its potential and limitations for the future."[98] Central to much of their work was geophysicist Gordon J.F. MacDonald, who chaired the panel and later served on the Council on Environmental Quality in the Nixon Administration. The NAS-NRC panel released their two-volume final report, "Weather and Climate Modification Problems and Prospects," in 1966, and it gave particular attention to inadvertent, carbon-dioxide fueled weather modification. A full section of the report's second volume was devoted to "Inadvertent Modification of Atmospheric Processes," which began with a detailed discussion of the potential effects of increased carbon dioxide in the atmosphere.[99] When the National Academy panel made its recommendations, it listed as among its "highest priority" studies those that investigated the "meteorological effects of atmospheric pollution (including carbon dioxide)."[100]

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[97] *Id.* at 42. The quotation inside the quotation is from NATIONAL RESEARCH COUNCIL COMMITTEE ON ATMOSPHERIC SCIENCES, VOLS. I AND II, NAS-NRC PUB. NO. 1350, WEATHER AND CLIMATE MODIFICATION PROBLEMS AND PROSPECTS: FINAL REPORT OF THE PANEL ON WEATHER AND CLIMATE MODIFICATION (1966), which had not yet been publicly released but evidently had been shared with the NSF.

[98] Gordon J.F. MacDonald, *Preface* to NATIONAL RESEARCH COUNCIL COMMITTEE ON ATMOSPHERIC SCIENCES, VOLS. I AND II, NAS-NRC PUB. NO. 1350, WEATHER AND CLIMATE MODIFICATION PROBLEMS AND PROSPECTS: FINAL REPORT OF THE PANEL ON WEATHER AND CLIMATE MODIFICATION (1966).

[99] *Id.* Vol. II at 82–83.

[100] *Id.* Vol. I at 25. MacDonald explored this issue further in a 1968 book chapter entitled "How to Wreck the Environment." He suggested that the deliberate addition or subtraction of atmospheric components could alter the climate so much as to be a potentially potent instrument of war; he called this "geophysical warfare." The "key to geophysical warfare" he explained, was "the identification of the environmental instabilities in which the addition of a small amount of energy would release vastly greater amounts of energy." MacDonald's paper was highly speculative, including discussion of using nuclear weapons to alter ice sheets and change global reflectivity, but he did note that if a nation thought it to their advantage, it

The numerous reports of the NSF and the NAS in the early-mid 1960s speaks to the significance that both the scientific community and the federal government placed on the topic. The reports focused their attention on research efforts to modify and control weather and climate deliberately, often through cloud-seeding, for both military and civilian purposes, but also addressed inadvertent alterations. The NSF's 1962 annual report (released in 1963), for example, cited a 1962 seminar in which the Weather Bureau's Harry Wexler had analyzed a variety of factors that could modify Earth's radiation balance, including changing the carbon dioxide content of the atmosphere.[101] The report suggested that this was cause for concern, as Plass had "suggested that man may already be inadvertently modifying the atmosphere at an alarming rate by burning ever-increasing amounts of fossilized fuel, thus releasing larger amounts of carbon dioxide than ever before in historical times."[102] Such warming, it continued, could cause the icepack to "vanish from the frozen north and frozen tundra would thaw."[103] The framing of the project in terms of Plass's work—as well as the reference to the Arctic icepack, frozen north, and tundra—make clear that the scientists were addressing planetary-scale effects of CO_2-induced global warming.

Weather modification was also reviewed by the Texas Water Commission, which

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could alter the climate by adding CO_2 to the atmosphere: "If a nation's meteorologists calculated that a general warming or cooling of the earth was in their national interest, improving their climate while worsening others, the temptation to release materials from high-altitude rockets might exist." Gordon MacDonald, *How to Wreck the Environment*, *in* UNLESS PEACE COMES: A SCIENTIFIC FORECAST OF NEW WEAPONS 181, 190 (Nigel Calder, ed., 1968).

[101] NATIONAL SCIENCE FOUNDATION, WEATHER MODIFICATION: FOURTH ANNUAL REPORT 19 (1962) *citing* Harry Wexler, Seminar on weather control, Dept. of Meteorology, UCLA (February 1962).

[102] *Id. citing* G.N. Plass, *The Influence of Infrared Absorptive Molecules on the Climate,* 95 ANN. NY. ACAD. SCI. 61-71 (1961).

[103] *Id.* at 20.

in 1964 released *The Current Status of Weather Modification.* The report focused on the need for weather modification to prevent damaging weather—hail, floods, tornadoes, hurricanes and drought, but also discussed military uses, such as aiding civilian aviation.[104] The Commission distinguished between weather modification—related to specific events like hurricanes and activities such as cloud-seeding—and climate control, which they defined as the "control or significant alteration of the climate over vast areas of the earth," such as "controlling the horizontal wind circulation patterns over millions of square miles." Envisaging possible attempts to deliberately alter the planetary climate, they wrote "Such undertakings would most certainly require international effort and agreement, because what seems to benefit one large area may be harmful to another."[105] While the report was broadly in favor of attempts to modify the weather, it also warmed of inadvertent modification, linking it explicitly to atmospheric pollution. Citing the NSF's Fourth Annual Report on weather modification (1962), the Texas report stated: "[We] must consider and try to understand the effects of inadvertent artificial modification. … [T]he atmosphere is polluted at all levels by industrial effluents, by rocket exhausts, and by the activity involved in living in a highly technological society. We suspect that such events affect the weather or climate or both."[106]

Weather and climate were also addressed by the U.S. Interdepartmental Committee on Atmospheric Sciences (ICAS), which issued a report in 1966. Authored by NASA assistant Administrator Homer Newell, the report mirrored the language of

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[104] JOHN T. CARR, JR., TEXAS WATER COMMISSION, BULLETIN 6504, THE CURRENT STATUS OF WEATHER MODIFICATION: A SUMMARY (1964)
[105] *Id.* at 47.
[106] *Id.* at 48 *citing* NATIONAL SCIENCE FOUNDATION, *supra* note 103.

Volume I of the 1966 NAS-NRC report in its discussions of "inadvertent modifications of weather and climate." But it also specifically identified as a research priority "new and comprehensive studies of the meteorological effects of atmospheric pollution (including carbon dioxide)" and referred to carbon dioxide as "atmospheric pollution."[107] This report was transmitted by the Assistant Secretary of Commerce for Science and Technology and chair of ICAS, J. Herbert Hollomon, to Presidential Science Advisor Donald Hornig.

The National Center for Atmospheric Research

Another line of research recognizing the potential importance of CO_2 in relation to climate emerged at the U.S. National Center for Atmospheric Research (NCAR). NCAR was established in 1960 by the National Science Foundation as a central facility to consolidate and strengthen basic research in atmospheric science and be a focal point for analyzing data from the International Geophysical Year (IGY).[108] In later years, NCAR would become a leading scientific center for climate modelling.

Historian Joshua Howe describes early NCAR research as organized around four themes: "radiation budget modeling, general circulation modeling, the study of weather

[107] HOMER E. NEWELL, FEDERAL COUNCIL FOR SCIENCE AND TECHNOLOGY INTERDEPARTMENTAL COMMITTEE ON ATMOSPHERIC SCIENCE, REPORT NO. 10a: A RECOMMENDED PROGRAM IN WEATHER MODIFICATION I-4 (1966). ICAS, which was established by and reported to the Federal Council for Science and Technology, Executive Office of the President, coordinated atmospheric research across disparate federal government offices.

[108] *On the history of NCAR*, see HOWE, *supra* note 23 at 27-32; JOSHUA HOWE, MAKING CLIMATE CHANGE HISTORY: DOCUMENTS FROM GLOBAL WARMING'S PAST 77-84 (2017); Walter Orr Roberts, *Atmospheric Research: A Powerful Concept Emerges*, 5 SCIENCE 1093 (1965); JAMES RODGER FLEMING, INVENTING ATMOSPHERIC SCIENCE: BJERKNES, ROSSBY, WEXLER, AND THE FOUNDATIONS OF MODERN METEOROLOGY 203-207 (2016).

and climate control, and the CO_2 question."[109] While the motivation was to advance basic science—particularly in a field that had been heavily oriented towards applied science, particularly weather forecasting—the scientists involved in establishing NCAR recognized that the impact of human activities on the environment demanded attention, too. One of these impacts involved fossil fuels and CO_2. In a report prepared for the National Science Foundation in 1959, arguing the case for establishing NCAR, scientists explained: "[M]an's activities in consuming fossil fuels during the past hundred years, and in detonating nuclear weapons in the last decade, have been on a sufficient scale to make it worthwhile to examine the effects these activities have had upon the atmosphere. Reference is made here to the still unsolved question of whether the carbon dioxide content of the atmosphere is increasing as a result of combustion processes..."[110]

Within a few years, Keeling's Mauna Loa measurements had convinced most scientists that the question of increasing CO_2 was no longer "unsolved"; the question had moved to its effects. With NCAR firmly established, the April 1965 issue of the NCAR quarterly linked their basic science to air pollution and climate control.[111] That same year, NCAR staff chemist James P. Dixon co-authored a paper in *Science* magazine reporting on the work of the Air Conservation Commission of the American Association for the Advancement of Science. The paper began by noting that, in quantity, CO_2 was the most important waste product of using fuels, second only to water, and that its global

[109] HOWE, *supra* note 23 at 32-33.
[110] JOSHUA HOWE, MAKING CLIMATE CHANGE HISTORY: DOCUMENTS FROM GLOBAL WARMING'S PAST 83 (2017).
[111] NCAR QUARTERLY (April 1965), s. V.A.5, b. 373, f. 13, Edmund S. Muskie Papers, Edmund S. Muskie Archives and Special Collections Library, Bates College [*hereinafter* BC-ESM].

atmospheric content had already increased by 5%. This increase was of potential concern because "carbon dioxide is intimately involved in the mechanism that maintains the overall temperature of the earth [and] it is possible that a continued increase over a long period would change the climate."[112]

Keeling's 1969 assessment of the state of the science

By 1969, Keeling had compiled sufficient data from Moana Loa to pose and answer the question, "Is Carbon Dioxide from Fossil Fuel Changing Man's Environment?" In a symposium on atmospheric air pollution sponsored by the American Philosophical Society, he explained that scientists had good data on how much fossil fuel had been burned since the mid 19th century, and to show that about 40% of the CO_2 produced was now in the atmosphere. Over the decade 1958-1968, since he began making systematic measurements, atmospheric CO_2 had risen by approximately 0.7 ppm per year—a small but discernible effect. Overall, data suggested that CO_2 had increased 30 ppm since 1850—about a 10% increase—and the rate of increase was rising in tandem with fossil fuel use.

What was the climatic response to this increase? Keeling drew on theoretical calculations and newly developed climate models, particularly the work of Syukuro Manabe (who in 2021 would win the Nobel Prize in Physics) suggesting a climate sensitivity of 2.8° C for doubling CO_2 (i.e. a 100% increase.) If there were no other

[112] James P. Dixon and James P. Lodge, *Air Conservation Report Reflects National Concern*, 148 SCIENCE 1060, 1060 (1965). A copy of this report was found in s. V.A.5, b. 373, f. 13, BC-ESM. We discuss this report in depth below.

factors involved, that might mean that the planet had already warmed somewhat.[113] Scientists held "widely divergent views concerning a possible peril," but Keeling's read of the situation was that "no atmospheric scientist doubts that a sufficiently large change in atmospheric CO_2 would change the climate."[114] Was this an immediate threat? Keeling did not think so, but it might in time become serious: "If the human race survives into the twenty-first century with the vast population increase that now seems inevitable, the people [still] living… may also face the threat of climatic change brought about by an uncontrolled increase in atmospheric CO_2 from fossil fuels."[115]

Summary

By 1969, when Congress held hearings pursuant to the Clean Air Act, scientists had been working on the foundations of understanding the relationship between CO_2 and global climate for more than a century. While climate modelling was in its infancy, climate science was not; there had already been a wide and deep scientific conversation—among atmospheric scientists, climate modelers, geochemists making atmospheric and oceanic measurements, and meteorologists—affirming that the earlier concerns of Arrhenius and Hurlburt were not misplaced. CO_2 was increasing, and there was good scientific reason to think that that increase would alter the climate in substantive, deleterious ways. Policymakers at the end of the decade had this foundation

[113] Charles D. Keeling, *Is Carbon Dioxide from Fossil Fuel Changing Man's Environment*?, 114 PROC. AM. PHIL. SOC. 10, 14 (1970).
[114] *Id.*
[115] *Id.* at 17. Keeling underestimated the threat, suggesting "most of us today will, every likely, live out our lives without perceiving that a problem may exist." (at 14) He died in 2005, well after the IPCC had declared climate change to be "discernible," and significant effects had been documented.

on which to base decisions. The scientific basis for a clear statement had been established. An important part of this was the recognition of CO_2 as a pollutant. We turn now to that issue.

II. Understanding "The Carbon Dioxide Problem"

Conservation Foundation Consensus Report

In March 1963, the Conservation Foundation convened a conference to discuss "the implications of rising carbon dioxide content in the atmosphere." The group of seven experts brought together for the discussion included Keeling, Plass, Erik Eriksson of the International Meteorological Institute in Stockholm, biologists from Yale and the Atlantic Marine Lab, and the aerial landscape photographer William Garnett. Their purpose was to clarify the current state of knowledge and propose ideas for the future of scientific research. The final report of the conference was a consensus statement of scientific thinking about the increasing accumulation of atmospheric CO_2, an issue the scholars thought should be one of "considerable concern and controversy." In the forward the authors wrote:

> It is known that the carbon dioxide situation, as it has been observed in the last century, is one which might have considerable biological, geographical, and economic consequences within the not too distant future. … [W]ith the rise of carbon dioxide, by way of exhaust gases from engines and other sources, there is a rise in the temperature of the atmosphere and oceans. It is estimated that a doubling of the carbon dioxide content of the atmosphere would produce an average atmospheric temperature rise of 3.8 degrees Fahrenheit.[116]

[116] CONSERVATION FOUNDATION, IMPLICATIONS OF RISING CARBON DIOXIDE CONTENT OF THE ATMOSPHERE i (1963)

The report defined CO_2 as "not a pollutant in the ordinary sense. It is colorless and odorless. It has no immediate nasty effects."[117] Unlike other pollutants, atmospheric accumulation of CO_2 by itself would not lead to any detrimental effects to life on the planet. The threat came from the effect of that accumulation on atmospheric and ocean temperatures, and "immense flooding of the lower portions of the world's land surface, resulting from increased melting of glaciers."[118] Concluding their introduction, the conference emphasized the global and intergenerational nature of climate change: "The effects of a rise in atmospheric carbon dioxide are world-wide. They are significant not to us but to the generations to follow."[119]

One important question, already raised by Callendar, Hulburt, Plass, Revelle, and others, was whether CO_2 uptake by plants or absorption into the ocean might prevent, or at least seriously slow, the accumulation of carbon dioxide in the atmosphere and therefore prevent adverse effects. The scientists noted that while there was a lack of "exact" knowledge of the carbon cycle, it seemed "quite certain" that the atmospheric CO_2 accumulation was sufficiently large that in time it would increase the global surface temperature, and this in turn would cause melting of polar ice caps.[120] Moreover, sea level rise and ocean warming would disrupt global patterns of marine species distribution.

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[117] *Id.* at 1.
[118] *Id.* at i.
[119] *Id.* at 1.
[120] *Id.*

The authors recognized that there were several possible naturally occurring checks and balances that could offset these effects. Ocean absorption—already mentioned—was the most obvious one, but a more subtle effect involved sulfur dioxide. An increase in atmospheric sulfur dioxide (also from burning fossil fuels) could change ocean acidity or increase marine biologic activity, increasing the amount of CO_2 that the ocean and ocean sediments could absorb. On land, a carbon dioxide rich environment could lead to an addition in plant biomass, which would in turn reduce atmospheric CO_2 by "locking it up" in the woody trunks of trees.[121] The natural exchange of carbon dioxide between the atmosphere, the biosphere, and the oceans had been working to maintain a balance despite the increased output of manmade carbon dioxide emissions. But measurements comparing the ppm of carbon dioxide in 1890 and the current figure from measurements in 1953 was 25 ppm higher. And—in one of the first instances to highlight the emerging data from Keeling's Mauna Loa work, begun during the IGY—the authors noted that data coming in from Keeling's monitoring station demonstrated consistent yearly increases in CO_2 , as expected from the burning of fossil fuels.[122]

The attendees of the conference could not pinpoint any natural check on the increase of atmospheric CO_2 that they felt could reliably offset the most damaging possible effects of anthropogenic climate change. Each of the situations they presented lacked concrete supporting data that the carbon system could adequately balance itself at the present rate of increase—estimated to be 0.7 ppm or around 0.2%. They calculated

[121] *Id.* at 3.
[122] *Id.* at 2, 6.

that it would take thousands of years for the ocean to balance out oceanic and atmospheric carbon dioxide at present rates of emissions, and once it did the new equilibrium would still result in higher atmospheric CO_2 levels than at present.[123] The earth had been able to balance its carbon system in the past through a variety of "checks and balances," but the authors strongly cautioned against disregarding the rising levels of carbon dioxide in the atmosphere on those grounds. They wrote:

> The present liberation of such large amounts of fossil carbon in such a short time is unique in the history of the earth, and there is no guarantee that past buffering mechanisms are really adequate. It is not a cause for complacency that nature seems to have a lot of checks and that these checks seem thus far to be controlling any artificial imbalances. There may be processes presently going on which are due to man's activities and which will eventually be alarming.[124]

In the coming years, the Conservation Foundation continued to be concerned with the carbon dioxide problem. The issue became of particular concern to its President from 1965-1969, Russell E. Train. In the late 1960s, Train served as the Chairman of President-elect Nixon's Task Force on Environment, as Under Secretary of the Department of the Interior from 1969 to 1970, and as the first Chairman of the Council on Environmental Quality, where his staff included geophysicist Gordon MacDonald. He was the second administrator of the Environmental Protection Agency under Presidents Nixon and Ford.

During Train's tenure as Conservation Foundation president, the Foundation paid substantial attention to the CO_2 problem. Of particular interest is a February 1968

[123] *Id.* at 6.
[124] *Id.* at 5.

Foundation newsletter featuring the article "Is Mankind Playing a Game of Environmental Russian Roulette?," which was retained by Senator Muskie's staff and can be found in his archive. The wide-ranging article quoted an array of scientists and discussed a variety of Congressional proposals on environmental issues. On the article's first page, the Conservation Foundation noted: "While some might question the degree of seriousness or urgency of the threat, it exists. As a congressional committee tells us, 'our power to disturb or alter the ponderous forces and rhythms of nature by man-induced manipulations has increased to the point where mistakes or unknown effects may be profound and irreversible.'"[125]

The paragraph of the House report from which this quotation was taken offered several examples of "manmade disruptions" that were "familiar to everyone," including carbon dioxide: "Carbon dioxide accumulations from the burning of gas, petroleum, and coal change the nature of the atmosphere. Weather patterns can be altered purposefully or accidentally by human activity. These powerful forces have only come about recently and are not well understood."[126] The Conservation Foundation newsletter enumerated several problems that "illustrate our lack of knowledge and foresight." Among them: "We release

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[125] *Is Mankind Playing a Game of Environmental Russian Roulette?* CF LETTER, Feb. 23, 1968 at 1, s. V.A.6, b. 598, f. 5, BC-ESM *quoting from* SUBCOMM. ON SCIENCE, RESEARCH AND DEVELOPMENT REPORT TO THE H. COMM. ON SCIENCE AND ASTRONAUTICS, 89TH CONG., 2D SESS., ENVIRONMENTAL POLLUTION: A CHALLENGE TO SCIENCE AND TECHNOLOGY 3 (Comm. Print 1966). Other materials from the Conservation Foundation can also be found in the Muskie archive, including a 1966 commentary that referenced the organization's 1963 report RISING CARBON DIOXIDE CONTENT OF THE ATMOSPHERE. See, s. V.A.5, b. 368, BC-ESM.

[126] SUBCOMM. ON SCIENCE, RESEARCH AND DEVELOPMENT REPORT TO THE H. COMM. ON SCIENCE AND ASTRONAUTICS, 89TH CONG., 2D SESS., ENVIRONMENTAL POLLUTION: A CHALLENGE TO SCIENCE AND TECHNOLOGY 3 (Comm. Print 1966). This House report, and the hearings from which it emerged, considered the carbon dioxide issue at some length and will be discussed further in Lanier-Christensen et. al., *Climate Change and the 1970 Clean Air Act Part 2: Testimony to Congress* (forthcoming.)

carbon dioxide into the air in great quantities -- faster than it can be used up by plants or dissolved into the oceans."[127] On February 28, 1968, Washington Senator Henry "Scoop" Jackson inserted the Conservation Foundation article into the Congressional Record. Jackson commented that it was "devoted to a review and discussion of the need for developing intelligent, long-range Federal policies on environmental quality management. I commend the newsletter to the attention of the Senate, because the problem of maintaining the quality of our environment is a matter of critical concern to all of us and, in some respects, is the shared responsibility of at least four or five of the standing committees of the Senate."[128]

The 1965 Report of the President's Scientific Advisory Committee

Revelle and Keeling served on the Environmental Pollution Panel of the President's Scientific Advisory Committee (PSAC) under President Lyndon Johnson. The Panel was led by Princeton professor John Tukey, one of America (and the world's) leading mathematicians and statisticians.[129]

In 1965, the PSAC issued a major report entitled "Restoring the Quality of our Environment." The panel include a subpanel on "Atmospheric Carbon Dioxide," and their concern over carbon dioxide made it to the first page of the report's introduction:

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[127] CF LETTER, *supra* note 126, at 6.

[128] 114 Cong. Rec. S4515-18 (daily ed. Feb 28,1968) (statement of Sen. Henry Jackson). Jackson's interest in the article was no doubt heightened by the fact that his name appeared in the newsletter article several times, including for discussion of a bill he was cosponsoring which, along with a number of bills under consideration, called for the establishment of a Council of Environmental Quality in the executive office of the president.

[129] Among other things, Tukey was known for the invention of the Fast Fourier transform algorithm, a major tool in modern signal processing, digital recording, and computer science. Tukey also served on numerous government and NAS committees and panels on air pollution, weather modification, and other matters as well as on an American Statistical Association review of Alfred Kinsey's path-breaking work on human sexuality. DAVID R. BRILLINGER, JOHN W. TUKEY 1915-2000 (NAS BIOGRAPHICAL MEMOIR, 2018).

"pollutants have altered on a global scale the carbon dioxide content of the air and the lead concentrations in ocean waters and human populations."[130] The issue was raised again throughout the report. In examining the climatic effects of pollution, the authors asserted: "By the year 2000 there will be about 25% more CO_2 in our atmosphere than at present. This will modify the heat balance of the atmosphere to such an extent that marked changes in climate, not controllable through local or even national efforts, could occur."[131] The report placed CO_2 into context with other conventionally understood pollutants:

> The combustion of coal, oil, and gas in our homes, vehicles, and factories results in the discharge into the air of sulfur dioxide, carbon dioxide, carbon monoxide, oxides of nitrogen, and partially burned hydrocarbons. Some of these gases, together with gasoline and natural gas vapors, undergo chemical change in air and in sunlight, and become the noxious constituents of smog; others, like carbon dioxide, are accumulating in such large quantities that they may eventually produce marked climatic change. Large amounts of lead are dispersed into the atmosphere from motor vehicle exhausts.[132]

The panel recommended new investments in baseline measuring programs under the Environmental Science Services Administration (ESSA, part of the Commerce Department) to determine precise levels of CO_2 in the atmosphere "where its effects on our climate are likely to be significant," as well as expand research into the mechanisms by which CO_2 might be removed from the atmosphere by the ocean or other biological processes.[133] The full findings of the subpanel were transmitted over twenty-two pages in

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[130] ENV'T POLLUTION PANEL OF THE PRESIDENT'S SCI. ADVISORY COMM., RESTORING THE QUALITY OF OUR ENVIRONMENT 1 (1965).
[131] *Id.* at 9.
[132] *Id.* at 12.
[133] *Id.* at 26.

Appendix Y4, where the authors discussed possible effects of increased atmospheric CO_2 such as global temperature increases, melting of the Antarctic ice cap, sea level rise, and sea water warming.[134]

One source of potential disagreement over the impact of added atmospheric CO_2, the panel noted, involved the complicating effect of natural climate variability and the countervailing effects of other forms of pollution, particularly particulate matter. For example, a worldwide cooling appeared to have taken place between 1940 and 1960, a period when more than 40% of the total CO_2 increase from fossil fuels took place. This enigma led the panel to posit that "climatic 'noise'" from other processes had at least partially "masked any effects on climate due to past increases in atmospheric CO_2 content."[135] One such process included particulate pollution—dust, soot, sulfuric acid aerosols and other substances that could block the sun. (They proffered the possibility of exploring "countervailing climatic changes" such as deliberately spreading buoyant reflective particles over large oceanic areas to change the earth's albedo.) This prompted debate about whether the warming effect of CO_2 or the cooling effect of particulates would dominate, since pollution contributed both to the atmosphere.[136] Other reports at this time also noted the potential cooling effect of particulates; in coming years scientists would conclude that the mid-century cooling was due to emissions of particulate matter,

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[134] *Id.* at 121-124.
[135] *Id.* at 123.
[136] *Id.* at 127. *See also generally,* Robert A. McCormick and John H. Ludwig, *Climate Modification by Atmospheric Aerosols,* 156 SCIENCE 1358 (1967); Walter Munk et. al., GORDAN JAMES FRASER MACDONALD 1930-2002 (NAS BIOGRAPHICAL MEMOIR, 2004).

which had affected planetary reflectivity.[137]

Three days after the PSAC report's publication, Frank Ikard, president of the American Petroleum Institute (API), discussed it at the organization's annual meeting in 1965, specifically noting that addressing the CO_2 problem might include changes such as finding alternatives to internal combustion engines in automobiles:

> One of the most important predictions of the [PSAC] report is that carbon dioxide is being added to the Earth's atmosphere by the burning of coal, oil, and natural gas at such a rate that by the year 2000 the heat balance will be so modified as possibly to cause marked changes in climate beyond local or even national efforts. The report further states, and I quote: "… the pollution from internal combustion engines is so serious, and is growing so fast, that an alternative nonpolluting means of powering automobiles, buses, and trucks is likely to become a national necessity."[138]

Ikard emphasized that the "substance of the report is that there is still time to save the world's peoples from the catastrophic consequence of pollution, but time is running out."[139] In the years to come, this report would be repeatedly referenced and cited.

The Air Conservation Commission of the AAAS

In 1962, the American Association for the Advancement of Science (AAAS) created an Air Conservation Commission, which in 1965 issued what would become a

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[137] *See generally*, Martin Wild et. al., *Impact of Global Dimming and Brightening on Global Warming,* 34 GEOPHYS. RES. LET. L04702 (2007); P.V. Forster et. al, *Changes in Atmospheric Constituents and in Radiative Forcing*, *in* CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS. CONTRIBUTION OF WORKING GROUP I TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 131 (2007); Thomas C. Peterson et. al., *The Myth of the 1970s Global Cooling Scientific Consensus,* 89 BULL. AM. MET. SOC. 1325 (2008).
[138] F.N. Ikard, *Meeting the Challenges of 1966*, 45 PROCEEDINGS OF AM. PETROLEUM INST. 12, 13, (1965). *See also,* Benjamin Franta, *Early Oil Industry Knowledge of CO_2 and Global Warming*, 8 NAT. CLIM. CHAN. 1024 (2018).
[139] *Id.*

landmark report on air pollution.[140] This report, as with others from the period, was not limited to local air pollution. Rather, the global effects of air pollution—including carbon dioxide—were considered; CO_2 was discussed in the same framework as pollutants with documented health impacts. The commission was chaired by James Dixon, President of Antioch College, and included prominent figures in the air pollution field such as James P. Lodge, Jr. of the National Center for Atmospheric Research (NCAR) and Caltech professor Arie J. Haagen-Smit.[141] The report itself was written for a wide readership and was reprinted in 1968. In his introduction, Dixon emphasized that the Commission had to condense or omit "a considerable amount of material."[142] Yet, despite this limitation, considerable space was devoted to carbon dioxide.

Part 1 of the report, "Air Conservation and Public Policy," aimed for the widest audience. Here, the Commission offered four major recommendations, of which the third was "that air pollution be viewed as a problem that transcends political boundaries and as one that has global significance." Just as nuclear weapons testing resulted in pollution around the world, "Other pollutants also have global significance." Specifically, the report highlighted, the "gradually increasing concentration of carbon dioxide in the earth's atmosphere may cause a slow increase in world temperature, and it may cause

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[140] AIR CONSERVATION COMMISSION OF THE AAAS, PUB. NO. 80, AIR CONSERVATION (1965). The AAAS Committee on Science in the Promotion of Human Welfare convened the Air Conservation Commission in 1962. After two years' work, the Commission released its report in 1965. See generally, AAAS Committee on Science in the Promotion of Human Welfare, *Air Conservation*, 137 SCIENCE 9 (1962).

[141] The interdisciplinary committee included public officials and professors from diverse fields (e.g., biology, economics, city planning). Notable members included John W. Bodine, President of Penjerdel (the Pennsylvania-New Jersey-Delaware Project, Inc); Arie J. Haagen-Smit (professor of biology, California Institute of Technology); James P. Lodge, Jr. (staff chemist, NCAR); and Norton Nelson (director, Institute of Industrial Medicine, New York University Medical Center). *Scientists in the News*, 137 SCIENCE 27 (1962).

[142] AIR CONSERVATION COMMISSION, *supra* note 139 at x.

glacial melting and higher sea levels. Such a change, if it is occurring, or if it should occur, would be difficult or impossible to stop."[143] Part 2 of the report, "Summary of the Facts," emphasized that while there were a great number of pollutants, only a small number of substances made up the majority of industrial emissions and were therefore "singled out for special attention." CO_2 was one of them. While increased emissions of CO_2 had to date had "no effect on any known living organism," the report emphasized the potential for major impacts, including economic ones:

> Carbon dioxide is intimately involved in the mechanism that maintains the overall temperature of the earth. Although … it is impossible to evaluate the effect of any given increase in atmospheric carbon dioxide, a continued increase over a long period could possibly change the global climate. And, if such a change were to involve an increase of the earth's temperature, thereby causing a large portion of the global ice caps to melt and the oceans to rise, available land area would be reduced at precisely the time when more land is needed for an increasing population. In the light of this possibility, the use of fossil fuels as the principal source of our energy should be continually evaluated.[144]

The authors further noted that the ocean was "the disposal point for most of the soluble inorganic substances" and it did indeed absorb CO_2, but human production of CO_2 appeared to be "outstripping the ocean's ability to remove it from the atmosphere." They estimated that about one-third of CO_2 emissions would remain in the atmosphere and "may have an effect on the world's weather."[145] This was less than Plass and Keeling's estimate of about half of all emissions, but it was still substantial. Among other things, the report clearly qualified CO_2 as a pollutant. The "atmosphere has tremendous

[143] *Id.* at 7.
[144] *Id.* at 26-27.
[145] *Id.* at 35.

powers to dilute, disperse, and destroy a large variety of substances that man, for one reason or another, elects to discharge into it," but a substance became a pollutant when "these processes cannot keep up with the rate of discharge."[146]

The idea that CO_2 only became a pollutant when it reached some level of accumulation was part of a larger argument about what *kind* of pollutant CO_2, was. Most scientists at the time agreed that CO_2 *was* a pollutant, but saw it as distinct from other substances conventionally understood as pollutants, because it was not visible, it was naturally occurring, and it did not have acute health effects at the levels under consideration. Others saw it as distinct because it was necessary for life.[147] This perspective was offered in in Part 3 of the AAAS report, "Background Reports," which included an extensive section on "Pollutants and Their Effects," including a section on CO_2.[148] It began: "Carbon dioxide is not normally considered an air pollutant because (i) the uncontaminated atmosphere has a concentration of approximately 300 ppm, (ii) it is essential for animal and plant life, and (iii) there must be at least 5000 ppm in the air before man's respiration is adversely affected …"[149]

On the other hand, the report noted, CO_2 was rising because of *industrial activity*,

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[146] *Id.* at 36.
[147] The "necessary for life" argument was unsound, because many trace elements that are necessary for life are nonetheless toxic in large doses, or because they differentially affect different life forms. One environmentally important example is selenium, which was implicated in the death of migratory waterfowl in the Kesterson Reservoir, California. See Harry Ohlendorf et. al., *Bioaccumulation of selenium in birds at Kesterson Reservoir, California,* 19 ARCHIVES OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY 495 (1990). Still, the argument was made.
[148] The eleven sections covered: "Sulfur and Its Compounds, Carbon Monoxide, Carbon Dioxide, Oxides of Nitrogen, Photochemicals, Particulate Matter, Lead and Other Metals, Fluorides, Environmental Carcinogenesis, Economic Poisons, and Radioactive Pollution." AIR CONSERVATION COMMISSION, *supra* note 139, at xi.
[149] *Id.* at 78.

which made it comparable to other substances conventionally recognized as pollutants: "[S]ince about the middle of the 19th century, worldwide atmospheric concentrations of carbon dioxide have been rising steadily because of the increasing dependence of our industrial era on fossil fuels," [150] and "the extra amounts of atmospheric carbon dioxide … from the combustion of fossil fuel" could affect the earth's "heat balance, and hence on the climate of the whole earth."[151] Ultimately, the Commission concluded, "[t]he fear seems legitimate that an unchecked increase in the rate of combustion of carbon fuels may eventually extend carbon dioxide levels to meteorological and physical significance, and that carbon dioxide concentrations may become great enough to cause climatic changes.[152]

An important feature of this discussion is that the scientists recognized that controlling CO_2 could require major changes to prevailing patterns of power generation. They wrote: "Significant effects may occur in the coming centuries … if the combustion of fossil fuels continues to increase—and it will keep rising if the fuel and power requirements of our worldwide industrial civilization continue to rise exponentially, and if these needs are met only to a limited degree by the development of tidal, solar, and nuclear power."[153] In the event of undesirable climatic changes, humans "may be forced to turn to new sources of energy in order to reestablish a viable carbon dioxide equilibrium."[154]

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[150] *Id.*
[151] *Id.* at 79.
[152] *Id.* at 81.
[153] *Id.* at 80.
[154] *Id.* at 81.

Dixon summarized the Commission's report in articles in *Science* and the *Bulletin of the Atomic Scientists* and discussed carbon dioxide in both.[155] In the *Science* article, co-authored by Commission member and NCAR staff chemist James Lodge, Dixon particularly emphasized CO_2 and climate; this article was sent to Senator Muskie at least twice in 1965, including by NCAR's Walter Orr Roberts. In correspondence with Lodge in October 1965, Muskie wrote that he had read the paper and was looking forward to reading the report.[156]

In the coming years, the Commission's report would be cited frequently in discussions of air pollution. Significantly, the observation that CO_2 was "not normally considered an air pollutant" would largely drop away, as numerous leading scientists explicitly discussed CO_2 as a pollutant, despite the fact that it was naturally occurring and necessary for life. For example, physicist and *Science* editor Philip Abelson drew on the Commission's report in a 1968 article on "Man-made environmental hazards" published in the *American Journal of Public Health*, citing it as an example of "air pollution … getting the considerable attention [it] deserve[s]."[157] Abelson reminded readers that "today man is changing his environment on a planetary scale," repeating the prediction of a 25% increase in atmospheric CO_2 by the year 2000, and warning of its potential to

[155] Dixon and Lodge, *supra* note 111; James P. Dixon, *For Air Conservation*, 21 BULL. OF THE ATOM. SCI. 7 (1965).
[156] *Id.* at 1060, s.V.A.5, b. 375, f. 8, BC-ESM. Reprint sent from Gene Malecki to Muskie, May 24, 1965; Walter Orr Roberts to Muskie, August 20, 1965, s. V.A.5, b. 373, f. 13; Muskie to James Lodge, October 1, 1965, s. V.A.5, b. 376, f. 2, all BC-ESM.
[157] Philip H. Abelson, *Man-Made Environmental Hazards. I. How Man Shapes His Environment*, AM. J. PUB. HEALTH & NAT. HEALTH 2043, 2044 (1968).

increase global temperature.[158]

III. Establishing CO_2 as an Air Pollutant

US Public Health Service Air Pollution Conferences

In the 1950s and 1960s, the subject of air pollution spurred a vast scientific literature. A complete review of the air pollution literature from this period is beyond the scope of this paper, but a few examples will make the point that by the late 1950s and 1960s, CO_2 was being discussed not just as a factor in meteorology, atmospheric physics, and climate science, but in air pollution science and public health, including in conferences sponsored by the federal government.

Federal responsibility for air pollution rested with the U.S. Public Health Services (PHS, a division of the Department of Health, Education, and Welfare (HEW). Control efforts expanded over the course of the 1960s, with the creation of the National Center for Air Pollution Control (NCAPC), which in 1968 was reconstituted as the National Air Pollution Control Administration (NAPCA).[159] Until that time, most federal efforts were restricted to research and technical cooperation with state and local officials. National

[158] *Id.* at 2046. Abelson cited the 1965 PSAC report for the statistic on carbon dioxide increases. He also discussed the counter-argument for the effects of particulate matter. *See also generally,* Philip H. Abelson, *Social Responsibilities of Scientists*, 167 SCIENCE 241 (1970).

[159] Federal work on air pollution began with the Air Pollution Control Act of 1955 which provided PHS funds to conduct research on the "national problem" of air pollution. Responsibility for air pollution *control* remained largely a state-level problem throughout the decade. The 1963 Clean Air Act was the first federal level U.S. law to allow for setting emissions standards (the Senate Subcommittee on Air and Water Pollution was created the same year), but control efforts remained a largely state-level affair. That began to change with the creation of NCAPC within the PHS in 1966 and the passage of the 1967 Air Quality Act amendments established national emissions standards (for stationary sources) and air quality criteria. On the history of federal air pollution control efforts, including NAPCA, see CHARLES O. JONES, CLEAN AIR: THE POLICIES AND POLITICS OF POLLUTION CONTROL (1975).

conferences were an important means of exchanging information on the latest research, bringing together leaders in the field.[160]

Most of the air pollution literature in the late 1950s and 1960s focused on urban air pollution in relation to public health, which at the time was the major impetus for air pollution legislation. Even though CO_2 was not considered an immediate threat to public health, it was, nonetheless, often discussed in this context. We have already noted Christian's Junge's presentation at the 1960 PHS-sponsored Third Air Pollution Research Seminar, which demonstrates that the work by the meteorologists and atmospheric physicists was known to participants in the air pollution fields.[161] Additional examples will help to make the point.

The first National Conference on Air Pollution, sponsored by the US Public Health Service, was held November 18-20, 1958.[162] The conference's purpose was to "discuss the current state of knowledge in the field and chart a practicable future course of action."[163] Participants included scientific experts such as Caltech chemistry professor Arie Haagen-Smit, politicians such as California Senator Thomas Kuchel, and representatives from the steel, automobile, chemical, and petroleum industries and from environmental groups.

CO_2 was not discussed in the published 1959 conference summary, but the full

[160] *See generally* Orford, *supra* note 30; BAILEY, supra note 30.
[161] Junge, *supra* note 83.
[162] US DEP'T OF HEALTH, EDUCATION, AND WELLNESS, PUBLIC HEALTH SERVICE, PUB. NO. 654, PROCEEDINGS: NATIONAL CONFERENCE ON AIR POLLUTION (1959).
[163] Leroy Burney, *Forward*, to US DEP'T OF HEALTH, EDUCATION, AND WELLNESS, PUBLIC HEALTH SERVICE, PUB. NO. 654, PROCEEDINGS: NATIONAL CONFERENCE ON AIR POLLUTION AT iii (1959).

conference proceedings show that it was discussed. [164] Dr. Chauncey Leake, Assistant Dean of the College of Medicine at Ohio State University, spoke on "Social Aspects of Air Pollution," asking, "What about the tremendous increase in the blanket of carbon dioxide that we are throwing above us, and which will inevitably tend to increase heat capture from the sun? What will we do if this occurs, with gradual melting of the huge polar ice caps, and the gradual rise of our oceans, drowning out still further our shore lines?" Leake suggested that CO_2 accumulation might be slowed somewhat by planting trees, which at least "even in a very slight degree [it] may alter the extent of heat capture."[165]

Haagen-Smit, one of America's leading experts on urban smog, noted that it was not always easy to distinguish between toxic effects of air pollution and nuisance effects, because they both could hinge on concentration levels and exposure times. He cited CO_2 as an example: "All chemicals, whatever their nature, may be harmful to humans when a certain concentration is reached and maintained for sufficiently long time. This is true for natural constituents of the air—oxygen, nitrogen and carbon dioxide—as well as the group of poisonous gases such as cyanides, sulfur dioxide or trioxide, chlorine, and many others."[166] Wendell Hewson— the University of Michigan Professor who had been working with the Cambridge Air Force Research group on the issue since the early 1950s—offered a list of seven "outstanding problems or tasks." Number four was "[a]tmospheric contaminants, such as carbon dioxide, which may be causing long-period

[164] James P. Dixon et al., *National Conference on Air Pollution: Conference Report*, 74 PUBLIC HEALTH REPORTS 409 (1959).
[165] U.S. DEP'T OF HEALTH, EDUCATION, AND WELLNESS, *supra* note 161 at 23-24.
[166] *Id.* at 81.

changes in our climate, [which] should be monitored on a national basis at appropriate stations."[167]

Industry representatives stood on both sides of the debate over the possible harmful effects of carbon dioxide. Representing the Smoke and Fumes Committee of the American Petroleum Institute, Charles A. Jones described CO_2 as a "harmless" product of combustion.[168] Dr. Charles Lapple, of the industry-oriented Stanford Research Institute, similarly referred to carbon dioxide as a "relatively innocuous" gas."[169] However, Harry Ballman of the Bituminous Coal Institute recognized that CO_2 was a form of pollution, even if he did not necessarily think anything could be done about it. He argued that "Oxides of nitrogen, hydrocarbons, moisture, and carbon dioxide play a large part in air pollution, and many people are concerned about them." The problem, he felt, was that "no recommended practices for control are available."[170]

In 1961, the U.S Public Health service hosted a symposium on "Air Over Cities."[171] Like many meetings of its type, its primary focus was urban air pollution, widely recognized as a threat to public health. Carbon dioxide frequently appeared in these discussions. Helmut Landsberg, Director of the Office of Climatology for the US Weather Bureau, included it in a table labelled "Concentration of Some Air Pollutants in the Atmosphere of urban areas." Carbon dioxide was the first pollutant listed, followed by carbon monoxide, oxides of nitrogen, sulfur dioxide, aldehydes, chlorides, and

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[167] *Id.* at 108.
[168] *Id.* at 177.
[169] *Id.* at 303.
[170] *Id.* at 320.
[171] US PUBLIC HEALTH SERVICE, SEC TECH. REP. A62-5, SYMPOSIUM: AIR OVER CITIES (1961) [*hereinafter* 1961 PHS SYMPOSIUM].

others.[172] James Lodge of NCAR also highlighted CO_2, noting that it was "generally agreed that the concentration of this compound in the earth's atmosphere has increased since the turn of the century…."[173] Lodge agreed that more research was needed, particularly to improve measurement techniques.[174] Wendell Hewson also attended this meeting and argued for more research to better understand "the possible influence on our climate of increased CO_2 in the atmosphere resulting from our combustion of fossil fuels."[175]

In a February 1962 Special Message to Congress, President John F. Kennedy asked for legislation that would give the PHS more authority on air pollution; as part of that framework, HEW Secretary (later Connecticut Senator) Abraham Ribicoff called for another conference. This resulted in the second National Conference on Air Pollution, held in December 1962.[176] While the focus of the conference was once again primarily on urban air pollution and health—and some participants continued to hold that CO_2 was "harmless"—others reminded the meeting that CO_2 could pose a significant long-range threat.[177] For example, John E Bebout, Director of the Urban Studies Center at Rutgers

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[172] H.E. Landsberg, *City Air—Better or Worse*, *in* 1961 PHS SYMPOSIUM at 1, 4.
[173] James P. Lodge*, Recent Developments in the Chemistry of Urban Atmospheres, in* 1961 PHS SYMPOSIUM at 31, 31-32.
[174] *Id.* at 35. Lodge argued that measurement methods had greatly improved since the start of the century and referenced Keeling's measurements as an "fine example."
[175] E.W. Hewson et. al, *Measurement Programs Required for Evolution of Man-Made and Natural Contaminants in Urban Areas*, *in* 1961 PHS SYMPOSIUM at 239, 254.
[176] Arthur C. Stern, *History of Air Pollution Legislation in the United States,* 32 J. APCA 44 (1982); US DEP'T OF HEALTH, EDUCATION, AND WELLNESS, PUBLIC HEALTH SERVICE, PUB. NO. 1022, PROCEEDINGS: NATIONAL CONFERENCE ON AIR POLLUTION (1963) [*hereinafter* 1963 PHS PROCEEDINGS].
[177] For example: Wolfgang E. Meyer, an engineering professor at Penn State, noted that "When the hydrogen and carbon that are the elements that make up petroleum fuels combine with oxygen, water vapor and carbon dioxide are formed. Both of these products of the ideal, complete combustion are invisible, cannot be smelled, and are harmless." Wolfgang E. Meyer, *Air Pollutants from Motor Vehicles, in* 1963 PHS PROCEEDINGS at 46.

University, referred back to Leake's comments at the 1958 meeting, recalling that he had advocated planting trees "to keep down the increase in the blanket of carbon dioxide which threatens to make drastic and very uncomfortable changes in our climate and the distribution of water over the globe." Bebout suggested the need for policy attention: the possible long range "concern of mankind over the mounting pollution resulting from the general increase in the burning of hydrocarbons throughout the world, including the burning of them in fast-moving jetplanes and other long range vehicles, simply underscores the necessity for acceptance of the ultimate responsibility for conservation of the air we breathe at the highest possible levels of public decision making."[178] John W. Bodine, President of Penjerdel (the Pennsylvania-New Jersey-Delaware Project, Inc), also noted the "possibility that further emissions of carbon dioxide may alter the climate of our planet or the level of our oceans."[179]

The Third National Conference on Air Pollution was held in December 1966. Here, we find an extensive discussion of carbon dioxide. The chair of the AAAS Air Conservation Commission, James P. Dixon, gave a broad address on "The State of Our Atmosphere," in which he suggested there was no doubt that carbon dioxide could and should be included among pollutants. He noted that the "principal pollutants" could be divided into inorganic gases, organic gases, and particulates.

> Carbon dioxide and monoxide, sulfur dioxide, some hydrogen sulfide, nitric oxide and dioxide, are the main inorganic gases produced from the combustion of fossil fuels... Described in chemical terms, the major air pollutants arise because of the combustion of fossil fuels. The burning of hydrocarbon fuels in internal

[178] John E. Bebout, *How Can We Get Action for Clear Air Through—and at—All Levels of Government?, in* 1963 PHS PROCEEDINGS at 352, 355.
[179] *John W. Bodine,* How Can We Get Action for Cleaner Air Through Community Action?, *in* 1963 PHS PROCEEDINGS at 360, 361. Bodine served on the AAAS Air Conservation Commission a few years prior.

> combustion engines is the single most important pollutant source. Small wonder, then, that there is a revived interest in the electric-powered automobile.[180]

While some speakers stressed that the effects of increased atmospheric carbon dioxide were speculative, others argued otherwise. John S. Chapman, Assistant Dean at University of Texas, Dallas Medical School and member of the American Medical Association Council on Environmental and Public Health, stressed that the effects were at least "roughly predictable and would not meet with unqualified approval."[181] Morris Neiburger, Professor of Meteorology at the University of California, Los Angeles and a past president of American Meteorological Society, argued that important aspects of the problem were not speculative. In fact, carbon dioxide was one of the better studied pollutants, he suggested, at least in terms of its atmospheric concentration, as well as its potential to alter the climate. Like others at the conference, Neiburger specifically called carbon dioxide a pollutant, akin to sulfur dioxide and carbon monoxide, noting that its increase had received "much attention."

> We do not really know whether the worldwide average concentration of such toxic pollutants as sulfur dioxide, nitrogen dioxide, and carbon monoxide has been rising through the years, since suitable measurements for the past are not available**.** *In the case of one pollutant, carbon dioxide, however, there is definite evidence that the concentration for the atmosphere as a whole has risen about 10 percent of its value*, from approximately 0.029 percent in 1900 to over 0.032 percent at present.
>
> There are no direct toxic effects to humans from an increase of carbon dioxide as long as it does not greatly reduce the available oxygen, and even a tenfold increase in CO_2 would still leave plenty of oxygen for animal respiration....
>
> A possible indirect adverse effect has received much attention, namely, the

[180] James Dixon, *The State of Our Atmosphere*, *in* US DEP'T OF HEALTH, EDUCATION, AND WELLNESS, PUBLIC HEALTH SERVICE, PUB. NO. 1649, PROCEEDINGS: THIRD NATIONAL CONFERENCE ON AIR POLLUTION 18, 19-20 (1967) [*hereinafter* 1967 PHS PROCEEDINGS].
[181] John Chapman, *Air Pollution and Our Health*, *in* 1967 PHS PROCEEDINGS at 23, 24.

> influence of the increase of carbon dioxide on the balance of heat and temperature of the atmosphere. Carbon dioxide … is largely responsible for the "greenhouse" effect….The increase in carbon dioxide which has taken place must have altered the greenhouse effect, producing an increase of average temperature of the earth's surface. ... Since continuation of this temperature rise with continued increase in CO_2 concentration may result in the melting of the ice caps over Antarctica and Greenland and cause a rise of sea level and flooding of populated coastal areas, it is important to evaluate this effect, and perhaps to limit or eliminate the use of fossil fuels to prevent an excesesive [sic] increase of carbon dioxide.[182]

He concluded that "Whether or not we are already exceeding the limit of the air's capacity to cleanse itself, we certainly will do so in the future unless prompt and effective steps are taken to prevent it."[183]

John T. Middleton, former professor at the University of California, Riverside and NCAPC director also spoke at the 1966 conference. (Middleton would continue as the director of NAPCA in 1968, and later, when NAPCA was folded into the newly-established EPA, he served as its first deputy assistant administrator for the Air Program). He was an expert on the impacts of air pollution on plants, including agricultural crops; he placed carbon dioxide into the context of air pollution—particularly from motor vehicles—and was explicit that carbon dioxide was a pollutant of concern:

> The array of pollutant chemical compounds emitted by motor vehicles is extensive and includes carbon dioxide, carbon monoxide, gasoline, hydrocarbons, oxygenated hydrocarbons, nitrogen oxides, nitrogen-containing organics, sulfur oxides, aldehydes and acids, phenols, polynuclear hydrocarbons, particulate matter, and lead salts. *These materials are air pollutants as emitted to the atmosphere* or participate in atmospheric photochemical reactions which lead to the production of other pollutants, such as nitrogen dioxide, ozone, and the peroxyacyl nitrates.[184]

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[182] Morris Neiburger, *What Factors Determine the Optimum Size Area for an Air Pollution Control Program?, in* 1967 PHS PROCEEDINGS at 442, 447. Emphasis added.
[183] *Id.*
[184] John T. Middleton, *Future Air Quality Standards and Motor Vehicle Emission Restrictions*, *in* 1967 PHS PROCEEDINGS at 45, 46. Emphasis added.

In language similar to what would soon be written in the definition of welfare in the 1970s Clean Air Act, Middleton explained that pollutants from motor vehicles, "alone and in conjunction with those from other emission sources, [create] adverse effects upon the public health and welfare; it affects man's health, irritates the senses, damages property, and interferes with visibility."[185]

Another prominent conference speaker was physicist and Nobel Laureate Glenn Seaborg, at that time Chairman of the Atomic Energy Commission. Seaborg offered carbon dioxide pollution as a reason to develop nuclear power, which had the "decided advantage" over fossil fuel plants in terms of air pollution, because "the stacks of fossil fueled plants must release to the atmosphere effluents containing amounts of carbon dioxide which cannot be reduced, and of sulfur dioxide for which no effective removal system has yet been developed."[186]

Several politicians spoke at this conference, including U.S. Representative Emilio Q. Daddario (D-CT), New Jersey Governor Richard Hughes, Cleveland Ohio mayor Ralph S. Locher, and Wisconsin Senator Gaylord Nelson. These men discussed CO_2 in terms of long-range policy, nuclear power, public understanding of science, and the role of the U.S. Congress. Also present was Senator Edmund Muskie, and his staff member, Leon Billings.[187]

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[185] *Id.*
[186] Glenn T. Seaborg, *Development of National Policy with respect to Nuclear and Other New Sources of Power, in* 1967 PHS PROCEEDINGS at 131, 132.
[187] US DEP'T OF HEALTH, EDUCATION, AND WELLNESS, PUBLIC HEALTH SERVICE, ATTENDANCE LIST, NATIONAL CONFERENCE ON AIR POLLUTION DECEMBER 12-14, 1966 at 24, 43 (1967). This attendance list

Representative Daddario (who spoke earlier that year on CO_2 in House hearings on pollution abatement technology) argued that we should not use the long timeline for environmental damage as an excuse for inaction.[188] He advocated developing "an 'early warning' capability for environmental effects," analogous to national security early warning systems, which would "give us the time to revise the activities of society, or to take countermeasures, when manmade disruptions appear to be going contrary to our best interests."[189] A specific example was carbon dioxide: "The complex problem of the increase in carbon dioxide in the atmosphere from fossil fuel combustion" is an example "where an early warning is needed to direct research, development, and deployment of technology."[190] Daddario echoed Seaborg's suggestion that the emerging effects of CO_2 might warrant a "crash program" for nuclear power plants: "[N]uclear energy... is a most promising answer to pollution of the air. Adverse reports in the next few years on the carbon dioxide effect might bring a crash program to install nuclear electric power." [191]

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was transmitted directly to Muskie from the NCAPC, *see* National Air Pollution Control to Edmund Muskie, Apr. 3, 1967, s. V.A.6, b. 540, f. 1, BC-ESM.

[188] As Chairman of the Subcommittee on Science, Research, and Development of the House Committee on Science and Astronautics, Daddario presided over a month of hearings on pollution abatement technologies, in which CO_2 was discussed at length. The Subcommittee produced two associated reports, both of which considered CO_2. *See The Adequacy of Technology for Pollution Abatement: Hearings Before the Subcommittee on Science, Research, and Development of the H. Comm. on Sci. and Astro*., 89th Cong, 2nd Session (1966); SUBCOMM. ON SCIENCE, RESEARCH, AND DEVELOPMENT, *supra* note 126. These reports are discussed further in Lanier-Christensen et. al., *Climate Change and the 1970 Clean Air Act Part 2: Testimony to Congress* (forthcoming.)

[189] Emilio Q. Daddario, *A Congressional View of the Problem*, *in* 1967 PHS PROCEEDINGS at 183, 185. Daddario's Subcommittee on Science, Research and Development first proposed this warning system in their 1966 progress report in which they referenced atmospheric CO_2, shifting weather patterns, "disturbed planetary temperatures," melting ice caps and sea level rise that would leave "Seattle or San Diego…no longer on the map" as possible concerns that merited such a system. *See*, SUBCOMM. ON SCIENCE, RESEARCH AND DEVELOPMENT OF THE H. COMM. ON SCIENCE AND ASTRONAUTICS, 89TH CONG. 2ND SESS., 2ND. PROGRESS REPORT 26 (Comm. Print 1966).

[190] *Id.* at 185-186.

[191] *Id.* at 187.

Governor Hughes offered seven points on what New Jersey's experience could offer to other states and their air pollution programs. The seventh was public understanding of air pollution "in both its importance and its complexity." He explained: "Air pollution is complex. It can exist as a threat to public health or simply as a minor source of discomfort. It can and does affect crops, trees, flowers and buildings visibly. It can also affect the permanent condition of the atmosphere which surrounds the earth. Some scientists argue, for example, that the uncontrolled discharge of carbon dioxide could have very dangerous results."[192] Cleveland Mayor Ralph Locher also addressed CO_2 and climate: "The conservationists tell us of [that t]he average temperature will rise as more carbon dioxide is pumped into the air ..." [193]

One of the most extensive and well-informed discussions came from Wisconsin Senator Gaylord Nelson, known for his commitment to environmental protection and in 1970 one of the founders of Earth Day. Nelson offered "A Congressional View of the Problem," noting that the Senate Interior committee had already heard testimony on carbon dioxide and climate change.

> [U]p there in the once blue sky, concealed behind a blanket of smog, things are happening which no average person can detect.
>
> A Cornell University scientist, Dr. LaMont Cole, testified before our Senate Interior Committee [and] said: **'**Man is burning fossil fuel at an ever-increasing rate and it is probably that more than half of the fuel ever burned by man has been burned in this century. One result of this is to release carbon dioxide into the atmosphere more rapidly than it can be taken up by green plants or dissolved in the oceans and eventually precipitated … It appears probable that the carbon dioxide content of the atmosphere has increased by at least 10 percent since the turn of the century. Atmosphere [sic] carbon dioxide is believed to have

[192] Richard J. Hughes, *The Case for a State Air Pollution Control Program*, *in* 1967 PHS PROCEEDINGS at 364, 367.
[193] Ralph S. Locher, *The Case for a Local or Regional Air Pollution Control Program*, *in* 1967 PHS PROCEEDINGS at 400, 402.

drastic effects on climate...'

The scientists also remind us that this orgy of fuel burning—which stokes the fires of American industries and powers our autos and planes—is using up oxygen at an accelerating rate.[194]

Critical to the perspective of Congressional awareness of the CO_2 problem and intent in passing the Clean Air Act was the work of Maine Senator Edmund Muskie. Among the materials that can be found in the Muskie archives from this time is an article published in the April-May 1966 edition of *National Wildlife*. The article, written by National Wildlife foundation Executive Director Thomas Kimball, and reprinted for the Air Pollution Conference, explained that

> [An] apparent result of our profligacy with our atmosphere sounds like a chapter from a science fiction novel, but is unfortunately true: Carbon dioxide is an innocuous, important gas in our atmosphere. Among other things, it supports our plants, which inhale it and exhale oxygen. The natural envelope of carbon dioxide in our atmosphere is the primary retainer of the sun's heat around the earth. But as we increase the carbon dioxide content of our atmosphere — and remove vegetation that might have absorbed it — we increase the amount of heat the earth can hold, with potentially disastrous results. [195]

Muskie spoke at the conference on December 13th, and while his conference speech did not specifically address CO_2, it did indicate his approach to air pollution. This was to address not only immediate health effects of single pollutants but also to develop a

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[194] Gaylord Nelson, *A Congressional View of the Problem*, *in* 1967 PHS PROCEEDINGS at 450, 451-2.The quotation from Cole is reproduced as it reads in the text, which has minor typographical changes from the original Senate testimony. Senator Nelson was quoting from a hearing over which he had presided earlier that year. *Ecological Research and Surveys*, *hearing on S. 2282 before the S. Comm. on Interior and Insular Affairs*, 89th Cong., 2d Sess. 65 (1966) (statement of Dr. Lamont Cole, Professor of Zoology, Cornell University).

[195] Thomas Kimball, *Air Pollution*, 4 NAT. WILD. 12 (1966), reprinted for US DEP'T OF HEALTH, EDUCATION, AND WELLNESS, PUBLIC HEALTH SERVICE, NATIONAL CONFERENCE ON AIR POLLUTION, DEC 12-14 1966, s. V.A.5, b. 368, f. 10., BC-ESM.

framework that would include long-term effects on health and well-being, and embrace flexibility to address issues that arose in the future that had not yet been predicted:

> [Air quality] criteria need to go beyond questions of clinical injury or gross insults from specific pollutants. They need to include considerations of subtle, long-term effects of pollutants on our health and well-being. Those criteria must take into account health, esthetics, conservation of natural resources and the protection of public and private property. The criteria must be modified, as our knowledge expands, to provide added protection against unforeseen pollution hazards.[196]

The federal government was "the logical entity to develop the criteria," Muskie explained, because "community or state jurisdictions bear little or no relationship to the geographic spread of air pollution. Metropolitan areas are not consistent with meteorological areas. The old institutional arrangements for air pollution control are not really adequate to the task." Moreover, the traditional interstate compact has not given sufficient attention to the changing requirements of a complex modern society. *It has not been flexible enough to deal with changing concepts of pollution control…*"[197]

The Senator discussed plans for Congressional hearings related to the Clean Air Act, and exploring alternative energy vehicles, including the "battery-driven electric car." He concluded by emphasizing that air quality was a question of general welfare: "[W]e must all realize that no narrow personal or private motive can be allowed to outweigh the importance of the public health and welfare of the people of the United States."[198]

The Automobile and Air Pollution: A 1967 Report

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[196] Edmund Muskie, *Setting Goals for Clean Air*, *in* 1967 PHS PROCEEDINGS at 596, 597. Copy of speech also found in s. V.D, b. 31, f. 3, BC-ESM.
[197] *Id.* at 597-597. Emphasis added.
[198] *Id.* at 599.

On October 18, 1967, Secretary of Commerce Alexander Trowbridge forwarded a report to Senator Muskie: *The Automobile and Air Pollution: A Program for Progress Part I*. Trowbridge sent the report to Muskie one day before its public release; Muskie replied immediately, requesting Part II as soon as it was available.[199] The Department of Commerce had begun expressing interest in examining the effects of automobile usage on air pollution in late 1966, and in January 1967 the Panel on Electrically Powered Vehicles was appointed by then-Secretary John Connor.

The panel was chaired by Richard Morse from MIT and consisted of both academic researchers and industry affiliates.[200] Originally charged with producing a narrowly focused report on the feasibility of the development of electric vehicles for mass market, during organizing the study was expanded to examine broadly the issue of air pollution related to automotive transportation, to present recommendations for action, and to investigate all possible alternatives to the gasoline engine. The timeline was also accelerated: what was supposed to be a twelve-month study produced a preliminary report in less than seven months because of "pressures from Congress, the Executive

[199] Trowbridge to Muskie and Muskie to Trowbridge, October 18, 1967, s. V.A.6, b. 485, f. 8, BC-ESM. The report can be found in b. 478, f. 7. Part II was published in December 1967 and included the reports of subpanels.

[200] The group was conducted in cooperation with a Commerce Department advisory board with support from the DOD, HEW, HUD, DOT, Post Office, DOT, AEC, and FPC. Membership was skewed towards industry, and two of the seven academics had industry ties in addition to their academic appointments. Nine representatives from Ford, Consolidation Coal, Esso, Westinghouse, R.C.A., GM, Chrysler, Gulton, and AEP comprised the bulk of the panel, rounded out by Paul O'Day, from Trowbridge's office. The subpanel on Air Pollution was less representative of industry interests—chaired by Rolf Eliassen of Stanford, the other members included representatives from the State of California, the Los Angeles and New York City air pollution Control Boards, the Harvard School of Public Health, Arthur Stern from NCAPC and HEW, and representatives from Chrysler and Mobil. In 1969, Morse served on the steering committee for the MIT Study of Critical Environmental Problems (SCEP).

Branch, the press, and the public."[201] Muskie later credited the panel's work with creating "renewed interest in alternatives to internal combustion.[202]

Upon its completion, the report was transmitted widely amongst executive branch agencies: copies were sent to Robert McNamara (DOD), Postmaster General Lawrence O'Brien, Secretary of the Interior Udall, Trowbridge, John Garner (HEW), Robert Weaver (HUD), Secretary of Transportation Alan Boyd, Glenn Seaborg (AEC) and Lee White (FPC).

In defining the problem of air pollution, the panel used language similar to the definition of welfare that would soon appear in the Clean Air Act: "The atmospheric contamination which accompanies industrial society is a continuing insult to man and his environment. This pollution shortens life, destroys vegetation, damages property, and threatens to alter basic meteorological processes."[203] Like other reports from this era, the group emphasized that exact research on the effects of many specific pollutants was lacking, but that should not be reason for delay: a "delay in action pending availability of conclusive evidence which identifies the precise damage associated with various levels of

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[201] US DEPARTMENT OF COMMERCE, PANEL ON ELECTRICALLY POWERED VEHICLES, THE AUTOMOBILE AND AIR POLLUTION: A PROGRAM FOR PROGRESS 8 (1967). In April a revised schedule was announced because "hearings on bills presented before the US Senate by Senator Warren Magnuson and Senator Edmund Muskie, as well as several national professional conferences, increased interest in the problem." The proposed bills from Magnuson and Muskie are presumably S. 451, 90th Cong. (1967) and S. 453, 90th Cong. (1967), the first a bill to fund research on less polluting vehicles, the second specifically for funding research on electric vehicles. *See* 113 CONG. REC., S. 612-617 (daily ed. Jan. 17, 1967). A preliminary report was submitted in July, with the final publication in October.

[202] Muskie to Robert Ayres of Resources for the Future, in correspondence inviting Ayres to a hearing, May 8, 1968, s. V.A.6, b. 597, f. 6, BC-ESM. Very similar letters were sent to Ford and GM Presidents and Ralph Nader—those ones co-signed by Warren Magnuson (chairman of Commerce Committee). Muskie also corresponded with Richard Morse about the panel's report while their work was underway. *See* Muskie to Richard Morse, May 22, 1967, s. V.A.6, b. 485, f. 8, BC-ESM.

[203] US DEPARTMENT OF COMMERCE, *supra* note 200 at 9.

each pollutant currently contaminating the air is unreasonable."[204] Testing should be increased as soon as "economics and advancing technology will allow," but the evidence available was enough to serve as a "basis for action until more definitive studies are completed."[205]

The panel took each of the topics laid out in their definition in turn in their section on the "effects of air pollution." The fourth sub-section, "Weather modification," concisely summarized the possible meteorological effects of carbon dioxide:

> Attention has been focused for some time on the effects of rising levels of carbon dioxide in the atmosphere due to increasing rates of combustion of fossil fuels. The infra-red absorption properties of CO_2 cause out-going radiant heat from the earth to be captured near the surface, resulting in an increase in the temperature of the atmosphere. This phenomenon is popularly known as the 'greenhouse effect.' Should carbon dioxide levels be allowed to rise continually at current rates, it has been suggested that the resulting temperature rise would have dire meteorological effects, resulting in melting of the polar ice caps and raising ocean levels.[206]

Given the significance of this issue, more work was needed. The Panel had been "surprised and disturbed to learn that the existing knowledge about atmospheric processes is so inadequate," and recommended that the Environmental Science Services Administration (ESSA)—which was responsible for research on inadvertent weather modification—should, as soon as possible, establish a robust research program on the effects of air pollution on atmospheric processes. [207] Here, the panel emphasized the global implications and explicitly linked the problem to human welfare:

> To date, very little research has been undertaken on the interrelationships between pollution in the atmosphere and the basic meteorological processes which govern

[204] *Id.* at 12.
[205] *Id.* at 12-13.
[206] *Id.* at 15.
[207] *Id.* at 15-16.

> weather. These effects could have extremely significant implications upon the welfare of the world's population and a start should be made as soon as possible to learn more about this potentially important aspect of air pollution. Since the problems in this area have obvious worldwide implications, an attempt should be made in such a program to construct and cooperate in international research and monitoring efforts.[208]

The global nature of air pollution resurfaced later in the report. Under a section examining the role of government for air pollution research and regulation, the panel differentiated between what they termed "micrometerology," an area of knowledge that looked at "small-scale atmospheric convection and diffusion" and which they classified as one area of "uncertainties in air pollution control," and world air pollution, which was given its own subsection.[209] Carbon dioxide was not directly addressed in this section, but the panel alluded to it when it wrote that "although this aspect of the problem has not yet fired public opinion, the world-wide significance of air pollution is, at least today, probably more serious in terms of health and welfare than that of radioactive fallout from nuclear tests. The need is clear for early action and the establishment of cooperative programs should be delayed no longer."[210]

The work of the Panel on Electrically Powered Vehicles reflects the recognition by the mid 1960s that matters of pollution—including CO_2—had significant economic ramifications, in this case potentially for the entire automobile industry. As Robert White framed it, ESSA was created "to enable the Department of Commerce to treat the physical environment as a whole … because various aspects of the physical environment

[208] *Id.* at 16.
[209] *Id.* at 37, 40.
[210] *Id.* at 41.

relate one to the other."[211] ESSA's weather modification work was related to their other weather activities (such as the Weather Bureau) and was guided by the goals articulated by the NAS Panel on Weather and Climate Modification and the NSF Special Commission on Weather Modification. This included work on the "Modification of weather and climate by air pollution." One description of this research arena specifically noted the Mauna Loa CO_2 measurements and the relationship between fossil fuels, pollution, and man-made climate change.

> Research on the degree to which both global and local climates are being affected by industrialization, urbanization, and agricultural practices is an important element of the ESSA program. Air pollution from the burning of coal and oil in particular may produce long-term effects on the natural climate of the earth. Long-term pollutant concentration trends are being monitored by an observatory on Mauna Loa, Hawaii, and measurements of ozone and other atmospheric properties are being made to provide data for evaluating possible man-made climatic changes.[212]

NAPCA-North Carolina Consortium on Air Pollution Conference

In October 1969, NAPCA co-sponsored a symposium with the North Carolina Consortium on Air Pollution. John Middleton was now NAPCA director, and he

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[211] *Departments of State, Justice, and Commerce, the Judiciary, and Related Agencies Appropriations for 1970*: *Hearing on Environmental Science Services Administration before a H. Subcommittee of the Comm. On Appropriations House of Representatives*, 91st Cong, 1st Sess., 616, 634 (Part 3, 1969) (testimony of Robert White, Administrator, ESSA).

[212] *Id.* at 738 (Explanation and Justification of Adjustments to Base Program.) Three years later, a 1970 ESSA publication would reiterate this point: "Research is underway on the effects of industrialization, urbanization, and agricultural practices upon global and local climates. The role of air pollution is under study to determine its long-term effects on the natural climate of the earth. Specifically, the R&D program in air pollution deals with the radiation energy budget and with inadvertent weather modification caused by the action of gases (carbon dioxide and ozone), particulate matter (cirrus clouds), and surfaces (albedo)." *Weather Modification Research and Development Programs,* 52 ESSA SCI. & AND ENG. JUL. 1, 1967 TO JUN. 30, 1969 48, 49 (1970). In 1968, Commerce became the lead US agency for participating in GARP—the Global Atmospheric Research Program—as established by Presidential memorandum and Senate endorsement in 1968. *See Departments of State, Justice, and Commerce, the Judiciary*, *supra*, note 210, at 629.

delivered the keynote speech, with CO_2 on his agenda.[213] He acknowledged that the science surrounding the effects of increased atmospheric CO_2 was not certain, but they could not for that reason be dismissed as insignificant.

> Estimates differ about the potential effects on world temperature and climate due to increased atmospheric carbon dioxide and particulate concentrations. ...[O]pinions differ about the details of processes involving temperature trends, climate, melting of polar ice caps, sea level, photosynthesis, and the distribution of fish, to name a few.
>
> There are, of course, many other examples. The point is, that when man alters the balance of Nature, it is like tossing a pebble into a pond: the resulting ripples spread out concentrically from the entry point until they touch every point on the shore. Continued small alterations of our environment may have drastic effects later, effects we cannot foresee now.[214]

Morris Neiburger gave the banquet speech, with the title, "Progress + Profits + Population = Pollution." He returned to a point he had made earlier in the 1960s: that the rate at which pollutants were being added to the atmosphere might be greater than the natural processes that removed them; in regards to CO_2, this was definitely the case.

> [W]e do not know whether, on a world-wide basis, toxic contaminants are being put into the air faster than the natural cleansing processes of the atmosphere remove them.… We do know of one pollutant, though not a toxic one, of which there is an accumulation in the atmosphere. Carbon dioxide has been sampled long enough, and with enough accuracy, to show that the total amount is increasing steadily year by year.[215]

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[213] The symposium was held October 27-30, 1969, at Research Triangle Park in North Carolina. NAPCA functions were transferred to the Air Pollution Control Office within the EPA on December 4, 1970, and thus it was published by EPA and all references to NAPCA were changed to APCO of the EPA. For this reason, NAPCA nearly disappears historically, its work hard to reconstruct. It is also easily confused with APCA, the industry group. US ENVIRONMENTAL PROTECTION AGENCY, APCO PUB. NO. AP-86, PROCEEDINGS OF SYMPOSIUM ON MULTIPLE-SOURCE URBAN DIFFUSION MODELS iii (Arthur C. Stern, ed., 1970) [*hereinafter* 1970 EPA PROCEEDINGS]

[214] John T. Middleton, *Diffusion Modeling for Air Pollution Abatement and Control*, *in* 1970 EPA PROCEEDINGS at 1-1, 1-2.

[215] Morris Neiburger, *Progress + Profits + Population= Pollution*, *in in* 1970 EPA PROCEEDINGS at 12-1, 12-8-9.

The insights offered at these various symposia and conferences were summarized in an April 1970 conference report of the American Public Health Association, published in the journal *Public Health Reports*. In a section entitled "Pollutants Can Unbalance Earth's Delicate Ecosystems," the report recounted a lecture by Barry Commoner, the Director of the Center for the Biology of Natural Systems at Washington University, St. Louis, in which he discussed the competing effects of particulates and CO_2.

> The future of the temperature of the earth, he pointed out, depends on balancing the effects of two pollution processes—a rise in the fraction of solar radiation retained in the atmosphere because of the accumulation of carbon dioxide and a decline in this fraction caused by the shielding effects of pollutant aerosols. If the carbon dioxide accumulation is too great, the rise in temperature may melt the polar ice cap and cause huge floods.[216]

The Air Pollution Control Association and Industry Awareness

The Air Pollution Control Association (APCA, not to be confused with NAPCA), was an industry group dating back to 1907.[217] Throughout the 1960s, the APCA worked alongside the PHS and independent scientists to understand air pollution issues that might affect its members. At the APCA's 60th annual meeting in June 1967, NCAR's James Lodge chaired a session on "Long Lived Pollutants," and Keeling spoke on "Carbon

[216] *APHA Conference Report, 1969*, 85 PUB. HEAL. REP. 283, 343 (1970).
[217] APCA began as the International Association for the Prevention of Smoke in 1907. In 1915 it changed its name to the Smoke Prevention Association of America, and in 1950 to the Air Pollution Control Association. The 1950 name change was part of broader discussions in the association about the need to control all forms of air pollution, rather than just visible "smoke." Over the years, the association had several cooperative programs with the federal government and a number of federal employees served on the APCA board of directors, including Arthur Stern and John Middleton. *See* John S. Lagarias, *The Story of the Air Pollution Control Association: Seventy-Five Years of Growth,* 32 J. APCA 31 (1982).

Dioxide from Fossil Fuel—A Potential World-Wide Air Pollutant." On the same day, Don Nicoll, administrative assistant to Senator Muskie, also delivered a talk. While neither the proceedings nor a summary was published in the *Journal of the Air Pollution Control Association*, Senator Muskie's office retained a copy of the conference program.[218]

In 1969, the Association held a meeting featuring a keynote speech by Guyford Stever, President of Carnegie-Mellon University and later (1972-1976) Director of the National Science Foundation. Stever called attention to the diversity of air pollution, including carbon dioxide, which could threaten "major changes." There were many kinds of air pollution, but

> [O]ur problem today is concentrated in the air pollution produced as a result of largescale activities of man. I am always amazed at the range of kinds of air pollutants and causes that we have. The air is polluted with radioactive material from the explosion of atomic bombs; the air is heated by the tremendous and growing combustion of fossil fuels for heating and cooling as well as processing our materials; we are told that the carbon dioxide balance is also being upset, with the consequent threatening of major changes in the absorption and reflection of sunlight by the earth.... [219]

In 1970, APCA heard again about the CO_2 problem, this time from Russell Train, Assistant Secretary of Interior (1969-1970) and, at the time of his presentation, the first head of the Council on Environmental Quality (1970-1973) under President Richard Nixon. As assistant secretary, Train had given many public speeches on carbon dioxide and climate.[220] He now explained how the new Council would have to address "different

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[218] 60th Annual Meeting, Air Pollution Control Association, June 11-16, 1967, Program, 22, s. V.C, b. 32, f. 4; a copy of Don Nicoll's speech is found in s. V.C, b. 39, f. 1, both in BC-ESM
[219] *62nd Annual Meeting Summary of Activities*, 19 J. APCA 548, 549. (1969).
[220] *See generally* box 69, 70, and 71 various folders, Russel E. Train Papers, Manuscript Division, Library of Congress, Washington, D.C. [*hereinafter* LOC-RET].

forms of pollution" from what had garnered attention in the past, and one of these was carbon dioxide.

> The environmental problems of the future will increasingly cut across the somewhat arbitrary categories of air pollution, water pollution, and so forth, which have evolved over the years. ... The ecological problems we face, whether it be the accumulation of carbon dioxide in the atmosphere or the construction of an Everglades jetport, defy analysis solely in terms of the separate established categories. We need new ways of looking at the environment, and the Council will be working to develop these new perspectives.[221]

Train made it clear that carbon dioxide was not of concern merely as a local effect, but as a global one. He stressed that many "aspects of the environment" were "truly global," and CO_2 was one of them. "The worldwide fallout from nuclear testing underlined the unity of the atmosphere. How long will it be until California has to deal with the pollution from Japan? How long will it be until the carbon dioxide from North America and Europe begins to affect the climate in Asia and Africa?"[222]

Industry leaders were aware of Train's work, including his earlier work with the Conservation Foundation, and understood that the carbon dioxide "problem" was a global one. In 1966, for example, J.H. Huguet, an engineer and the Industrial Conservation Coordinator for the Ethyl Corporation (formed in the 1920s as a joint venture between General Motors and Standard Oil to produce leaded gasoline), presented the North American report on air pollution at the International Clean Air Congress held in London in October 1966.[223] One section of his report, published in the *Journal of Air Pollution*

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[221] *63rd Annual Meeting Summary of Activities*, 20 J. APCA 508, 510 (1970).
[222] *Id.* at 511.
[223] This was the first conference of the International Union of Air Pollution Prevention Associations (IUAPPA). On the history of APCA, including IUAPPA, *see* Lagarias, *supra* note 216.

Control Association, addressed carbon dioxide in the context of the 1963 Conservation Foundation Report, and suggested that the remedy might involve new ways of generating energy, including solar power.

> Additional problems arising from our mounting production of energy are oxides of nitrogen and carbon dioxide. ... A report issued in 1963 by the Conservation Foundation indicates that the carbon dioxide content of the atmosphere is rising at a rate which may cause the temperature of the earth's surface to increase. There is much speculation as to the effects that this temperature increase will have on the world. The use of atomic power, solar energy, increased use of hydraulic power, and new concepts show some promise for reducing the combustion requirements and problems associated with products of combustion.[224]

The International Clean Air Congress met again in December 1969, in Washington DC, hosted by APCA, with a keynote speech by U.S. Senator Jennings Randolph. Randolph—the chair of the Senate Public Works Committee, where the 1970 Clean Air Act originated—spoke at length about carbon dioxide from burning fossil fuels, its character as a global problem, and the need for global monitoring.

> There is a need for a coordinated worldwide system to monitor pollution in the total environment. We know from past experience with nuclear fallout that radioactive wastes are transported widely and rapidly through the environment. However, we do not have comparable information on chemical pollutants, and there is a demand for more extensive, continuous data on which to base an international control effort.
> For example, such a system would be invaluable in adding to our knowledge of the worldwide increase in carbon dioxide resulting from the burning of fossil fuels. There are many theoretical implications of higher concentrations of carbon dioxide, but they cannot be verified unless there is more information of the kind that can be obtained only by global monitoring. Scientists need to know to what extent and where carbon dioxide concentrations are increasing, the interaction of carbon dioxide with the oceans, and its effect on weather and climate.[225]

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[224] *Id.* at 587.

[225] Jennings Randolph, *A Worldwide Commitment,* 21 J. APCA 57, 58 (1971). The conference took place in December 1969, but the full proceedings were not published until 1971: THE AIR POLLUTION CONTROL ADMINISTRATION, PROCEEDINGS OF THE SECOND INTERNATIONAL CLEAN AIR CONGRESS (H.M. Englund and W.T. Beery, eds., 1971).

Air Pollution Textbooks

One measure of the establishment of a subject as part of mainstream scientific research is its inclusion in textbooks.[226] In 1968, Academic Press published a three-volume compendium, entitled *Air Pollution*. In the first volume, *Air Pollution and Its Effects*, Leslie Chambers of the University of Southern California, offered a discussion of "Classification and Extent of Air Pollution Problems." Like other scientists, he noted that there was some ambiguity about how to think about carbon dioxide, particularly as compared with other substances that had long been recognized as pollutants. He also noted that the ultimate solution, if required, would involve shifting sources of electricity generation. "Carbon dioxide is not often considered to be an air pollutant," he wrote, "since it produces adverse physiological effects only at relatively high concentration, and because biological and geochemical processes are known to provide a sufficient natural disposal system." However, the "[u]nchecked increase in the rate of combustion of carbon fuels apparently will increase general CO_2 levels eventually to meteorologically and physiologically significant levels. Perhaps it may, within a few generations, compete with radioactive wastes for the dubious distinction of being a worldwide air polluter." The "planetary CO_2 equilibrium," he continued, would be re-established by shifting from fossil fuels to nuclear or solar power, in which case the "the community air pollution problem would be reduced to more or less routine policing of localized sources."[227]

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[226] *See* Thomas Kuhn, The Structure of Scientific Revolutions 136-43 (1962).
[227] Leslie Chambers, *Classification and Extent of Air Pollution Problems*, *in* AIR POLLUTION AND ITS EFFECTS 1, 10-11 (Arthur C. Stern, ed., 2d ed. 1968). See also Bernard Tebbens, *Gaseous Pollutants in the*

The most extensive discussion of CO_2 in the textbook came from Elmer Robinson of the Stanford Research Institute, whose chapter, "Effect on the Physical Properties of the Atmosphere," concerned "the more permanent effects of air pollutants on various properties of the earth's atmosphere."[228] In the chapter's introduction, Robinson wrote, "Gaseous air pollutants have been emitted in sufficient quantities to significantly alter worldwide atmospheric concentrations of a number of materials. Carbon dioxide is the classic example of such an accumulating pollutant." Like others, he commented that CO_2 was not "usually" considered to be a pollutant, but suggested it was time for that to change:

> The fact that air pollution emissions can cause changes in the atmosphere on a worldwide scale must be of serious concern to all those associated with the field of air pollution. In this regard it seems ironic that although emissions of carbon dioxide from air pollution sources have caused well-documented changes in atmospheric composition on a worldwide scale and have produced arguments among geophysicists and atmospheric chemists as to the seriousness of possible worldwide and long-term consequences of these changes, CO_2 is not usually considered to be an 'air pollutant' by the air pollution investigator (1). It is perhaps time for an awakening on the part of serious analysts to the fact that significant air pollution effects can extend beyond fly ash-soiled laundry and tear-producing automobile exhaust.[229]

A review of the textbook that year deemed the content on CO_2 to be significant enough to highlight, noting that the volume's final section dealt with the effects of air pollution, including "changes in the atmosphere as a whole, of which the most important because of

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Air at 23 and AJ Haagen-Smit and Lowell G Wayne, *Atmospheric Reactions and Scavenging Processes* at 149 in the same volume.

[228] Elmer Robinson, *Effect on the Physical Properties of the Atmosphere*, *in* AIR POLLUTION AND ITS EFFECTS 349, 351 (Arthur C. Stern, ed., 2d ed. 1968).

[229] *Id.*

their possible effect on radiation are the increase in carbon dioxide and particle content."[230]

While not a textbook, Robinson also co-authored a report that year for the American Petroleum Institute (API), which made much the same argument. The discussion of carbon dioxide was based on the summary article "Atmospheric Carbon Dioxide" prepared by a committee led by Revelle for the PSAC Environmental Pollution Panel. The authors noted that the possibility of CO_2 changing "world climate" was not a new idea but had been "the source of much discussion and investigation" since Chamberlain and Arrhenius proposed it in 1899 and 1903, respectively.[231] Research since then indicated it was "likely that noticeable increases in temperature could occur" due to increasing CO_2, which could cause "major changes in the earth's environment" including melting polar ice caps. It "seem[ed] ironic that given this picture of the likely result of massive CO_2 emissions so little concern is given to CO_2 as an important air pollutant." In fact, CO_2, was *"[t]he most commonly emitted air pollutant*." It was "so common and such an integral part of our activities," that it sometimes went unrecognized as a pollutant, which was "perhaps fortunate for our present mode of living, centered as it is around carbon combustion." [232] In 1969, Robinson published a supplemental final report for the API based on new research that included a significantly expanded discussion of CO_2. In

[230] M.H. Unsworth, *Review: Air Pollution. In Three Volumes, Volume I: Air Pollution and Its Effects. A. C. Stern (Ed.), New York and London (Academic Press). 2nd Edition, 1968*, 94 Q. J. ROY. MET. SOC. 435, 436 (1968).
[231] E. ROBINSON AND R.C. ROBBINS, SOURCES, ABUNDANCE AND FATE OF GASEOUS ATMOSPHERIC POLLUTANTS, STANFORD RESEARCH INSTITUTE PROJ. NO. PR-6755 105 (1968) (prepared for the American Petroleum Institute).
[232] *Id.* at 8.

the introduction they argued that "the CO_2 emission, is the only air pollutant…that has been shown to be of global importance as a factor that could change man's environment on the basis of a long period of scientific investigation. Because of this obvious relation, we believe that any discussion of atmospheric pollutants should also include a discussion of CO_2." [233]

The American Chemical Society

By the late 1960s, many scientists felt confident calling CO_2 a pollutant. However, some still perceived a tension in defining it so. As already noted, on the one hand, like other recognized pollutants—smoke, smog, sulfur dioxide, oxides of nitrogen, carbon monoxide—CO_2 was a byproduct of industrial activity, and like these pollutants it could do harm. On the other hand, it was different from the chemicals and particles responsible for urban air pollution in that it was not visible, it did not appear to be a direct threat to human health, and its effects might not be discerned for some time. Some scientists also noted the unlike some pollutants, such as synthetic pesticides, CO_2 was a naturally occurring substance. Yet, other naturally occurring materials, such as pollen, were discussed as pollutants, so this distinction was not dispositive.

The view that carbon dioxide was not a pollutant—because it occurs naturally in air and does not immediately affect health—can be found in public health literature at this time. An example is a paper written in 1965 by a British medical researcher and published in the *Bulletin of the World Health Organization*, on "the Nature of Air

[233] ROBINSON AND ROBINS, *supra* note 230 at 7.

Pollution and the Methods Available for Measuring It," which stated, "The two main products of efficient combustion, carbon dioxide and water, are not regarded as pollutants because they are normally present in air and the quantities that man releases do not normally alter the concentration in the atmosphere to a sufficient extend to affect health."[234] On the other hand, scientific papers dealing with air pollution in the 1960s often included carbon dioxide among the "gaseous air pollutants" alongside sulfur dioxide, nitrogen oxide, hydrocarbons, carbon monoxide and ozone, in some cases measuring CO_2 along with those other pollutants.[235]

A 1969 monograph produced by the American Chemical Society tried to square this circle. A "pollutant," the ACS authors wrote, was defined as a "contaminant" that "adversely affect[s] something that man values and is present in high enough concentration to do so." By this definition CO_2 was both a contaminant and a pollutant. On the other hand, the ACS, concluded:

> Carbon dioxide is not commonly regarded as an air pollutant, although man generates an enormous amount of it in combustion processes using fossil fuels such as coal, oil, and natural gas. Carbon dioxide is a normal constituent of the air … However, its global concentration is rising above the natural level by an amount that could increase global temperature enough to affect climate markedly.[236]

The ACS noted that the definition of a pollutant could and would change over time, if, for example, people began to see effects that they had not previously noticed. "If

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[234] J.M.K.Ellison, *The Nature of Air Pollution and the Methods Available for Measuring It*, 32 BULLETIN WHO 399, 399 (1965).
[235] *See for example*, Arthur C. Stern, *Present Status of Atmospheric Air Pollution in the United States*, 50 AJPH 346 (1960).
[236] AMERICAN CHEMICAL SOCIETY, CLEANING OUR ENVIRONMENT: THE CHEMICAL BASIS FOR ACTION 39 (1969).

the substance is to be formally classified as a pollutant, its effects must be perceived," and perceptions changed over time, both because of changing scientific knowledge and changing cultural concerns. Perceptions of pollution were once "nearly limited to soiling of houses and laundry by soot," but scientists now "look now for subtle effects on the human lifespan, and they are beginning to look for even broader effects, such as modification of regional and even global climate."[237] Under this framework, if CO_2 did not yet meet the definition for "contaminant" and "pollutant," it could in the future when its effects were evident.

Strikingly, the 1969 ACS discussion as to what kind of a pollutant CO_2 was added an extra-scientific twist directly relevant to the legal standard raised by the Court in *West Virginia v EPA*: the question of the economic consequences of addressing carbon dioxide pollution. The ACS suggested that CO_2 might be treated separately from other pollutants *not* because it was invisible, nor because it might not directly affect health, but "because it is not considered a contaminant that can be controlled, except by replacing the combustion process with another source of energy, such as nuclear power."[238] Here as elsewhere, we see the recognition that addressing CO_2 pollution might require generation shifting.

Overall, we find that the majority view at this time, particularly among physical scientists who were calling attention to long-term environmental consequences as something to consider in addition to immediate public health ones, is that CO_2 *was* a

[237] *Id.* at 6.
[238] *Id.* at 25; *West Virginia v. EPA*, No. 20-1530 (June 30, 2022).

pollutant, albeit one with different characteristics and consequences than the more commonly recognized ones. Howe has characterized this view as recognizing CO_2 as an "unconventional" pollutant.[239]

President Nixon Sounds an Alarm

In 1968, the National Science Foundation issued its tenth annual report of the topic of weather modification, and in 1969 President Richard Nixon and his staff drafted a two-page, impassioned message to Congress on the "special interest" of this report in the aftermath of Hurricane Camille. Nixon's message was vivid: "In recent months many American communities were ravaged by storms that were among the most violent and destructive in our history… Swept away by wind and water were families, homes, businesses, and dreams for the future." Writing two months after the hurricane, Nixon stated that "the residue of suffering for the thousands of Americans affected" remained incalculable. He linked the storm wreckage to "mounting concern with the quality of the environment generally," and emphasized to Congress the importance of a research program in "facing the issue of air pollution, including the possible effect on weather and climate."[240]

In November 1969, Nixon appointed a Task Force on Air Pollution to evaluate the effectiveness of existing air pollution control efforts. Arie Haagen-Smit chaired the task force, which included representatives of the United Steelworkers of America, the US

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[239] HOWE, *supra* note 23 at 42.
[240] Richard Nixon, Letter of Transmittal to the Congress of the United States 2 (October 27, 1969), f. Atmos. Sci. [Oversized Materials, 1969-70], b. 4, Edward E. David papers (WHCF:SMOF), RNPL. For the full report *see*, NATIONAL SCIENCE FOUNDATION, NSF REP. NO. 69-18, WEATHER MODIFICATION: TENTH ANNUAL REPORT FOR FISCAL YEAR ENDED JUNE 30, 1968 (1969).

Steel Corporation, Ford Motor Company, an array of prominent scientists, and Princeton statistician John Tukey. The resulting report, *Cleaner Air for the Nation*, was transmitted to the President in June 1970 and publicly released in August, contemporaneous with the first CEQ report. In a section on "Climatic Effects of Pollutants," the report proclaimed, "the greatest consequences of air pollution for man's continued life on earth are its effects on the earth's climate."[241]

Summary

The discussion presented here does not exhaust all the instances we have encountered of sustained scientific discussion of the problem of CO_2 as a pollutant, produced by industrial activity, that could adversely affect the climate system and in that way adversely affect public welfare. More could be said about the scientific background, particularly regarding research in Europe and the Soviet Union.[242] However, our discussion suffices to demonstrate that by the mid 1960s, scientists had articulated the "CO_2 problem" as a problem of *pollution*, one that could, and if left unaddressed almost certainly would, alter the global climate, and that dramatic and consequential global changes could ensue. By the late 1960s, it was broadly accepted by scientists that CO_2 was a pollutant, even if in some respects different from the other gases and particulates that had been studied in the context of urban air pollution. Indeed, many of the conferences and reports discussed here took place explicitly in the context of the urban

[241] PRESIDENT'S TASK FORCE ON AIR POLLUTION, REP. ON CLEANER AIR FOR THE NATION 34 (1970).
[242] For some discussions of this work *see generally*, EDWARDS, *supra* note 22 at 51-49, 126; HOWE, *supra* note 23 at 27; WEART, *supra* note 22 at 81-83; JAMES RODGER FLEMING, INVENTING ATMOSPHERIC SCIENCE: BJERKNES, ROSSBY, WEXLER, AND THE FOUNDATIONS OF MODERN METEOROLOGY (2016).

air pollution that the Clean Air Act was explicitly and unequivocally intended to address.

The scientists involved in these discussions included John Middleton, the director of the first U.S. agency dedicated specifically to air pollution, who discussed carbon dioxide alongside established air pollutants such as carbon monoxide and the oxides of nitrogen and sulfur—and explicitly stating "these materials are air pollutants." Middleton also specifically used language of "health and welfare effects" similar to what would be included three years later in the language of the Clean Air Act. Middleton would later testify to similar effect in Congressional hearings pursuant to the Act.[243]

By the late 1960s Senators involved in the writing and passage of the Clean Air Act were participating in these conferences including Senator Edmund Muskie, chair of the Senate subcommittee on Air and Water Pollution of the Committee on Public Works where the 1970 Clean Air Act originated, and Jennings Randolph, the Chair of the Committee on Public Works. Senator Muskie specifically invoked the idea that air pollution legislation would need to account for subtle long-term effects of air pollution and have the flexibility to address "unforeseen" problems as they arose. We also see that participants in these discussions, including U.S. Atomic Energy Commission Chair Glenn Seaborg, noted that addressing carbon dioxide pollution might require large scale technological change such as a shift to electric cars or generating electricity from nuclear power with possible major economic consequences. As early as 1965, observers articulated concerns that, because of the threat of global climate change, humans "may be

[243] These hearings will be discussed further in Lanier-Christensen et. al., *Climate Change and the 1970 Clean Air Act Part 2: Testimony to Congress* (forthcoming).

forced to turn to new sources of energy in order to reestablish a viable carbon dioxide equilibrium."[244]

IV. International Efforts

In 1967, NCAR director Walter Orr Roberts wrote a paper for *Physics Today*—a semi-popular science magazine—explaining a proposed new large scientific initiative, the Global Atmospheric Research Program (GARP). Roberts made the case that society needed to understand the atmosphere because the practical demands of life—food, travel, recreation, commerce—all hinged on weather and climate, as did the "subtle joys of life," which might rest upon "wind and storm...the smell of rain in a wheat field, the flowers on a mountain hillside, the beauty of a sunset, or even the opportunity to see a sunset at all." But the most urgent reason was the problem of "deliberate and inadvertent actions" that could change the climate and were "becoming increasingly crucial to the welfare of man...", and they could not be understood purely in a local or even national context.[245]

While scientists in the 1950s had not come to consensus as to whether the climate was already changing, Roberts now suggested that it was, and because of its global character international regulation might be in order. "Man appears, indeed, already to be influencing this climate, his atmospheric environment, to an alarming degree. If this is actually so, it suggests that international regulation of deliberate and inadvertent actions that change our atmosphere has become a necessity... The problem may soon be even

[244] AIR CONSERVATION COMMISSION, *supra* note 139, at 81.
[245] Walter Orr Roberts, *Climate Control*, 20 PHYS. TODAY 30, 30 (1967).

more pressing that the A-bomb!" [246] GARP would provide the scientific basis required to properly understand the challenge and inform decision-making. While Roberts did not discuss CO_2 specifically, he did discuss the evidence that large volcanic explosions could cool the planet and noted that "large climatic changes can be triggered by small causes."[247] This idea—that climate was a global problem that would require global attention—was by the mid 1960s becoming a scientific commonplace, and expressing itself in a number of different venues, both scientific and political.

Carbon Dioxide and the International Biological Program

The relationship between carbon dioxide pollution and climate played a role in debates surrounding U.S. participation in the International Biological Program (IBP), a global effort to advance environmental biology that stretched from 1964–1974. Building on the success of the IGY, the IBP's early proponents pitched the initiative as a large-scale collaborative effort to study "human genetics, conservation, and improvements in the use of natural resources."[248] Over the course of its decade-long operation, the IBP effected a major pivot towards the collection of synoptic data in ecology. It also drew its roots from the same emergent environmental awareness that buttressed the increased anti-pollution drives of the decade. Introducing the program to both the scientific and political communities, inaugural IBP director Roger Revelle presented it as a response to the

[246] *Id.*
[247] *Id.* at 32.
[248] SHARON KINGSLAND, THE EVOLUTION OF AMERICAN ECOLOGY 1890-2000 221 (2008). *See also* Elena Aronova et. al., *Big Science and Big Data in Biology: From the International Geophysical Year through the International Biological Program to the Long Term Ecological Research (LTER) Network, 1957-Present,* 40 HIST. STUD. NAT. SCI. 183 (2010).

"destructive changes in the web of life that is stretched so thinly over the surface of our planet."[249]

While anthropogenic climate change did not form a focus of the IBP research agenda in its initial years, key figures in the IBP's institutional apparatus engaged with political leaders on the ecological implications of a disrupted climate system. During testimony on governmental funding of the U.S. contribution to the IBP, the geophysicist and botanist David Gates, a Professor at Washington University in St. Louis, discussed concerns over "man-made changes of climate." [250] When Professor Gates noted that "if the climate was getting warmer," it could have a profoundly negative effect on ecological systems, staff consultant Philip B. Yeager immediately extrapolated to the greenhouse effect, asking, "[a]ccording to the CO_2 greenhouse theory, isn't there a possibility that there might be a warming trend?"[251]

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[249] *International Biological Program: Hearing on H. Con. Res. 273 Before the Subcomm. on Science, Research, and Development of the H. Comm, on Science and Astronautics*, 90th Cong., 1st Sess. 2 (1967) (statement of Dr. Roger Revelle, Chairman, US Nat'l Comm. For the IBP). A shortened, public-facing version of Revelle's statement was also printed as Roger Revelle, *International Biological Program*, 155 SCIENCE 957 (1967).

[250] *Id.* at 157, 364. Full statement of Dr. David M. Gates, Director, Missouri Botanical Garden begins at 153, and his article *Conservation and Understanding*, 55 MO. BOTANICAL GARDEN BULLETIN 1 (1967) was included at 363.

[251] *Id.* at 158. Philip B. Yeager was a former Naval Reserve Officer, Naval Research Laboratory administrator, and lawyer who served as Staff Consultant for the H. Comm. On Astronautics and Space Exploration from its inception in 1958 to at least 1979 (the committee's name changed to the H. Comm. on Science and Technology in 1974, and in 1979 Yeager was appointed the full committee's general counsel. The exact end date of Yeager's service is unclear). He also served as Daddario's chief of staff for the committee for over a decade. *See* KEN HECHLER, US HOUSE OF REPRESENTATIVES, TOWARD THE ENDLESS FRONTIER: HISTORY OF THE COMMITTEE ON SCIENCE AND TECHNOLOGY 133 (Comm. Print 1980). In 1958, Yeager published a detailed discussion of carbon dioxide related global climate change, and the possible impacts of sea-level rise on Naval operations in the UNITED STATES NAVAL INSTITUTE PROCEEDINGS. He also discussed the possible impacts of global climate change on national and international legislation in his 1960 book YOUR INALIENABLE RIGHTS. *See* Philip B. Yeager, *Carbon, Oxygen, and a Rising Sea*, 84 US NAV. INST. PROCC. 51 (1958); PHILIP B. YEAGER AND JOHN R. STARK, YOUR INALIENABLE RIGHTS 244-245 (1960).

Scientists in the 1960s remained unsure of the precise interplay of warming and cooling effects on the world's climate, but Professor Gates expected a warming trend to be far more damaging to the earth's flora and fauna than any possible cooling trend. He responded to Yeager that "considerable evidence through calculations and measurement showed that the increase in carbon dioxide from industrialization caused the greenhouse effect."[252]

The term "climate" as used in this context referred almost exclusively to "global climate." Notably, when speakers intended to refer to a more localized climate system, they would use the term "microclimate," or the plural form, "climates." When congressmen and scientists discussed "climate" in these 1967 hearings, it was in the context of the "earth's atmosphere" or the "chemistry of the biosphere." The "natural meaning" of "climate" in this context was the world's climate system.[253]

In 1968, the House Subcommittee on Science, Research, and Development issued a report on the IBP, devoting significant passages to man-made changes to global climate. Discussing the evidence supporting the necessity of U.S. participation in the international program, the report stated that "the effects of human activity are undoubtedly being felt by another instrumental ecological element—the climate." Again, the report uses the term climate to refer to the global climate, linking it to broad-scale ecological effects that could be tackled by an international research program. Quoting NCAR Director Roberts, the report treats climate as synonymous with the atmospheric

[252] *Id.*
[253] *Id.* throughout.

system, noting, "[m]an appears, indeed, already to be influencing his climate, his atmospheric environment, to an alarming degree." The report also makes a critical pivot from research to regulation, again quoting Roberts for the proposition that, if changes to the climate are occurring, "it suggests that international regulation of deliberate and inadvertent actions that change our atmosphere has become a necessity, and that major measures should be taken for the welfare of mankind." [254]

Planning for 1972 UN Conference on the Human Environment

One more topic will help to demonstrate the range and depth of scientific discussions of carbon dioxide, the greenhouse effect, and climate change prior to the passage of the Clean Air Act, and to help place those discussions in political context. It is the preparations for the first UN Conference on the Human Environment (UNCHE), held in Stockholm, Sweden in 1972. While the conference did not take place until two years after the passage of the Clean Air Act, preparations began in the fall of 1968, and the delegation included numerous individuals involved in the debate over CO_2, air pollution control, and American federal legislation, such as Robert White, Gordon MacDonald, John Tukey, and Russell Train. The leadership of the delegation also included the U.S. Senator who served on the Senate Committee on Public Works, where the 1970 Clean

[254] SUBCOMM. ON SCIENCE, RESEARCH, AND DEVELOPMENT OF THE H. COMM. ON SCI. AND ASTRO., 90TH CONG. 2ND SESS., REP. ON THE INTERNATIONAL BIOLOGICAL PROGRAM: ITS MEANING AND NEEDS 5 (Comm. Print 1969).

Air Act originated (and later served as Senate Majority leader and then Chief of Staff to President Ronald Reagan): Tennessee Republican Howard H. Baker, Jr.[255]

As we have seen, by the late 1960s, scientists had stressed on various occasions that carbon dioxide was a global problem, in that increased atmospheric concentrations would alter the *global* climate. Therefore, some argued, it warranted international attention and cooperation. In a panel discussion on the Economic and Social Aspect of Air Pollution Control at the 1966 Third National Air Pollution Conference (where several American political leaders were in attendance), Morris Neiburger stressed this point.

> In the case of carbon dioxide...we can expect the gradual build-up ... possibly leading to an intolerable concentration, a concentration too noxious for the sustenance of human life, not just in metropolitan areas like New York and Los Angeles, but all over the world.
>
> It seems to me that it's important to recognize this development at an early stage. ... Unless, on an international basis as well as on national and local and interstate bases, we start developing standards and control programs, we may find that even though we clean up the air here in the United States the activities in other countries will raise the background concentration of pollution on a worldwide basis to an intolerable level. Therefore it seems to me vital that we begin now, through international agencies and by international compacts, to attempt to establish standards of clean air on a worldwide basis.[256]

His respondent, Vernon MacKenzie, Director of the Division of Air Pollution Control at the Public Health Service, noted that several international organizations were discussing the issues, including the World Health Organization (WHO), the World Meteorological Organization (WMO), and the Organization for Economic Cooperation

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[255] Baker did not chair the delegation; that distinction went to Russell Train. But he was the Chairman of the US Advisory Committee on the UN Conference on the Human Environment, so in the role was closely involved. *See* MEMBERS OF THE DELEGATION OF THE US TO THE UNCHE, S. COMM. ON FOR. REL., 92ND CONG. 2ND SESS., REP. ON UNITED NATIONS CONFERENCE ON THE HUMAN ENVIRONMENT 11 (Comm. Print 1972).

[256] 1967 PHS PROCEEDINGS at 627.

and Development (OECD). “There is not only interest in these international agencies, but there have been specific recommendations by the President's Science Advisory Committee that so-called base-level measurements (and this is the worldwide problem) should be given greater emphasis and attention than they have received up to now.” [257]

By 1968, planning for the UNCHE was underway. In September, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) held an Intergovernmental Conference of Experts on the Scientific Basis for Rational Use of Conservation of the Resources of the Biosphere. This was the first time that any arm of the United Nations had devoted an international conference to the subject of conservation and the environment, and the Paris meeting brought together “some 320 experts from 63 nations and 23 international organizations.”[258] A provisional report circulated in October that year detailed twenty recommendations from the experts. A copy was sent to the US Department of Health, Education, and Welfare. (UNESCO published the full proceedings report in 1970.)

The report’s first recommendation was for an international research program on “man and the biosphere,” and the second paragraph of that recommendation identified atmospheric carbon dioxide as a major problem of pollution, caused by industrial activity:

> Noting that the technological developments of man as shown by his achievements in industry, transport, communications, and urbanization, all of which are essential aspects of human welfare, have nevertheless resulted in major problems

[257] *Id at* 628.
[258] *UN Votes to Hold Conference on Human Environment in 1971*, CF LETTER 5, February 24, 1969, b. 3 f. 12, Records of Predecessors of the Environmental Protection Agency 1944-71, Records of the Environmental Protection Agency, Record Group 412, held at Lees Summit, MO FRC, accessed at National Archives and Record Administration- Kansas City, MO [*hereinafter* NARA-NAPCA].

> of pollution: the carbon dioxide balance in the atmosphere is being altered and a variety of pollutants, including radio-active [sic] materials and a wide range of toxic chemicals, is being added to the biosphere.[259]

The recommendation emphasized the necessity of international action, because "many of the changes produced by man affect the biosphere as a whole and are not confined within regional or national boundaries…these problems cannot be solved on a regional, national or local basis but require attention on a global scale."[260] They cited the IBP alongside the International Council of Scientific Unions and the International Union for Conservation of Nature and the Natural Resources as important precedents, but were concerned that the end of the IBP in 1972 would leave many aspects of environmental concern only "partially explored," with few "studied to conclusion."[261] The report specifically called for a swift approval at the forthcoming UN General Assembly session of a United Nations Conference on the Human Environment, at which the UN would consider "the advisability of a Universal Declaration on the Protection and Betterment of the Human Environment."

On December 3, 1968, the United Nations General Assembly unanimously adopted the resolution to hold a the UNCHE in 1972. The resolution, put forward by Sweden and co-sponsored by 51 other nations including the United States, stated that the UN was "convinced of the need for intensified action at the national, regional, and international level in order to limit and, where possible, eliminate the impairment of the

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[259] UNITED NATIONS EDUCATIONAL, SCIENTIFIC, AND CULTURAL ORGANIZATION, INTERGOVERNMENTAL CONFERENCE OF EXPERTS ON THE SCIENTIFIC BASIS FOR RATIONAL USE AND CONSERVATION OF THE RESOURCES OF THE BIOSPHERE 2 (1968).
[260] *Id.* at 3.
[261] *Id.*

human environment."[262] The UN Ambassador from Sweden, Sverker Aström, noted that, "[t]he risks inherent in the uncontrolled application of modern technology are very real and very frightening,"[263]

The US Delegation submitted a statement to the General Assembly in support of the resolution from Ambassador James Russell Wiggins. Wiggins argued that pollution was a "world concern," because "our cities, industries, and farms operate on such a scale that their physical environment is literally the whole planet, with its all-encircling ocean of both air and water. Man-made pollution crosses every boundary, riding the wind and rain, the rivers and ocean currents, the bodies of migrating fish and birds," and he included carbon dioxide among the forms of pollution.[264]

> And what are we going to do about the steadily rising burden of carbon dioxide in the earth's atmosphere? Already in the past 100 years, since fossil fuels began to be burned in huge quantities atmospheric carbon has increased close to 10 per cent. This increase will probably total about 25 per cent by the year 2000, given the rapidly accelerating rate of fuel consumption. Will the resulting "greenhouse" effect cause a permanent warming of the earth's climate—and perhaps even a rise in the world sea level as the polar ice caps melt? … [M]uch of human destiny could depend on the answer.[265]

Wiggins implored UN countries to not wait until 1972 before taking "energetic action to relieve the wounds we have inflicted on nature and on ourselves," urging "all in authority" to "act without delay….the period between now and 1972 should be one of ferment, not only of preparation for the conference, but of practical action in every field:

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[262] United Nations General Assembly, 23rd Sess., Res. 2398: The Problems of the Human Environment 2 (1968) b. 3, f. 12, NARA-NAPCA.
[263] CF LETTER, *supra* note 262, at 1. The article was also provided by Democratic Texas Senator Ralph Yaborough for the Congressional Record on October 6, 1969. *See* 115 Cong. Rec. 28598 (1969).
[264] James Russel Wiggins, US Delegation to the UN Assembly, Pres. Rel. USUN-225, Statement on the Problems of the Human Environment 5 (1968) b. 3, f. 5, NARA-NAPCA.
[265] *Id.* at 6.

new scientific work, technical and administrative development, training of qualified manpower, public education, and political decision."[266]

In April 1969, the US released an official statement expressing unequivocal support for the proposed Stockholm conference: "The United States Wished to Reiterate that it considers this United Nations Conference on Human Environment to be held in 1972 as of great importance, dealing as it will with a broad range of highly critical problems." The statement detailed "objectives" and "problem areas" that should be addressed at the conference; under the latter it identified CO_2 as among the issues that "cover problems of international significance, transcending national boundaries and calling for international action; e.g. the nitrogen cycle, carbon dioxide, the oceans, capacity of the biosphere to support the population, etc."[267] The same month, Russell Train, then Nixon's Undersecretary of the Interior, spoke about fossil fuel combustion and atmospheric CO_2 levels and their implications for global climate in the context of the upcoming Stockholm conference.[268] Conference planning accelerated in 1970 and Gordon MacDonald and Russell Train both emphasized the need for global monitoring to measure increasing carbon dioxide and inadvertent weather and climate modifications.[269]

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[266] *Id.* at 8.
[267] US Dept. of State to USUN NY, USUN Ref. No. A-150, United States Response to United Nations Concerning 1972 United Nations Conference on Human Environment, 4, (April 7, 1969) b. 3 f. 12 NARA-NAPCA.
[268] Russel Train, Speech to American Museum of Natural History: Man's Survival in a world worth living in (April 9, 1969) b. 69, f. 5, LOC-RET.
[269] Letter April 30, 1970, to The Chairman from Gordon Macdonald**,** Subject: LDCs and Environmental Problems, b. 80, f. OCMS, John W. Whitaker papers (WHCF:SMOF), RNPL; Memo to President on Dr. Dubridge's report to president, May 22, 1970, b. 11, f. 10, LOC-RET.

The UNESCO meeting, and subsequent UN declaration, spurred immediate organizational efforts. The International Council of Scientific Unions (ICSU) general assembly met in Paris from September 27 to October 2 of 1968, where they created an "Ad Hoc Committee on Problems of the Human Environment."[270] On December 30th, the president of the International Union on Geodesy and Geophysics, G.D. Garland, sent a memo to the members of the committee suggesting topics for consideration. Number one on his list was "possible effects of climate and living creatures brought about by increase of CO_2 in the atmosphere from the burning of fossil fuels."[271] In early 1969, the ad hoc committee proposed the creation of a more permanent structure: the ICSU Scientific Committee on Problems of the Environment (SCOPE), which held its first meeting in Madrid in September 1970.[272] At the request of Maurice Strong, the secretary general of the UNCHE, SCOPE began to prepare a set of suggestions on the development of a global environmental monitoring system, to be presented at the 1972 conference. These suggestions relied heavily on a report that had already been undertaken by the MIT led Study of Critical Environmental Problems (SCEP).

Study of Critical Environmental Problems (SCEP)

[270] *International Union of Crystallography Report of Executive Committee for 1968,* A25 ACTA CRYSTAL 725 (1969).
[271] Letter to Members of the ISCU/IUBS-IUGG Ad Hoc Committee on the Environment from G.D. Garland, December 30, 1968, b. 3, f. 12, NARA-NAPCA. This letter and list were also transmitted to John Ludwig at NAPCA and R.A. McCormick of NAPCA and NOAA at the Air Resources Cincinnati Laboratory.
[272] Gilbert F. White, *SCOPE: The First Sixteen Years*, 14 ENV. CONS. 7, 7 (1987).

The Study of Critical Environmental Problems was sponsored by the Massachusetts Institute of Technology (MIT). Convened in July of 1969, the group issued a report in 1970 titled "Man's Impact on the Global Environment." According to the study report, the impetus came from discussions between scientists and public officials in the context of the scheduled UN Conference on the Human Environment. The authors wrote, "In examining the status of governmental and nongovernmental preparations for the 1972 UNCHE, several of us concluded that an initiative such as this study would provide an important input into planning for that conference and for numerous other national and international activities."[273]

The forty-member study was chaired by MIT Professor of Management (and from 1947-1950 General Manager of the AEC), Carroll L. Wilson. Members included leading academic scientists such as Christian Junge, Charles Keeling, Penn State Professor Hans Panofsky, and NCAR's William Kellogg, as well as important agency officials including Lester Machta, Director of the Air Resources Laboratory at ESSA, James T. Peterson, research meteorologist at NAPCA, and Joseph Smagorinsky, head of the National Weather Service's Geophysical Fluid Dynamics Laboratory. Their report was intended to focus on problems "arising from the impact of man's activities on the global environment."[274]

Several federal departments and agencies supported the study, either financially through grants and contracts, or through preparation of background materials. These

[273] STUDY OF CRITICAL ENVIRONMENTAL PROBLEMS (SCEP), MAN'S IMPACT ON THE GLOBAL ENVIRONMENT: ASSESSMENT AND RECOMMENDATION FOR ACTION xi (1970).
[274] *Id.*

included the U.S. Forest Service, the U.S. Geological Survey, ESSA, NASA, NAPCA, the NSF, the AEC, and the Departments of State, Agriculture, Transportation. The study also received support from the Ford, Rockefeller, and Sloan Foundations; from the National Academy of Sciences, NCAR, the Oak Ridge National Laboratory, and the Rand Corporation; and from private corporations Allied Chemical, American Electric Power, Consolidated Edison of New York, ESSO Research and Engineering, and General Electric.

The report dealt with various environmental pollutants, including DDT and other persistent chlorinated hydrocarbons; mercury and other toxic heavy metals; potential effects of supersonic transport aircraft; ecological effects of petroleum in the oceans; and ecological effects of nutrients in estuaries, lakes, and rivers. But a major focus was the radiation balance of the atmosphere and, within that, carbon dioxide. Indeed, CO_2 was the first topic specifically mentioned in the introduction, which discussed the issue at length and in some detail:

> All combustion of fossil fuels produces carbon dioxide (CO_2) which has been steadily increasing in the atmosphere at 0.2 percent per year since 1958. Half of the amount man puts into the atmosphere stays and produces this rise in concentration... A projected 18 percent increase resulting from fossil fuel combustion to the year 2000 (from 320 ppm to 379 ppm) might increase the surface temperature of the earth 0.5 degrees celsius; a doubling of the CO_2 might increase mean annual surface temperatures 2 degrees celsius. This latter change could lead to long-term warming of the planet.…[T]he long-term potential consequences of CO_2 effects on the climate or of societal reaction to such threats are so serious that much more must be learned about future trends of climate change. Only through these measures can societies hope to have time to adjust to changes that may ultimately be necessary.[275]

[275] *Id.* at 10-12.

The scientists involved were not environmental activists; most worked at universities with strong links to the private sector, including energy and chemical companies and, as noted, the report was supported by several corporations. Yet, these scientists did not assume that the carbon dioxide problem was negligible, that technologies would necessarily develop to address it, or that 'the economy' would have to take precedence over "the environment." They explained: "In the effort to arrive at an optimal balance in specific situations, something will have to give. But the old routine assumption that it is the environment that must give has become intolerable. This assumption must be rejected in favor of an optimal balance to be reached from a point of departure in affixing the responsibilities for pollution."[276]

The committee's working group on climate, which including Keeling and Junge, differentiated between the global effect of CO_2 on climate and local problems "such as local weather modification and urban air pollution."[277] They also differentiated anthropogenic change from natural climate variability; the recent changes in the concentration of carbon dioxide were demonstrated to be the result of human activity. While so far any effects from concentration change were "not larger than natural changes," the future would likely be different. A key scientific challenge was "to identify those 'leverage points' that man can reach, points where his relatively subtle alterations of the environment could influence significantly the global climate. It is in the interest of rational society to be on the lookout for any such changes and to develop theories of

[276] *Id.* at 32.
[277] *Id.* at 40.

atmospheric behavior sufficient to allow us to forecast the atmosphere's future course, give a knowledge of what man will be doing. The effort expended will certainly be trivial compared to the possible return."[278] And despite the considerable uncertainties, and the primitive state of climate models at that time, the available evidence indicated what to expect:

> Radiative equilibrium computations…suggest that the projected 18 percent increase of the carbon dioxide concentration by the year 2000 (to about 379 ppm) would result in an increase of the surface temperature of about one-half degree ... a doubling of the carbon dioxide concentration over the present level would result in an increase of the surface temperature of about 2 degrees Celsius and a 2 to 4 degrees Celsius decrease in the stratosphere at the same level.[279]

Global monitoring would be necessary to track developments and improve scientific understanding to be able to answer the question, "can man's activities produce catastrophic changes of climate?" [280]

The study also included a working group on "Implications of Change," which specifically addressed the question of what kind of a pollutant CO_2 should be understood to be. They differentiated between "residuals" or "waste," which they defined as "generated in all stages of the production and consumption of goods or services" and not necessarily harmful, like the carbon dioxide people exhale. But "residuals" became "'pollutants" or an "environmental problem'" when they became to have "harmful effects in the atmosphere, the oceans, or the terrestrial environment. 'Harmful effects,' are

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[278] *Id.* at 45-46.
[279] *Id*. at 88. They were very close to correct: the actual value would be 369, *see* NOAA Global Monitoring Laboratory data, available on the NOAA operated website https://gml.noaa.gov/webdata/ccgg/trends/co2/co2_annmean_gl.txt (last updated September 5, 2022).
[280] *Id.* at 191.

effects that are harmful to man, or to animals, plants, or inanimate objects or conditions that are important to man. Their importance to man may be biological, economic, religious, moral, aesthetic, or intellectual."[281]

SCEP was particularly concerned with what they called "key pollutants," meaning pollutants that had global effects, and whose effects were serious. CO_2 was one of the most important.

> [T]his SCEP has defined its mission in terms of key pollutants that have global effects. 'Global effects' have been taken to compromise [sic] effects on climate and on ocean and terrestrial ecology, together with such effects as recur on a significant scale in many countries in a kind of worldwide pattern. The 'key pollutants' are those whose global effects are such as to make it especially important to bring them under satisfactory control.... These include carbon dioxide; particulate matter; sulfur dioxide; oxides of nitrogen; toxic heavy metals (lead, mercury, arsenic, chromium, cadmium, nickel, manganese, copper, zinc); oil, chlorinated hydrocarbons, especially DDT and polychlorinated biphenyls, other hydrocarbons; radionuclides heat; and nutrients."[282]

CO_2 was given its own section. Here, the authors paused to review the terms of their analysis, stressing that they considered the matter of "what should be done and what the doing may involve" in terms of two variables: "The fact that [CO_2] is a key pollutant with harmful global effects has been established with a sufficient approximation of certainty or degree of probability to warrant remedial action," and that "informed scientific and professional opinion, or public and political opinion, or both, view with sufficient apprehension or concern to warrant appropriate measure." CO_2 met those criteria. However, it also introduced "an element not previously mentioned, relating to

[281] *Id.* at 224.
[282] *Id.* at 227.

scale and intensity of possible effects. In the usual case, if there appears to be only a remote and highly speculative possibility that a residual might have harmful global effects, little time and effort will be put into a program of inquiry affecting it. However, if the speculative effects are of such a nature that they would be devastating if they should occur and if it would require long years of arduous preparation to afford a realistic possibility of achieving preventive or corrective measures, prudence might indicate that a serious program of inquiry should be instituted and sustained…"[283]

CO_2 met that latter standard: "T]he consequences for the human condition and human endeavor could be enormous. They could threaten man's agriculture and food supply, his warmth in winter and his cooling in summer, and could throw his entire transportation system out of gear," and addressing the problem could involve a "radical curtailment of man's consumption of fossil fuels would be required."[284]

The authors concluded with a cautionary note about how hard the problem might be to fix. It was, they wrote:

> [H]ard to conceive of an effect more authentically global than an effect on the world's climate, and corrective action to be effective would have to be correspondingly universal. It is not hard to imagine the bitterness and recriminations that might be injected into international relations by mutual suspicions concerning the scale and pace of the reduction in the consumption of fossil fuels in different countries. The requirements of the occasion would test to the limit mankind's political and administrative capacity to establish and manage international controls.[285]

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[283] *Id.* at 244.
[284] *Id.* at 245.
[285] *Id.* at 245. The report also included two charts on fossil fuel production and CO_2 emissions from those fuels, "modeled on …the one contained in Appendix Y4 of *Restoring the Quality of our Environment* (PSAC 1965)." *Id*, figures 7.A.1 and 7.A.2 at 303-5.

1971 Study of Man's Impact on Climate (SMIC)

During the SCEP meetings, participants noted a need for a review of their findings with a particular eye at understanding and clarifying the state of the available science on man's impact on the global climate. Towards this end, the scientist organized a second report, the Study of Man's Impact on Climate (SMIC)**,** undertaken with the explicit goal of informing legislative and regulatory bodies. While the report, "Inadvertent Climate Modification" was not issued until 1971, much of the planning committee work was done in the fall of 1970 and communicated along the way to the sponsoring agencies, which included NAPCA, NOAA and ESSA. Therefore, the justification for the report and its general thrust are worth including as one further piece of evidence as to the science that was communicated to federal agencies at this time.

The Principal Investigators were MIT Professors Carroll L. Wilson (the chair of SCEP) and William H. Matthews, a professor of environmental engineering. In the study proposal they wrote:

> A major component of the SCEP Report dealt with the climatic effects of man's activities. The consequences and implications of any remedial actions to alleviate environmental problems which might be caused by buildup of carbon dioxide, particles, and other waste products in the atmosphere are so profound that it is highly desirable to obtain an international consensus on the nature of these effects at the earliest possible time...
>
> The report of SMIC will present the collective judgement and assessment of noted international scientists on the state of information and understanding of these important issues in 1971 and their recommendations for future action. This report should provide an important input for both national and international programs and would be particularly helpful in the preparations for the 1972 United Nations conference on the Human Environment. Major policy decisions on global environmental problems will require such firm foundations

> of broad and multinational scientific consensus on the nature and extent of those problems. [286]

Most important for our discussion, these scientific authors—working on behalf of the US government—framed the effect of CO_2 explicitly as a problem of pollution. When the report was finished, they wrote: "Direct man-made pollution is pollution by processes in which the atmosphere is deliberately used by man for disposal of waste products."[287] The result of this pollution? "Doubling of the CO_2 concentration could effect an increase of the temperature near the surface by about 2 degrees Celsius … The 2 degree change would constitute a modification of the climate which could trigger other warming mechanisms and possibly lead to irreversible effects."[288]

US Government Agencies Engagement with International Developments

These international developments—the UNESCO meetings, SCOPE, SMIC and SCEP—were closely monitored by officials engaged in the planning for the UNCHE and officials in the U.S. government, including John Ludwig, associate commissioner at NAPCA, R.A. McCormick, director of meteorology at NOAA, and Robert White at ESSA. Indeed, these agency officials were engaged in international questions to an extensive degree. Since 1967, NAPCA, NOAA, and ESSA representatives had been travelling internationally and submitting reports on global monitoring efforts, with a

[286] Carrol L, Wilson and William H. Matthews, Proposal for the Support of a 1971 International Summer Study of Man's Impact on Climate, February 1971, b. 11, f. 22, NARA-NAPCA.
[287] STUDY OF MAN'S IMPACT ON CLIMATE (SMIC), INADVERTENT CLIMATE MODIFICATION 187 (1971)
[288] *Id.* at 239.

specific focus on Western Europe as well as one two-week tour of the emissions laboratories of major car makers in Japan at the invitation of the executive vice president of Nissan in the fall of 1969.[289] US officials also participated in meetings of the OECD Air Management Research Group, as well as work at the WMO and WHO. In March of 1969, McCormick travelled to the WMO Working Group on Atmospheric Pollution meeting in Geneva.[290]

At NAPCA, Ludwig closely followed the development of SCEP and SMIC. In August 1969, SCEP member (and later SMIC joint secretary) G.D. Robinson of the Center for the Environment and Man Inc, in Hartford, CT, forwarded the SCEP proposal, which detailed the aims of the study and its intended impact on planning for the 1972 UNCHE. Ludwig read the document closely, annotating it extensively, and then stayed in close contact with the organizers of both studies until their completion.[291] At NOAA, McCormick corresponded with William H. Matthews, SCEP's associate director; Matthews later stressed that the cooperation between NAPCA, NOAA, WMO, and SCEP/SMIC was an "opportunity for 'cross-fertilization' as well as to make a double coordinate and consistent contribution to the conference of our views and recommendations with regard to man's impact on climate."[292]

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[289] *See* b. 1, NARA-NAPCA. Archival documents from 1967-1969 include reports from: The Netherlands, Japan, Sweden, the UK, Ottawa, Montreal, Toronto, Belgium, France, West Germany, Israel, and Holland.
[290] R.A. McCormick, Chief, Air Resources Cincinnati Laboratory to Director, ARL/ESSA; Assistant Commissioner, OS&T/NAPCA, April 1, 1969, "Trip Report, Meeting of WMO Working Group on Atmospheric Pollution and Atmospheric Chemistry, Second Session, Geneva, March 5-19, 1969," b. 1, f. 3, NARA-NAPCA.
[291] Letter, John H. Ludwig to William H. Matthews, Jan 22, 1971, b. 11, f. 22, NARA-NAPCA.
[292] Letter, R.A. McCormick to William H. Matthews, Jan 26, 1971, b. 11, f. 22, NARA-NAPCA.

V. Cultural Uptake

One question that arises from the review of scientific research and communication on carbon dioxide in the 1950s and ’60s is how much of the available scientific knowledge was generally known at this time? General cultural uptake does not establish what Congress knew or intended when it wrote the Clean Air Act, but it does help to establish how words and concepts were generally understood at that time, something that rises in significance in light of the Court’s new approach to the major questions doctrine. Because many words have a different sense when used in scientific contexts than in everyday use, popular discussion of the issue can help us to understand what people meant when they used the word “climate” in the context of increased atmospheric carbon dioxide. In this section, we offer selected examples of cultural uptake that show that the scientific message had been broadly communicated in the late 1950s and ’60s, and that the word ‘climate’ was being used, in the context of CO_2 pollution, to mean global climate change, in the same sense that we understand it today.

Frank Capra’s *Unchained Goddess*

Frank Capra was one of America’s most famous and successful filmmakers. The three-time Oscar winner’s films included *Mr. Smith Goes to Washington* (1939), *Arsenic and Old Lace* (1944), *It’s a Wonderful Life* (1946), and *Pocketful of Miracles* (1961). They were some of the most popular ever made and featured many of Hollywood’s most

bankable stars.[293] In 1958, he produced a film for The Bell System Science Series, entitled *The Unchained Goddess.*

The film was about weather, weather modification, and climate change. It featured a "Dr. Research" (Frank Baxter, a professor at the University of Southern California) explaining recent advances in weather prediction and modification and including a discussion of pollution and particulates in the atmosphere. At one point, Dr. Research's interlocutor asks whether future scientists would be able to control not just local weather, but even the global climate, such as reversing the jet stream? These were "extremely dangerous questions," Dr. Research explains, because "with our present knowledge we have no idea what would happen..." Even a few degrees of temperature rise could melt the polar ice caps, creating a future in sea level rise was so great that an "inland sea would fill a good portion of the Mississippi Valley [and t]ourists in glass bottom boats would be viewing the drowned towers of Miami through 150 feet of tropical water." This could happen, because of industrial CO_2:

> Even now, man may be unwittingly changing the world's climate through the waste products of his civilization. Due to our release through factories and automobiles every year of more than six billion tons of carbon dioxide, which helps air absorb heat from the sun, our atmosphere seems to be getting warmer. [294]

The issue was profoundly important, Dr. Research concluded, because when it came to weather and climate, scientists were dealing not only with forces more complex than even the atomic physicists dealt with, but with "life itself."[295] The Bell Science

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[293] LARY MAY, THE BIG TOMORROW: HOLLYWOOD AND THE POLITICS OF THE AMERICAN WAY 87 (2002).
[294] UNCHAINED GODDESS (Warner Bros. Pictures, 1958) Discussion of weather modification begins around 47:30.
[295] *Id*.

Series has been described as "among the best known and remembered educational films ever made," and *The Unchained Goddess* was broadcast on television and also shown in classrooms around the country.[296] Historian James Burkhard Gilbert estimates that by the mid 1960s the series had been watched by 5 million schoolchildren and half a million college students.[297]

Materials for School Children & Teachers

My Weekly Reader was a pamphlet produced weekly by American Education Publications, based at Wesleyan University, and distributed to millions of children in their classrooms. Self-described as "The Junior Newspaper," it often it covered scientific topics. [298] The "Science News Supplement" issue for October 5-9, 1959 included a multi-page "science news supplement," entitled "The Weather Is Changing." The article covered basic information on weather, the matter of whether weather and climate could be controlled, and the greenhouse effect.[299] It explained:

> Carbon dioxide is a gas found in the air. Living things need a little carbon dioxide. Soon, there may be too much.
>
> Every time a car is started, the amount of carbon dioxide in the air is increased. Carbon dioxide forms whenever fuels are burned.
>
> Carbon dioxide is changing our weather. This invisible gas acts like the glass in a greenhouse. It lets sun energy come in, but stops the radiation of heat

[296] GEOFF ALEXANDER, ACADEMIC FILMS FOR THE CLASSROOM; A HISTORY 66 (2010).
[297] JAMES GILBERT, REDEEMING CULTURE: AMERICAN RELIGION IN AN AGE OF SCIENCE 367, N. 62 (1997).
[298] "My Weekly Reader, News Report," was issued weekly during the school year (except Thanksgiving and Christmastime), by American Education Publications. It was published by Wesleyan University Press until 1965.
[299] *The Weather is Changing*, 4 MY WEEKLY READER SCIENCE NEWS SUPPLEMENT 25 (October 5-9, 1959). There is also a note after the last sentence of the quote to "See your Science Supplement on Fish in Issue 1"," so MY WEEKLY READER may have discussed this in more than one issue.

> from the inside out. Carbon dioxide acts like a heat trap. It is making the earth warmer.[300]

Another example is a brochure on pollution, written by Thomas G. Aylesworth, a prolific children's book author who also served as a senior editor at *Current Science* magazine, and at Doubleday. In 1968, he wrote an educational brochure, *Our Polluted World.* The front cover showed white smoke billowing from a set of smokestacks; the inside contained a message from Surgeon General to "science students" telling them they are about to learn about "one of the most challenging problems of our age." Much of the brochure focuses on what by that-time were the familiar topics of deadly air pollution, in London, Los Angeles, and Denora, PA, but a section on "Other pollutants," Aylesworth discussed CO_2: "Two common examples of this type of pollutant are carbon dioxide and aero-allegens. Buildup of CO_2 increases the daytime temperature [sic] and may have far-reaching influence on the weather."[301] A copy of this brochure made it to the offices of Senator Muskie.

Allan Ginsburg on *The Merv Griffin Show*

In March 1969, a concerned citizen in Seattle named Henry M. Watson wrote to Washington Senator Henry "Scoop" Jackson. He explained that, on a February 1969 episode of The Merv Griffin Show, the Beat poet Allen Ginsberg told an alarming story of planetary demise. Ginsberg claimed that "the current rate of air pollution brought about by the proliferation of automobiles and 'their excrement'" could cause "the rapid

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[300] *Id.*
[301] THOMAS G AYLESWORTH, OUR POLLUTED WORLD: APPLIED ECOLOGY OF AIR AND WATER 13-14 (Current Science and Math Weekly Unit Book, 1965), s. V.A.5, b. 376, f. 1, BC-ESM.

build-up of heat on the earth." This accretion would then "melt the polar ice caps, causing a flooding of the greater part of the globe." Ginsberg attributed this information to a presidential science advisor.[302]

Mr. Watson had no doubt that the eccentric poet—"one of America's premier kooks"—was wrong and wanted Jackson to do something to stop his spreading disinformation. "I would very much appreciate your efforts to throw light on this and recommend that a public statement by responsible public officials be made in refutation ... After all, quite a few million people watch this show, people of widely varying degrees of intelligence, and the possibility of this sort of charge—even from an Allen Ginsberg—being accepted even in part, is dangerous."[303] The constituent had sought assurances that Ginsberg was merely deranged and wanted Jackson to do something about it.

Jackson forwarded the letter to Presidential Science Advisor Lee DuBridge who replied with a detailed letter describing current knowledge of CO_2 and the greenhouse effect. DuBridge affirmed that CO_2 was in fact increasing. The CO_2 "greenhouse effect" was a known fact, and it was also known "[w]e are indeed filling the atmosphere with a great many gases and in very large quantities from our automobiles, from industry, and from the burning of fossil fuels."[304]

DuBridge was not necessarily ready to sound an alarm on the issue, explaining that "what effect this increased carbon-dioxide is having and will have on our atmosphere

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[302] Henry M. Watson to Senator Henry Jackson, March 6, 1969, b.7, f. Jackson, sen. Henry, Senators and Representatives 1963-1973, Office of Science and Technology, Record Group 359, National Archives and Records Administration, College Park, Maryland, United States [*hereinafter* NARA-OST].
[303] *Id.*
[304] Lee DuBridge to Senator Henry Jackson, March 25, 1969, b.7, f. Jackson, sen. Henry, NARA-OST.

and our climate is by no means clear." More research was needed. But echoing Roger Revelle, he acknowledged that it could be serious: "I do not imply by any of this that the problem is not of considerable importance… We are, in a word, performing a gigantic experiment on ourselves. It seems to me of great importance that we know the meaning of this experiment and its possible outcomes before discovering them too late and perhaps to our sorrow.."[305] A vivid description of the greenhouse effect had reached a powerful US senator, Jackson, from the President's Science Advisor in 1969, prompted by a letter from an ordinary citizen based on something he had heard on television from America's most famous (or infamous) poet.

Later that year, DuBridge appeared on the CBS television program *Meet the Press,* where he discussed science and technology in relation to the needs of society. The greatest needs, which he felt "everybody recognizes," had to do with "solving the problems of the environment."[306] Air and water pollution could be reduced, he thought, through "regulations, practices and requirements which will reduce the amount of pollution that is being put into the air by automobiles [and] industrial combustion..."[307] He also raised the possibility of a "polluter's tax,"[308] and defended scientists who might be accused of overstating their case: "I don't like to be a calamity howler, but sometimes it takes a few calamity howlers to wake people up to the fact that there are serious

[305] *Id.*
[306] Transcript: NBC's *Meet the Press*, Prod. By Lawrence E. Spivak, guest: Dr. Lee A. DuBridge, science advisor to the President 2 (December 28, 1969), b. 7, f. 3: DuBridge, Daniel Patrick Moynihan papers (WHCF:SMOF), RNPL.
[307] *Id.* at 3.
[308] *Id.* at 17.

problems and to arouse people to the point where they are willing to do something about it. I think we are at that point now."[309]

Towards the end of the interview, DuBridge was asked if it would ever be possible to build a pollution free car. He replied, "Certainly not, if by that you mean zero waste material going into the atmosphere. Any combustion process is bound at least to produce carbon dioxide and water and these may be regarded as pollutants."[310]

Popular Magazines

Numerous popular magazines also covered the carbon dioxide problem. These discussions were being followed by the staff of Senator Edmund Muskie; the Muskie archives at Bates College, Maine, include several press clippings and articles documenting public awareness of carbon dioxide and global climate change. Articles found in the Muskie papers include one in the *Rotarian*—the magazine of the Rotary Club—with an attached note saying it was sent to Muskie by fellow Senator Jennings Randolph. The article, entitled "Let's Clear the Air," was written by the popular children's book author, Clifford B. Hicks. Hicks mainly wrote fiction, but in 1965 he wrote a science book for children, *The World Above* (1965), about the atmosphere. The article, presumably intended to promote the book, explained the "worrisome... possible long-range effects" of human activity on our planet.

> Many scientists believe we may be fouling our own nests beyond the ability of future generations to clean them up. For example, we may be unknowingly tampering with the earth's climate by altering the delicate balance

[309] *Id.* at 6.
[310] *Id.* at 19.

> of the oxygen-CO_2 cycle. Man takes oxygen from the atmosphere, uses it, and gives back carbon dioxide. Plant life takes carbon dioxide, uses it, and gives back oxygen. It's a balanced swap. Today, though, we are burning fossil fuels in such huge amounts that we are slowly but steadily increasing the level of carbon dioxide in the atmosphere. Meanwhile we are scraping away more and more plant cover to make room for an expanding population—plant cover required to remove the CO_2.
>
> In our delicately tuned atmosphere, carbon dioxide performs the function of passing incoming heat radiation to the earth's surface, but preventing it from being reflected back out into space; it's the same function that a pane of glass serves in a greenhouse. If we are increasing the level of carbon dioxide (and according to one estimate the CO_2 level is rising at a rate of about 6 billion tons a year), we may be slowly raising the earth's temperature as more and more heat is trapped inside the atmospheric greenhouse. Such a rise in temperature probably would not be detectable in a single generation. But a rise of only a few degrees would melt polar ice caps, inundate cities, and alter the natural environment everywhere.[311]

Another article, also in 1965, "We Can Afford Clean Air," came from *Fortune* magazine.

The article, which was reprinted by the Department of Health, Education and Welfare in a bound edition, which Muskie staff preserved, presented CO_2 and other greenhouse gases as a substantial threat to clean air, particularly since the problem was likely to grow in the future.[312] A third article in 1965, from the Federal Reserve Bank of Philadelphia Business Review, discussed CO_2 in the context of the Conservation Foundation work on the subject.[313]

Scientists including geophysicist Gordon MacDonald communicated concerns

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[311] Clifford B. Hicks, *Let's Clear the Air*, 107 THE ROTARIAN 16, 20 (July 1965), s. V.A.5, b. 375, f. 3, BC-ESM.
[312] Edmund K. Faltermayer, *A Fortune Proposition: We Can Afford Clean Air*, FORTUNE (November 1965) at 4, s. V.A.6, b. 535, f. 5, BC-ESM.
[313] *Good Air for the Great Society*, FEDERAL RESERVE BANK OF PHILA. BUSINESS REV. 1,11 (December 1965), s. V.A.6, b. 535, f. 5, BC-ESM.

about rising carbon dioxide to broader audiences. For example, in 1969 MacDonald published a paper in *Technology Review* entitled, "The Modification of Planet Earth by Man," and with the sub-heading: "Man's technology is changing his physical environment... The results could endanger man's future on Earth."[314] The paper was about climate change, and began by listing various forms of pollution that could alter the climate, including carbon dioxide from "burning fossil fuels," direct heating of the atmosphere by "burning of fossil and nuclear fuels," changing the albedo, and other factors; of all these, CO_2 was the most concerning, in part because it had "long been recognized as potentially affecting worldwide climate," and new work in climate modelling, "reported in the *Journal of Atmospheric Sciences* (1967), [calculated] that the change in carbon dioxide content of the atmosphere between 1900 and 1940 was sufficient to warm the earth by about 0.1 to 0.2° C."[315] MacDonald called for "urgent action" to deal with "the long-term problems of climate alteration," including world-wide programs to monitor carbon dioxide.[316] The article also discussed in detail the competing cooling effects of particulates versus the heating effect of CO_2. The article was republished in *Current* in January 1970 with the title "Caring for our Planet: How Man Endangers the Planet."[317] Another paper, published in 1970 in *Environmental Quality: The Forensic Quarterly*, also discussed the counter-vailing effects of carbon dioxide and

[314] Gordon J.F. MacDonald, *The Modification of Planet Earth by Man*, 72 TECHNOLOGY REVIEW 27, 27 (1969). The personal papers of MacDonald in which we found this article, and those for notes 321-326, were generously donated to us by his family. After our research was completed, we donated them, with the family's permission, to the Harvard University Archives where they await processing.
[315] *Id.* at 28.
[316] *Id.* at 31.
[317] Gordon J.F. MacDonald, *Caring for our Planet: How Man Endangers the Climate*, CURRENT (January 1970) at 17.

particulates, suggesting that with one or the other "probably taking the lead, the danger of the melting of the ice caps or the dangers of a new ice age are not trivial."[318] MacDonald made similar arguments in other wider-reaching settings, including, for example, a 1969 public conference on "our disposable world" sponsored by the Junior League of Los Angeles and The Rand Corporation and a 1970 address to the Industrial College of the Armed Forces.[319] MacDonald did not take a position in 1970 on which effect he thought would end up dominating—although he thought that particulate had dominated so far—but rather he stressed the enormity of the changes that both forms of pollution (carbon dioxide and particulates) could effect.[320]

By 1970, the issue of carbon dioxide and climatic change appeared often in popular publications. In a 1970 issue of the magazine, *Fortune* writer and editor Tom Alexander published an article entitled "Some Burning Questions About Combustion." The article discussed issues of acid rain, the greenhouse effect, and prospects for cleaning up the internal-combustion engine. "One combustion product that worries some scientists a great deal," Alexander wrote, "is not usually classified as a pollutant." CO_2, he noted, was "expected to increase another 25 percent by the year 2000" (no doubt referencing the statistic that was often cited at the time, which was offered in the 1965 PSAC report).

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[318] Gordon J.F. MacDonald, *How Can we Do a Better Job of Managing the Environment?*, 44 ENV. QUAL.: FOR. Q. 69, 79 (1970).

[319] MacDonald, Man and His Environment, conference speech for the Junior League of Los Angeles and the Rand Corporation (December 6, 1969*), in* OUR DISPOSABLE WORLD, 1970, at 2. John Middleton also spoke about air pollution at the conference. MacDonald, Our Beleaguered Environment: speech for the Industrial College of the Armed Forces (Sep. 30, 1970), *in* PERSPECTIVES IN DEFENSE MANAGEMENT 11 (Autumn 1971).

[320] At the time, he thought that particulates were dominating, but that would change as early air pollution laws got particulates and other visible pollutants under control but did not address CO_2. Personal communications with the first author, 2001-2002 (on file with Naomi Oreskes).

While it "probably poses no direct threat to health… quite a few scientists maintain that in the long run it may prove to be the most important pollutant of them all."[321] Alexander also discussed the impact of particulates, the cooling effects of which could outweigh the warming effects of carbon dioxide. Regardless, he wrote, "Whether the climate gets warmer or cooler, the implications are serious. Man and his institutions everywhere are critically adjusted to just the climatological conditions that prevail." Further, "relatively small perturbations could trigger latent instabilities," since, as he noted, as water gets warmer, its capacity to absorb CO_2 decreased, which could accelerate the greenhouse effect. [322]

Concern about carbon dioxide could even be found in *Sports Illustrated*. In February 1970, *Sports Illustrated* picked up an article which first appeared in *Foreign Affairs* the prior month. Two days after the article was published in *Sports Illustrated*, the article was cited in a Congressional Hearing convened by House Committee on Government Operations, Conservation and Natural Resources Subcommittee. There, Dr. Spencer Smith, (Secretary of the Citizens Committee on Natural Resources, a national conservation organization) asked for the article to be included in the record.[323] Addressing CO_2 and climate, the article recommended against taking out 99-year leases

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[321] Tom Alexander, *Some Burning Questions about Combustion*, FORTUNE (Feb. 1970) at 130, 131.
[322] *Id.* at 167.
[323] *The Environmental Decade (Action Proposals for the 1970'S): Hearing before a subcomm. of the H. Comm. on Gov't. Op.,* 91st Cong., 2nd Sess. 104 (1970) (statement of Dr. Spencer Smith, Jr., secretary, Citizens Committee on Natural Resources). It was cited in the record as having been published on Jan 30, 1970. However, the publication date for the copy in SPORTS ILLUSTRATED was Feb 2, 1970 (vol 32, no 5). It was first published in January 1970 in FOREIGN AFFAIRS (vol 48, no 2). It is the latter version that was entered into the Cong. Rec. In SPORTS ILLUSTRATED it was highlighted in that issue's letter from the publisher. The same version of the article was also entered into the Senate Cong. Rec. on Feb. 26, 1970 by Maryland Senator Joseph Tydings, 116 Cong. Rec. S4993-96 (daily ed. Feb. 26, 1970).

on sea-level properties. Several paragraphs from the article were excerpted and entered into the Congressional Record. They stated in part:

> [F]ossil fuels, locked away for eons of time, are extracted by man and put back into the atmosphere from the chimney stacks and the exhaust pipes of modern engineering. About 6 billion tons of carbon are mixed with the atmosphere annually. During the past century, in the process of industrialization, with its release of carbon by the burning of fossil fuels, more than 400 billion tons of carbon have been artificially introduced into the atmosphere. The concentration in the air we breathe has been increased by approximately 10 percent…This is something more than a public health problem, more than a question of what goes into the lungs of an individual, more than a question of smog. ... Carbon dioxide… can seriously disturb the heat balance of the earth because of what is known as-the "greenhouse effect."
>
> … [A]t the present rate of increase, the mean annual temperature all over the world might increase by 8.6 degrees centigrade in the next 40 to 50 years. The experts may argue about the time factor and even about the effects, but certain things are apparent…The north-polar ice cap is thinning and shrinking. The seas, with their blanket of carbon dioxide, are changing their temperature, with the result that marine plant life is increasing and is transpiring more carbon dioxide. As a result of the combination, fish are migrating, changing even their latitudes. On land the snow line is retreating and glaciers are melting. ... [and] the melting of ice caps or glaciers, in which the water is locked up, will introduce additional water to the sea and raise the level. Rivers originating in glaciers and permanent snow fields will increase their flow; and if ice dams, such as those in the Himalayas, break, the results in flooding may be catastrophic. In this process the patterns of rainfall will change, with increased precipitation in some areas and the possibility of aridity in now fertile regions. One would be well advised not to take 99-year leases on properties at present sea level."[324]

These examples, while by no means exhaustive, suffice to make the point: scientists working in the 1950s and 1960s on climate change were not isolated in ivory towers, their work unbeknownst to others. On the contrary, by the late 1960s concern about CO_2 and climate change had been communicated to school children and teachers,

[324] Lord Ritchie-Calder, *Mortgaging the Old Homestead,* SPORTS ILLUSTRATED (February 2, 1970) at 44, 48-49; *Id.* at 108-109.

to conservationists, and to ordinary Americans though film, television, and articles in popular magazines such as *Fortune* and *Sports Illustrated.* Furthermore, historical evidence shows that the staff of the principal Congressional architect of the Clean Air Act, Senator Edmund Muskie, was keeping track of this conservation.

Conclusion

The Clean Air Act remains at the center of U.S. climate policy. Until the Act is replaced by superseding legislation, the precise scope of its provisions will continue to shape the nature and ambition of EPA's regulatory program. *West Virginia* is unlikely to be the Supreme Court's final word on the Clean Air Act and climate change; future cases will define the limits of the American climate response as courts address the compatibility of each newly promulgated regulation with statutory language from the 1970s. Historical analysis will be critical to that inquiry.

Under the new major questions doctrine, "context"[325] and "history"[326] will guide the Court's interpretation of the most significant provisions of the Act. That history tells a remarkable story, one in which influential members of the science policy establishment engaged broadly with the effects of air pollution on global climate change in the years leading up to 1970. Congress recognized that its amendments to the Clean Air Act would have "vast economic and political significance,"[327] and understood far more about the

[325] *West Virginia v. EPA*, No. 20–1530, at 16 (June 30, 2022) (quoting Davis v. Michigan Dept. of Treasury, 489 US. 803, 809 (1989)).
[326] *Id.* at 17 (quoting Brown & Williamson Tobacco Corp. v. FDA, 529 U.S. 120, 159 (2000)).
[327] *Id.* at 11 (quoting Utility Air Regulatory Grp. v. EPA, 573 U.S. 302, 324 (2014)).

potential threat of anthropogenic climate change than either the Court or most commentators have recognized.

This Article has continued the process of fully exhuming the history of climate change and the 1970 Clean Air Act by analyzing sources far beyond the confines of the congressional record. In a follow up paper, we will document how extensively scientists and administrators conveyed their climate knowledge to Congress, including in specific testimony pursuant to the 1970 Clean Air Act. We also demonstrate how the word "climate" in the Clean Air Act's definition of welfare can be traced to a June 1970 draft of the bill that provided for research on "climatic modifications."[328] Understanding both the scientific and original public meaning of "climate," as used in § 302,[329] and the nature of broader governmental contemplation of global climate change in the 1960s and into 1970, provides the textual and contextual underpinnings for debate over the parameters of the Act's terms. The Court underestimated this history in *Massachusetts* and largely ignored it in *West Virginia*.

If the major questions doctrine is to have doctrinal heft in future climate cases, the Court will need to engage with the full scope of the history presented in this Article and elsewhere. Without sustained historical inquiry, the major questions analysis is grounded in little more than judicial intuition. We do not suggest that this history of climate science in the 1960s — or any form of historical evidence — can definitively resolve judicial

[328] Draft of "Air Pollution: A Bill," June 24, 1970 (Comm. Print. No. 1), 91st Congress Committee on Environment and Public Works Environmental Pollution Subcommittee Clean Air Act Box No. 13, legislative/oversight files, congressional sessions: 91-96, subgroup undefined: location 12E3/20/30/2, Records of the US Senate, 1789-2022, Record Group 46, National Archives Building, Washington, DC.
[329] 42 U.S.C. § 7602(h).

disputes. In major questions cases like *West Virginia*, however, history should set the terms of the debate.