IN THE CIRCUIT COURT OF THE STATE OF OREGON

FOR THE COUNTY OF MULTNOMAH

COUNTY OF MULTNOMAH,

Plaintiff,

v.

EXXON MOBIL CORP., SHELL PLC, F.K.A. ROYAL DUTCH SHELL PLC, SHELL U.S.A., INC., EQUILON ENTERPRISES LLC DBA SHELL OIL PRODUCTS US, BP PLC, BP AMERICA, INC., BP PRODUCTS NORTH AMERICA, INC., CHEVRON CORP., CHEVRON U.S.A., INC., CONOCOPHILLIPS, MOTIVA ENTERPRISES, LLC, OCCIDENTAL PETROLEUM F.K.A. ANADARKO PETROLEUM CORP., SPACE AGE FUEL, INC., VALERO ENERGY CORP., TOTALENERGIES MARKETING USA F.K.A. TOTAL SPECIALTIES USA, INC., MARATHON OIL COMPANY, MARATHON OIL CORP., MARATHON PETROLEUM CORP., KOCH INDUSTRIES, INC., AMERICAN PETROLEUM INSTITUTE, WESTERN STATES PETROLEUM ASSOCIATION, MCKINSEY & COMPANY, INC., MCKINSEY HOLDINGS, INC., NW NATURAL F.K.A. NORTHWEST NATURAL GAS COMPANY, OREGON INSTITUTE OF SCIENCE AND MEDICINE and DOES 1-250 INCLUSIVE,

Defendants.

Case No. 23CV25164

SECOND AMENDED COMPLAINT
(Public Nuisance, Negligence, Fraud & Deceit, and Trespass)

PRAYER: $51,550,000,000

Or Laws 2012, ch. 48, Sec. 2;
ORS 21.160(1)(e)

CLAIMS NOT SUBJECT TO MANDATORY ARBITRATION

JURY TRIAL REQUESTED

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SECOND AMENDED COMPLAINT FOR CIVIL DAMAGES AND ABATEMENT OF PUBLIC NUISANCE

I. NATURE OF THE CASE

1.

This is a case that seeks damages and equitable relief for harm caused to Multnomah County (hereafter, "County" or "Plaintiff"), by Defendants' execution of a scheme to deceptively promote fossil fuel products as harmless and rapaciously selling the products, while knowing that carbon pollution emitted by their products into the atmosphere would likely cause deadly extreme heat events like that which devastated Multnomah County in late June and early July 2021. Beginning on June 25, 2021, the Plaintiff, Multnomah County was scorched by the most extreme heat event in its history. For several consecutive days and nights, a "heat dome," sometimes called a "blocking event" or an "extreme heat event," broiled the County, causing massive loss of life, grave ill health, destruction of County property, and the consumption of resources. Over three consecutive days, County temperatures reached highs of 108°, 112°, and 116° Fahrenheit. All three of those high temperatures exceeded those of any day in any previous year in the County, ever. Tree ring data revealed that the 2021 Pacific Northwest ("PNW") heat dome was the hottest event in the region since *the beginning of the record time* (starting in 950AD).[1]

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[1] Heeter, K.J., Harley, G.L., Abatzoglou, J.T. *et al.* Unprecedented 21st century heat across the Pacific Northwest of North America. *npj Clim Atmos Sci* 6, 5 (2023). https://doi.org/10.1038/s41612-023-00340-3.

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2.

Defendants engaged in an enterprise of misrepresentation and deception about the effects its products would have on the climate, and that they could cause extreme weather events such as the 2021 extreme heat event. Further, Defendants' individual and collective emissions, including those in Oregon, were a cause of the 2021 extreme heat event. This suit does not seek to challenge the legal rights of Defendants to create emissions that occur outside of the state of Oregon. The law, however, does not and should not permit Defendants to conceal and misrepresent the dangers of their products' emissions, which led to an increase in the demand and consumption of those products and lack of preparedness for extreme heat drastically exacerbating past and continuing damages from the 2021 extreme heat event.

3.

Because Multnomah County has historically enjoyed a mild climate, a substantial portion of its residents, even those who have financial resources, have no central cooling system or window units in their homes. A total of 69 people died in Multnomah County from overheating during this event. In a typical year, Multnomah County experiences *zero* deaths from heat-related illnesses. Prior to June 2021, Multnomah County recorded only two hyperthermia deaths since 2010 — one each in 2016 and 2018.[2] More people died from the June 2021 heat wave in Multnomah County

[2] Multnomah County, June 2021 Extreme Heat Event, Preliminary Findings and Action Steps https://www.multco.us/file/june-2021-heat-event-preliminary-findings-and-action-steps (last visited June 12, 2023).

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than died from heat in the entire state of Oregon in the past 20 years.[3] Deaths from *all causes* during the heat dome were double the normal level.

4.

Many other residents fell ill from heat strokes, heat exhaustion, and dehydration. Hundreds required emergency and critical medical care.

5.

The severity of the heat dome caused the County to expend enormous financial and human resources that it otherwise would not have, and thus added crushing economic burden upon the County, in tandem with the devastating human toll exacted upon its residents. In addition to providing many types of emergency health and human services for residents suffering from the extreme heat, the County spent taxpayer money to provide people with shelter, cooling centers, fans, food, portable air conditioners, clothes, and water. The agitation and desperation wrought by the record heat provoked an increase in crime and violence within the County, which further taxed the resources of law enforcement and County healthcare providers, who were already pushed beyond their limits in trying to care for those suffering from heat strokes and heat-related illnesses. Had the Defendants not deceived the County, the public and the scientific community about the dangers of the pollution emitted by use of their products, the County, and others, would have been better prepared for extreme heat events. In the wake of the June 2021 extreme heat event, the County spent significant sums of its taxpayer monies to prepare for future ones. These expenditures

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[3] Id.

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included increases in shelter space, supplies, warehousing of supplies, an early warning system, staffing, training, and tree density. Still, the County lacks the resources to adequately prepare for comparable or more severe heat extremes.

6.

The heat dome that cost so much life and loss was not a natural weather event. It did not just happen because life can be cruel, nor can it be rationalized as simply a mystery of God's will. Rather, the heat dome was a direct and foreseeable consequence of the Defendants' decision to lie to the County, the public, and the scientific community about the catastrophic harm that pollution from fossil fuel products into the Earth's and the County's atmosphere would cause in order to sell as many fossil fuel products over the last six decades as they could. And that is what Defendants precisely did, leading to an exponential increase in fossil fuel product use, fossil fuel dependence, and emissions during that time. In the aftermath of the June 2021 heat dome, world renown climatologists, physicists and statisticians researched the causes of that extreme heat event and published their conclusions in peer-reviewed scientific journals. One such study concluded that the occurrence of a heat wave of the intensity experienced in the study area would have been virtually impossible without anthropogenic climate change ("ACC").[4]

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[4] Philip, S. Y., et al., Rapid attribution analysis of the extraordinary heat wave on the Pacific coast of the US and Canada in June 2021, Earth Syst. Dynam., 13, 1689–1713 (2022). https://doi.org/10.5194/esd-13-1689-2022.

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7.

The same study concluded that this extreme heat event was 150 times less likely to have occurred in the absence of ACC.[5]

8.

Finally, the authors determined that in the absence of ACC, a heat event this extreme in this region might occur, if at all, one time in 1000 years. Escalating carbon pollution has increased the likelihood that it will reoccur every 5 to 10 years."[6]

9.

These autopsy-like climatic diagnoses corroborated the prognoses that the Defendants internally made since the late 1950s: The heat catastrophe was caused by carbon pollution emitted into and accumulated by the atmosphere that warmed the planet and the region where the County resides, as well as dried out the region's soil. It was so extreme and historically anomalous that it would not have occurred so intensely, nor at all, absent that pollution. In sum, but for carbon atmospheric pollution, the 2021 Pacific Northwest heat dome would have not occurred, and in the unlikely event that some atypical heating period may have still occurred, it would not have been as severe or as destructive. And but for the deception by the Defendants about the dangers of the pollution emitted by the use of their products the County, and others, would have prepared for their new climate reality.

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[5] Id.
[6] Id.

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10.

The extreme heat event that began on June 25, 2021, and the Plaintiff's damages caused by it, occurred because the Defendants' engaged in a sophisticated campaign of deflection and deception that denied what they knew was the foreseeable consequence of using their fossil fuel products. This campaign encouraged the use of Defendants' products and led to historical carbon and methane pollution heating up the Earth's (and the Plaintiff's) atmosphere.

11.

Defendants have known and foreseen for decades that their fossil fuel pollution would cause widespread and catastrophic harm throughout the world, including to Plaintiff, but they lied and cynically sought to sow "scientific" and public doubt in furtherance of their ceaseless, ravenous quest for more wealth. The use and consumption of fossil fuels—oil, natural gas, and coal—is the primary source of greenhouse gas emissions. Those greenhouse gas emissions have warmed the earth 1.1 to 1.2 ° C since 1900.[7] The American Petroleum Institute ("API"), in coordination with several Fossil Fuel Defendants that are long-standing members of that organization, investigated the science and advised *each other*, but not the public, in stark terms that fossil fuel usage would cause global warming and catastrophic climate changes like those experienced in Multnomah County.

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[7] 2020 World Meteorological Organization (WMO) Report, https://public.wmo.int/en/media/press-release/2020-was-one-of-three-warmest-years-record#:~:text=The%20differences%20in%20average%20global,(1850%2D1900)%20level.

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12.

API is a trade group that promotes the fossil fuel production and sales activities of its members, which include the following Defendants: Exxon, Shell, Chevron, BP, ConocoPhillips, Motiva, and Anadarko (Occidental). In 1965, API's president, Frank Ikard, stated *internally* to the group's members, "… there is still time to save the world's peoples from the catastrophic consequence of pollution, but time is running out."[8] In 1965, the Defendants could have publicly admitted what they privately understood: emissions into the atmosphere from the use of Defendants' fossil fuels threatened "the world's people" with "catastrophic consequence[s]." Defendants understood that such threats could be avoided if course corrections were implemented imminently, before "time [runs] out." Yet, Defendants did the opposite. They made no such public admission. They lied publicly and repeatedly about the harm their pollution was causing and the calamities it would cause. They chose to safeguard their financial bottom lines, rather than the health and safety of the Plaintiff, and its residents." They terminated research and development programs that relied on renewable energy sources. McKinsey, Western States Petroleum Institute, Oregon Institute of Science and Medicine and other organizations have facilitated, and promoted, deceptive messaging related to the harms that the use of fossil fuels would cause to the earth, climate, and populous. This deception led to an increase in demand and consumption of fossil fuels.

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[8] Franta, B., Early oil industry knowledge of CO_2 and global warming. Nature Clim. Change 8, 1024–1025 (2018). https://doi.org/10.1038/s41558-018-0349-9.

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13.

Fossil Fuel Defendants consciously decided that they would lie about the impact of their fossil fuel products on the global climate, and regional climate that includes Multnomah County. In 1989, Fossil Fuel Defendants mobilized a campaign to create the "Global Climate Coalition" ("GCC"). Through this organization, Fossil Fuel Defendants and others funded a marketing campaign that intended to deceive and violate Oregon's statutes and common law. That deception continues to this day.

14.

In the spring of 1998, Fossil Fuel Defendants further organized their deceptive scheme into what is now known as the "Victory" memorandum. The Defendants perceived that a "consensus" had formed among qualified scientists and the informed public that carbon pollution from fossil fuel consumption was substantially warming the planet and thereby inducing weather extremes that posed an existential threat. Rather than seeking to modify their business activities to reduce that threat, or invest in renewable energy sources, the Defendants set forth upon a plan *to change the narrative* about that serious problem and undermine the consensus with pseudo-science, fabricated doubt, and a well-funded, sustained public relations campaign to promote their spin. To that end, they sponsored a cadre of mercenary "experts" who were selected for the purpose of seeding scientific literature and serving as moles in climatology groupthink. Their role is and was to espouse fossil fuel industry-sponsored propaganda under a false pretense that it was objective and reliable contrary science, and they spread their disinformation across America, including in Multnomah County.

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15.

In furtherance of the scheme that Defendants hatched in the "Victory" memorandum, they, and the fabulists they sponsor, corrupted legitimate scientific literature by seeding it with anti-science, pro-industry propaganda, upon which consumers, including consumer taxpayers in Multnomah County, have detrimentally relied.

16.

The culpable conduct of the Fossil Fuel Defendants, as described more fully in this Second Amended Complaint includes:

(a). Defendants knew or should have known that carbon pollution emitted by their fossil fuel products would likely cause extreme heat events.

(b) Defendants proclaimed that climate change was not a real or imminent threat while knowing that it was.

(c). Defendants had a duty to disclose under Oregon laws but failed to disclose: 1) that global climate change was a genuine and serious threat; 2) that pollution from their fossil fuel products was a direct cause of that threat; and 3) extreme heat in otherwise mild climates like America's Pacific Northwest was one of the threats that was made more likely to happen with more severe consequences.

(d). To conceal their fraudulent marketing scheme, Defendants masked their activities through front groups, dark money funding, pseudo scientists for hire, all in an enterprise to deceive the public and Multnomah County.

(e). Defendants failed to warn the public, including Multnomah County and its residents of the external social, economic and environmental costs from using their products. Instead, the Defendants created a narrative of scarcity of resources to maintain their energy production monopoly and make higher profits.

17.

Defendants' false and misleading promotion of fossil fuel products are individually and collectively a cause, of Multnomah County's lack of preparedness for the extreme heat event that

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struck the County beginning on June 25, 2021, two similar heat events that occurred in 2022, one in May 2023, and one in May 2024. The harms caused by Defendants to Plaintiff are ongoing and will multiply. Because Defendants have polluted the atmosphere with enormous amounts of methane and carbon dioxide within territorial boundaries of Oregon, which remain aloft for decades, and they continue to do so without restraint, extreme heat events will reoccur with increasing intensity and frequency.[9] Defendants' false and misleading promotion of fossil fuel products also led to an increase in the demand and consumption of these products. Because Defendants' carbon and methane polluting products and activities in Oregon cause regional temperature rise and sustained periods of drought, Plaintiff has experienced and will continue to experience extreme heat events and toxic smoke from massive, unmanageable wildfires. Plaintiff lacks sufficient resources to prepare for the enormity of that impending harm and seeks all remedies from Defendants provided by Oregon state law for its damages, past and future, as well as for abatement of such harms.

18.

Plaintiff Multnomah County, through the County Attorney's Office, brings this action in its sovereign capacity for the public benefit and to promote the welfare of the public. The County of Multnomah also brings this action as an exercise of its police power, which includes, but is not limited to, its stewardship of the County's property, air, and waters, to prevent and abate nuisances

[9] Zhang, X., Zhou, T., Zhang, W. et al. Increased impact of heat domes on 2021-like heat extremes in North America under global warming. Nat Commun 14, 1690 (2023). https://doi.org/10.1038/s41467-023-37309-y.

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and harm, and to prevent and abate hazards to public health, safety, welfare, and the environment. Finally, the County of Multnomah also brings this action in its capacity as *parens patriae* on behalf of its taxpaying residents who have suffered and will suffer harms, including for the expenditures of County resources arising from extreme heat events and wildfires caused by Defendants' malfeasance, which is further described herein. **All of Plaintiff's claims for relief arise under Oregon state law for harms occurring in Multnomah County. Plaintiff seeks no remedy under Federal law and expressly disclaims all theories of recovery, if any, that may exist exclusively under Federal law. Plaintiff does not seek relief with respect to any federal enclave located within the County's geographic borders, or any federal enclave elsewhere.**

II. THE PARTIES, JURISDICTION AND VENUE

A. Plaintiff

19.

Multnomah County is an existing county government duly formed under the laws of the State of Oregon and is a body politic and corporate. The seat of Multnomah County is in Portland, Oregon. The Multnomah County Board of Commissioners is duly elected to exercise the powers of Multnomah County and has approved the filing of this lawsuit. According to the 2020 US consensus, 815,428 people reside in Multnomah County, the state's most populous county.

20.

It has long been the policy in the State of Oregon that the discharge into the air of gases and particulates that cause injury to human, plant or animal life is a public nuisance and, as such,

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is contrary to public policy.[10] Moreover, since 1951, it has been the public policy in Oregon "[t]o restore and maintain the quality of the air resources of the state in a condition as free from air pollution as is practicable, consistent with the overall public welfare of the state."[11]

21.

Multnomah County has standing and authority to bring this lawsuit under the Constitution of the State of Oregon, Oregon Revised Statutes, The Multnomah County Charter, and under the common law principle of *parens patriae*. Multnomah County has the right to bring this action to recover for harms caused by the Defendants' malfeasance and protect the public interest and public health of its citizens against fossil fuel induced weather extremes. The Multnomah County Attorney's Office is authorized to bring this suit on behalf of the County with the assistance of outside counsel.

22.

On June 22, 2023, the Multnomah County Board of Commissioners voted unanimously on a resolution declaring that ACC has caused an on-going public nuisance of climate-related mass catastrophe events driven by human caused climate change that has increased the frequency, duration, and intensity of multiple disasters, which include extreme heat events (including, but not limited to, "heat domes"), wildfires (and wildfire-generated smoke), and drought. Thus, the

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[10] *Smejkal v. Empire Lite-Rock, Inc.*, 547 P.2d 1363, 1367, 1976 Ore. LEXIS 904, *13 (April 26, 1976).
[11] *Id.* (citing Oregon Laws 1951, Chapter 425, § 7).

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existence of a public nuisance that burdens the County from anthropogenic climate change is memorialized by official decree of Multnomah County.

23.

This is an official action brought by the County Attorney's Office in its official capacity.

B. Defendants

1. Oil and Gas Defendants

24.

The Oil and Gas Defendants in this action, both individually and collectively, have substantially polluted the atmosphere with the greenhouse gases ("GHG") that super heat the planet's surface and catalyze extreme heat events. About three quarters of all fossil fuel combustion CO_2 emissions in history have occurred since the 1960s and estimates have more than half occurring since the late 1980s and even as late as 1994.[12] The annual rate of CO_2 emissions by some estimates from production, consumption, and use of fossil fuels has increased by more than 60% since 1990.[13] Cumulative carbon analysis allows an accurate calculation of net annual CO_2 and methane emissions attributable to each Defendant by quantifying the amount and type of fossil

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[12] R. J. Andres et al., A synthesis of carbon dioxide emissions from fossil-fuel combustion, 9 BIOGEOSCIENCES1845, at 1851 (2012), https://bg.copernicus.org/articles/9/1845/2012/bg-9-1845-2012.pdf (last visited June 20, 2023); See also ¶¶ 165-174.

[13] Le Quéré et al., Global Carbon Budget 2016, 8 EARTH SYST. SCI. DATA 605, at 630 (2016), https://essd.copernicus.org/articles/8/605/2016/essd-8-605-2016.pdf (last visited June 20. 2023).

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fuel products each Defendant extracted and placed into the stream of commerce, and multiplying those quantities by each fossil fuel product's carbon factor.[14]

25.

The Oil and Gas Defendants, listed below, (along with their co-venturer carbon majors) are directly responsible for knowing and unreasonable concealment and misrepresentations of the climate harms from their products causing increased demand and consumption of those products and to a lack of preparedness for the extreme weather caused by their massive amounts of GHG emissions from 1965-present, including in Oregon.

26.

Defendant, Exxon Mobil Corp. ("Exxon") is incorporated in New Jersey, with its principal place of business in Irving, Texas. It is registered with the SEC and is traded under the symbol, "XOM." Exxon, along with Defendants, BP, Shell, Chevron and their predecessor corporations

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[14] Richard Heede, Tracing Anthropogenic Carbon Dioxide and Methane Emissions to Fossil Fuel and Cement Producers, 1854–2010, 122 CLIMACTIC CHANGE 229-241 (2014), https://link.springer.com/content/pdf/10.1007/s10584-013-0986-y.pdf; see also, Richard Heede, Carbon Majors: Update of Top Twenty companies 1965-2017, CLIMATE ACCOUNTABILITY INSTITUTE (Oct. 9, 2019), https://climateaccountability.org/wp-content/uploads/2020/12/CAI-PressRelease-Top20-Oct19.pdf (last visited June 20. 2023).

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constituted a group in the 1970's known as the "Seven Sisters,"[15] which controlled around 85% of the world's petroleum reserves.[16]

27.

Exxon is an American multinational oil and gas corporation and has consistently ranked as the world's second largest company by revenue.[17] It is one of the largest of the world's Big Oil companies.[18]

28.

Exxon is vertically integrated and is active in every area of the oil and gas industry, including exploration and production, refining, transport, distribution and marketing, petrochemicals, plastics, power generation and trading.

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[15] "Seven Sisters" was a common term for the seven transnational oil companies of the "Consortium for Iran" oligopoly or Enterprise, which dominated the global petroleum industry from the mid-1940s to the mid-1970s. The industry group consisted of Anglo-Iranian (started as Anglo-Persian) Oil Company (now BP), Gulf Oil (later part of Chevron), Royal Dutch Shell, Standard Oil Company of California (SoCal, now Chevron), Standard Oil Company of New Jersey (Esso, later Exxon, now part of Exxon Mobil), Standard Oil Company of New York (Socony, later Mobil, also now part of ExxonMobil), and Texaco (later merged into Chevron).

[16] Ian Mann, Shaky industry that runs the world, THE TIMES (Jan. 24, 2010), https://www.timeslive.co.za/ideas/2010-01-24-shaky-industry-that-runs-the-world/ (last visited June 14, 2023).

[17] Fortune, Global 500, FORTUNE 500, https://fortune.com/fortune500/2022/ (last visited June 14, 2023).

[18] Id.

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29.

When ranked by oil and gas reserves, Exxon, is ranked 14th in the world.[19] Exxon's total assets at the end of 2018 were valued at $346.2 billion.[20]

30.

Exxon manages, directs, and controls its and its subsidiaries' policies and practices related to climate change and fossil fuel production. Exxon is the second largest investor-owned greenhouse gas emitter.[21]

31.

Exxon is the largest non-government owned company in the energy industry.[22] Exxon is organized functionally into several global operating divisions, namely Upstream, Downstream and Chemical, such as Exxon Coal & Minerals, Inc. It also owns hundreds of smaller subsidiaries, all fossil fuel based, such as Imperial Oil Limited (69.6% ownership) in Canada, and SeaRiver

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[19] Steve Forbes, Will We Rid Ourselves of This Pollution?, FORBES (Mar. 20, 2007), https://www.forbes.com/forbes/2007/0416/033.html?sh=350a237f22f4 (last visited June 14, 2023).

[20] Exxon Mobil, 2018 Annual Report Pursuant to Section 13 or 15(d) of the Securities Exchange Act of 1934 (Form 10K), EXXONMOBIL (Feb. 27, 2019), https://www.sec.gov/Archives/edgar/data/34088/000003408819000010/xom10k2018.htm (last visited June 15, 2023).

[21] Exxon Mobil, 2018 Financial & Operating Review, EXXONMOBIL (2019) https://corporate.exxonmobil.com/-/media/Global/Files/annual-report/2018-Financial-and-Operating-Review.pdf (last visited June 14, 2023).

[22] Roslan Khasawneh, Exxon Mobil Eyes Multi-Billion Dollar Investment at Singapore Refinery: Executive, REUTERS (Oct. 3, 2018), https://www.reuters.com/article/us-singapore-bunker-sibcon-exxon-mobil-idUKKCN1MD0EF (last visited June 14, 2023).

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Maritime, a petroleum shipping company.

32.

Exxon's upstream operation includes exploration, extraction, shipping, and wholesale operations. Those operations drive much of ExxonMobil's revenue, accounting for approximately 70% of the total.[23]

33.

Exxon's downstream operation, consisting of marketing, refining, and retail operations, is based in Houston, Texas. Exxon merged its refining and marketing divisions, namely ExxonMobil Refining and Supply Company and ExxonMobil Fuels, Lubricants & Specialties Marketing Company in 2018, which enables ExxonMobil to generate more cash flow from downstream activities – helping the energy giant to counter the volatility in its upstream business. Exxon's downstream operations include its sales of petroleum-based consumer products in Oregon.

34.

ExxonMobil Chemical is a petrochemical company which was created by merging Exxon's and Mobil's chemical industries. Its principal products include petroleum-based olefins and aromatics, ethylene glycol, polyethylene, and polypropylene along with specialty lines such as

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[23] Exxon Mobil, ExxonMobil Financial and Operations Summary: Overview and Highlights, EXXONMOBIL (2018) https://web.archive.org/web/20181024231915/https://corporate.exxonmobil.com/en/company/annual-report/financial-operating-highlights (last visited June 14, 2023).

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elastomers, plasticizers, solvents, process fluids, oxo alcohols and adhesive resins.

35.

Exxon's "Mobil 1" brand is the market leader in high-value synthetic lubricants and is sold in Oregon.[24]

36.

Exxon's "Infineum" line is a joint venture with Royal Dutch Shell that manufactures and markets petroleum additives for the fuel and lubricant industries to commercial and consumer markets.[25] The Infineum line manufactures and markets crankcase lubricant additives, fuel additives, and specialty lubricant additives, as well as automatic transmission fluids, gear oils, and industrial oils.[26] Infineum is a formulator, manufacturer and marketer of petroleum additives for the fuel and lubricant industries. Their products include small engine, passenger car motor, heavy-duty engine, gas engine, and marine oils along with fuels, transmission fluids, viscosity modifiers, and pour point depressants.[27] Their products are classified into five distinct groups: driveline additives, engine oil additives, fuel additives, marine additives and industrial products and are sold worldwide, including in Oregon and Multnomah County.

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[24] ExxonMobil, ExxonMobil 2018 Financial & Operating Review, EXXONMOBIL (Apr. 2. 2019) https://corporate.exxonmobil.com/-/media/Global/Files/annual-report/2018-Financial-and-Operating-Review.pdf (last visited June 18, 2023).

[25] Jack W. Plunkett, Plunkett's Chemicals, Coatings & Plastics Industry Almanac: The Only Complete Guide to the Chemicals Industry (2009).

[26] Id.

[27] Bloomberg, Infineum International Limited – Company Profile and News, BLOOMBERG https://www.bloomberg.com/profile/company/2573746Z:LN?leadSource=uverify%20wall (last visited June 20, 2023).

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37.

Exxon advertises, markets, and sells its products in Oregon and Multnomah County. Exxon conducts substantial fossil fuel product business in Oregon and purposefully avails itself of the rights, obligations, and privileges of Oregon's laws. Exxon operated a bulk fuel terminal facility located at 9420 NW St. Helens Rd., Portland, OR 97231 in Multnomah County that was also used by BP prior to its sale to NuStar Energy. The facility has been used since 1928 for storage and dispensing of fossil fuels. Now the site houses an ExxonMobil Lube Plant that handles petroleum lubricating oils.

38.

Exxon also has a known joint venture with another carbon major, Petrobras,[28] which is responsible for gigatons of industrial CO_2e GH emissions from 1965-2023.

39.

Exxon is a major carbon emitter, and its concealment and misrepresentations about the dangers of its emissions, as well as its emissions in Oregon, are individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which Exxon is individually as well as jointly and severally liable to Plaintiff.

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[28] ExxonMobil, Petrobras and ExxonMobil Form Strategic Alliance, ExxonMobil (Dec. 14, 2017) https://corporate.exxonmobil.com/news/news-releases/2017/1214_petrobras-and-exxonmobil-form-strategic-alliance (last visited June 20, 2023).

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40.

Exxon engaged in an enterprise of misrepresentation about the effect its products would have on the climate, and that they could cause such an extreme heat event to occur. Exxon's misrepresentations and fraud were individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which Exxon is individually as well as jointly and severally liable to Plaintiff.

41.

Defendant, Shell PLC F.K.A. Royal Dutch Shell PLC is a public limited company registered in England and Wales, with its international headquarters in The Hague, Netherlands. Shell's headquarters for its U.S. operations is in Houston, Texas. Shell manages, directs, and controls its and its subsidiaries' policies and practices related to climate change and fossil fuel production. Shell is the seventh largest investor-owned greenhouse gas emitter.

42.

Defendant, Shell USA, Inc. is a corporation incorporated in Delaware, and headquartered at 1000 Main Street, Houston, Texas 77002. Shell USA can be served through its registered agent in Oregon.

43.

Defendant, Equilon Enterprises LLC dba Shell Oil Products US is an oil refiner and marketer incorporated in Delaware and with headquarters located at 910 Louisiana Street, Houston, Texas 77002. Equilon Enterprises LLC dba Shell Oil Products US sold over 39,348,691 mtCO_2e worth of fossil fuels in Oregon.

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44.

Together Defendants Shell PLC F.K.A. Royal Dutch Shell PLC, Shell USA, Inc, Equilon Enterprises LLC dba Shell Oil Products US, and any other subsidiaries and affiliate entities are collectively, "Shell."

45.

Shell has operations in over 70 countries, produces nearly 3.2 million barrels of oil equivalent per day, sold 64.2 million tons of liquefied natural gas (LNG) during 2021 and has interests in 10 refineries.[29] Like Exxon, Shell has billions in proven reserves. As of the end of December 2014, Shell boasted 13.7 billion barrels of oil equivalent.[30] Shell is registered with the SEC and is traded as RDSA. At the end of 2018, Shell reported $339.2 billion in assets.[31]

46.

Like Exxon, Shell is vertically integrated and is active in every area of the oil and gas industry, including exploration and production, refining, transport, distribution and marketing, petrochemicals (plastics), power generation and trading.[32]

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[29] Shell Global, Who We Are, SHELL PLC https://www.shell.com/about-us/who-we-are.html (last visited June 14, 2023).

[30] Shell Global, Recommended Cash and Share Offer for BG Group PLC by Royal Dutch Shell PLC, SHELL PLC (Apr. 8, 2015) https://www.shell.com/media/news-and-media-releases/2015/recommended-cash-and-share-offer-for-bg-group-plc.html (last visited June 14, 2023).

[31] Royal Dutch Shell PLC, Form 20-F Annual Report Pursuant to Section 13 or 15(d) of the Securities Exchange Act of 1934 (Mar. 14, 2019) https://shell.gcs-web.com/static-files/548074c8-9ff1-4e08-9c69-ffd2c081f875 (last visited June 14, 2023).

[32] Vertical integration is the merging together of two businesses that are at different stages of production—for example, a food manufacturer and a chain of supermarkets. Merging in this way with something further on in the production process (and thus closer to the final consumer) is

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47.

Shell branded gasoline was sold in Oregon through retail stations and wholesale distributors. Shell lubricants are sold through Christensen USA in Oregon.[33] Shell's website reflects at least 205 Shell gas stations in Oregon, with as many as 156 in the Multnomah County area as of June 22, 2023.[34]

48.

Shell owns "Pennzoil," "Quaker State" and "Jiffy Lube." Shell sells its engine oil and lubricants in Multnomah County, Oregon, and around the world. Shell claims to be the number one global lubricant supplier, delivering market-leading lubricants to consumers in over 100 countries.[35] Shell advertises, markets, and sells its products, including consumer products, in Multnomah County. Shell conducts substantial fossil fuel product business in Oregon and purposefully avails itself of the rights, obligations, and privileges of Oregon's laws.

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known as forward integration. The Economist, Vertical Integration, THE ECONOMIST (Mar. 20, 2019) https://www.economist.com/news/2009/03/30/vertical-integration (last visited June 18, 2023).

[33] Shell United States, Find a Shell Lubricants Dealer, Shell United States https://www.shell.us/business-customers/lubricants-for-business/lubricants-distributor-locator.html (last visited June 15, 2023); Christensen, Fuel Products, Lubricants, Partners, Christensen USA https://christensenusa.com/products/ (last visited June 15, 2023).

[34] Shell United States, Gas Station Near Me, SHELL UNITED STATES https://www.shell.us/motorist/gas-station-near-me (last visited June 14, 2023).

[35] Shell United States, Shell Engine Oils and Lubricants, SHELL UNITED STATES https://www.shell.com/motorist/oils-lubricants (last visited June 14, 2022).

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49.

Shell also has joint ventures with another carbon major, Gazprom,[36] which is responsible for substantial GHG emissions from 1965-2023. Shell also has known joint ventures with another carbon major, National Iranian Oil Company,[37] which is also responsible for substantial GHG emissions from 1965-2023.

50.

Shell also has known joint ventures with another carbon major, China Petroleum,[38] which is responsible for substantial GHG emissions from 1965-2023. Shell also has known joint ventures with another carbon major, Pemex,[39] which is responsible for substantial GHG emissions from 1965-2023.

51.

Shell also has a known joint venture with another carbon major, Abu Dhabi National Oil Company,[40] which is responsible for substantial GHG emissions from 1965-2023.

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[36] Reuter Staff, Gazprom, Shell to invest $13 billion in projects in Russia: Russian Energy Minister, Reuters (June 16, 2016) https://www.reuters.com/article/us-russia-forum-gazprom-shell/gazprom-shell-to-invest-13-billion-in-projects-in-russia-russian-energy-minister-idUSKCN0Z223G (last visited June 14, 2023).

[37] Tom DiChristopher, The Billion-Dollar Gold Rush to Tap into Iranian Oil, CNBC (Nov. 6, 2016) https://www.cnbc.com/2016/11/03/the-billion-dollar-gold-rush-to-tap-into-iranian-oil.html (last visited June 14, 2023).

[38] Offshore Energy, Shell, CNPC Form Well Manufacturing JV (The Netherlands), OFFSHORE ENERGY (Jun. 20, 2011) https://www.lngworldnews.com/shell-cnpc-form-well-manufacturing-jv-the-netherlands/ (last visited June 20. 2023).

[39] Oil & Gas Journal, Pemex to Acquire Interest in Shell Texas Refinery, OIL & GAS JOURNAL (Aug. 31, 1992) https://www.ogj.com/home/article/17218678/pemex-to-acquire-interest-in-shell-texas-refinery (last visited June 20. 2023).

[40] Abu Dhabi National Oil Company, Our Partners, ABU DHABI NATIONAL OIL COMPANY https://www.adnoc.ae/en/our-partners (last visited June 14, 2023).

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52.

Shell also has a known joint venture with another carbon major, Kuwait National Petroleum Corporation,[41] which is responsible for substantial GHG emissions from 1965-2023.

53.

Shell is a major carbon emitter, and its concealment and misrepresentations about the dangers of its emissions, as well as its emission in Oregon, are individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which Shell is individually and jointly and severally liable to Plaintiff.

54.

Shell has engaged in an enterprise of misrepresentation about the effect its products would have on the climate, and that they could cause such an extreme heat event to occur. Shell's misrepresentations and fraud were individually and collectively (with the other Defendants) a cause of harm to Plaintiff for which Shell is individually and jointly and severally liable to Plaintiff.

55.

Defendant, Chevron Corporation is incorporated in Delaware with its principal place of business in San Ramon, California. Chevron manages, directs, and controls its and its subsidiaries'

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[41] 360 Feed Wire, Kuwait Petroleum and Shell Sign Agreement for Long-Term Supply of LNG to Meet Domestic Energy Needs, OIL AND GAS 360 (Dec. 27, 2017) https://www.oilandgas360.com/wired-news-kuwait-petroleum-and-shell-sign-agreement-for-long-term-supply-of-lng-to-meet-domestic-energy-needs/ (last visited June 15, 2023).

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policies and practices related to climate change and fossil fuel production.[42] Chevron is a publicly traded corporation registered with the SEC and its symbol is "CVX."

56.

Chevron Corporation is an American multinational energy corporation. One of the successor companies of Standard Oil, it is headquartered in San Ramon, California, and active in more than 180 countries.

57.

Defendant, Chevron U.S.A. Inc. is a Pennsylvania corporation with its principal place of business in California. Chevron U.S.A. Inc. does business in Oregon and is the wholly owned subsidiary of Chevron Corporation.

58.

Chevron Corporation and Chevron U.S.A. Inc. are hereafter referred to as "Chevron."

59.

Like Exxon and Shell, Chevron is a fully integrated oil company, engaged in every aspect of the oil industry, including hydrocarbon exploration and production, refining, marketing, and transport; chemicals manufacturing and retail sales; plastics from petrochemicals and power generation.[43]

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[42] Richard Heede, Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854–2010, CLIMATIC CHANGE, (Nov. 22, 2013) https://link.springer.com/content/pdf/10.1007/s10584-013-0986-y.pdf (last visited June 15, 2023).

[43] Chevron, Our History, CHEVRON, https://www.chevron.com/about/history (last visited June 15, 2023).

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60.

Chevron sells the "Delo," "Ursa," "Havoline," "IsoClean" and "Techron" heavy duty diesel engine oils, coolants/antifreeze, transmission fluids, gear oils, greases and hydraulic oils in Multnomah County and Oregon.

61.

Chevron is one of the world's largest oil companies; as of 2017, it ranked nineteenth in the Fortune 500 list of the top U.S. closely held and public corporations and sixteenth on the Fortune Global 500 list of the top 500 corporations worldwide.[44] It was also one of the Seven Sisters that dominated the global petroleum industry from the mid-1940s to the 1970s.[45]

62.

According to its 2017 corporate disclosures, Chevron had $253.8 billion in total assets and 11.7 billion barrels in proven reserves.[46]

63.

Chevron markets and sells its products in Multnomah County and Oregon. Chevron conducts substantial fossil fuel product business in Oregon and purposefully avails itself of the rights, obligations, and privileges of Oregon's laws.

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[44] Fortune, Chevron|2022 Fortune 500, FORTUNE, https://fortune.com/company/chevron/fortune500/ (last visited June 15, 2023).
[45] Id.
[46] Chevron, 2017 Annual Report, CHEVRON (2018). https://www.chevron.com/-/media/chevron/annual-report/2017/2017-Annual-Report.pdf (last visited June 15, 2023).

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64.

Like Shell, Chevron partners with other carbon majors worldwide.

65.

Chevron also has known joint ventures with another carbon major, PDSVA,[47] which is responsible for substantial GHG emissions from 1965-2023. Chevron and BP also have known joint ventures with other carbon majors, Eni, Sonangol, and Total SA.[48] Eni is responsible for substantial GHG emissions from 1965-2023. Sonangol is responsible for substantial GHG emissions from 1965-2023. Total SA is responsible for substantial GHG emissions from 1965-2023. Chevron also has known joint ventures with Nigerian National Petroleum,[49] which is responsible for substantial GHG emissions from 1965-2023.

66.

Chevron is a major carbon emitter, and its concealment and misrepresentations about the dangers of its emissions, as well as its emissions in Oregon, are individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which Chevron is individually and

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[47] Chevron, Venezuela, CHEVRON, https://www.chevron.com/worldwide/venezuela. (last visited June 20. 2023); Abu Dhabi National Oil Company (ADNOC), ADNOC Signs Landmark Strategic Partnership Agreements with Eni and OMV in Refining and Trading, ABU DHABI NATIONAL OIL COMPANY (Jan. 27, 2019) https://www.adnoc.ae/en/news-and-media/press-releases/2019/adnoc-signs-landmark-strategic-partnership-agreements. (last visited June 15, 2023).

[48] NS Energy, EU clears Angolan LNG joint venture by BP, Chevron, Eni, Sonangol and Total, NS ENERGY (May 16, 2012) https://www.nsenergybusiness.com/news/newseu-clears-angolan-lng-joint-venture-by-bp-chevron-eni-sonangol-and-total-170512/ (last visited June 15, 2023).

[49] Chevron, Nigeria, CHEVRON, https://www.chevron.com/worldwide/nigeria (last visited June 15, 2023).

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jointly and severally liable to Plaintiff.

67.

Chevron engaged in an enterprise of misrepresentation about the effect its products would have on the climate, and that they could cause such an extreme heat event to occur. Chevron's misrepresentations and fraud were individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff.

68.

Defendant, BP PLC is a public limited company registered in England and Wales, with its international headquarters in London, England. The headquarters for BP's U.S. operations is in Houston, Texas. BP manages, directs, and controls its and its subsidiaries' policies and practices related to climate change and fossil fuel production. BP is the third largest investor-owned greenhouse gas emitter.

69.

Defendant, BP America, Inc., is incorporated in Delaware, and is headquartered at 501 Westlake Park Blvd, Houston, Texas 77079. BP America can be served through its registered agent in Oregon. BP PLC, and BP America, Inc., sell fossil fuel products in Oregon under BP West Coast Products, LLC according to Oregon Department of Environmental Quality.

70.

Defendant, BP Products North America, Inc., F.K.A. The American Oil Company, F.K.A. the AMOCO Oil Company, is a Maryland corporation registered to do business in Oregon. BP

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Products North America is described as one of the largest retailers of oil and gas in the United States, including Oregon and Multnomah County.

71.

Defendants BP PLC, BP America, Inc., BP West Coast Products, LLC, and BP Products North America, Inc. and all subsidiaries and affiliates are collectively referred to as "BP."

72.

BP is one of the world's seven oil and gas "supermajors" (including Exxon, Shell, Chevron, ConocoPhillips among others).[50] Like Exxon, Shell, and Chevron, BP is vertically integrated in both the production, refining and marketing of oil-based products.

73.

BP upstream activities include exploring for new oil and natural gas resources, developing access to such resources, and producing, transporting, storing, and processing oil.[51] In 2017, BP produced around 3.6 million barrels per day of oil equivalent,[52] of which 2.26 million barrels per day were liquids and 7.744 billion cubic feet was natural gas. In 2017, BP boasted reserves of

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[50] Tom Bergin, Oil Majors Output Grown Hinges On Strategy Shift, REUTERS (Aug. 1, 2008) https://www.reuters.com/article/us-oilmajors-production-idUSL169721220080801 (last visited June 15, 2023).

[51] Forbes, BP Company Overview & News, FORBES https://www.forbes.com/companies/bp/?sh=6e11aa61384b#41b79e1c384b (last visited June 15, 2023).

[52] BP, BP Annual Report and Form 20-F 2017, BP (2018) https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/investors/bp-annual-report-and-form-20f-2017.pdf (last visited June 15, 2023).

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18.441 million barrels per day of oil equivalent.[53]

74.

BP downstream activities include the refining, marketing, manufacturing, transportation, trading and supply of crude oil, petrochemicals and petroleum-based plastic and resin products.[54] BP's downstream operation is responsible for BP's fuels, lubricants and petrochemical businesses and has major operations located in Europe, North America, and Asia.[55]

75.

Castrol is BP's main brand for industrial and automotive lubricants and is applied to a large range of BP oils, greases and similar products for most lubrication applications, selling these products worldwide,[56] including in Multnomah County. BP has three refineries located in the US that represent about 40% of their global refining capacity.[57] BP markets petroleum products in more than 50 countries worldwide.[58] It has around 18,300 service stations.[59]

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[53] Id.
[54] Forbes, BP Company Overview & News, FORBES https://www.forbes.com/companies/bp/?sh=6e11aa61384b#41b79e1c384b (last visited June 15, 2023).
[55] Reuters, BP PLC Stock Price & Latest News, REUTERS https://www.reuters.com/markets/companies/BP.L (last visited June 15, 2023).
[56] BP, Castrol, BP https://www.bp.com/en/global/corporate/who-we-are/our-brands/castrol.html (last visited June 15, 2023).
[57] BP, Refineries, BP, https://www.bp.com/en_us/united-states/home/what-we-do/production-and-operations/refineries.html (last visited June 15, 2023).
[58] BP, BP Annual Report and Form 20-F 2017, BP (2018) https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/investors/bp-annual-report-and-form-20f-2017.pdf (last visited June 15, 2023).
[59] Id.

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76.

BP is registered with the SEC and is traded as "BP." On July 28, 2018, it was reported that BP has acquired a portfolio of unconventional oil and gas assets from BHP Billiton Petroleum (North America) for $10.5 billion.[60] BHP was also a member of API.[61] BP markets and sells its products in Multnomah County and Oregon. BP conducts substantial fossil fuel product business in Oregon and purposefully avails itself of the rights, obligations, and privileges of Oregon's laws.

77.

As of February 27, 2022, BP held 19.75% of the shares of Rosneft Oil Company (OTC: OJSCY).[62] Rosneft serves as the leader of Russia's petroleum industry and remains the world's largest publicly traded petroleum company. BP and Rosneft have a joint-venture agreement to develop prospective resources in East and West Siberia. Rosneft is responsible for substantial GHG emissions from 1965-2023.

78.

BP, along with China Petroleum and Basra Oil Company, are working in partnership to develop Rumaila, an oil field in Iraq and the third-largest producing field in the world, estimated

[60] Sonali Paul and Ron Bousso, BP pays $10.5 billion for BHP shale assets to beef up U.S. business, REUTERS (Jul. 26, 2018) https://www.reuters.com/article/us-bhp-divestiture-bp-idUSKBN1KG34V (last visited June 15, 2023).

[61] BHP, Industry Associations 2019 Review: Second Update, BHP (2019) https://www.bhp.com/about/operating-ethically/industry-associations/2019-review-second-update (last visited June 15, 2023).

[62] BP, BP to Exit Rosneft Shareholding, BP (Feb. 27, 2022) https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-to-exit-rosneft-shareholding.html (last visited June 15, 2023).

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to have around 17 billion barrels of recoverable oil remaining.[63] BP is also providing technical assistance to the North Oil Company to aid the redevelopment of the Kirkuk field in Iraq. Kirkuk is estimated to have around 9 billion barrels of recoverable oil remaining. Basra Oil Company and North Oil Company are two of the nine companies that are owned by the Iraq National Oil Company,[64] another carbon major which is responsible for substantial GHG emissions from 1965-2023.

79.

BP also has known joint ventures with another carbon major, Sonatrach.[65]

80.

BP is a major carbon emitter, and its concealment and misrepresentations about the dangers of its emissions, as well as its emissions in Oregon, are individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff.

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[63] BP, What We do, Iraq, Reviving One of the World's Super-giant Oilfields, BP https://www.bp.com/en/global/corporate/what-we-do/bp-worldwide/bp-in-iraq.html (last visited June 15, 2023).

[64] Reuters, Iraq transfers ownership of nine state oil companies to new National Oil Company, REUTERS, (Oct. 18, 2018, 10:18 AM), https://www.reuters.com/article/us-iraq-oil/iraq-transfers-ownership-of-nine-state-oil-companies-to-new-national-oil-company-idUSKCN1MS27E (last visited June 15, 2023).

[65] BP, BP Has a Long History of Working in Algeria, BP https://www.bp.com/en/global/corporate/what-we-do/bp-worldwide/bp-in-algeria.html (last visited June 15, 2023).

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81.

BP has engaged in an enterprise of misrepresentation about the effect its products would have on the climate, and that they could cause such an extreme heat event to occur. BP's misrepresentations and fraud were individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff.

82.

Defendant, ConocoPhillips is incorporated in Delaware, with its principal place of business in Houston, Texas. ConocoPhillips manages, directs, and controls its and its subsidiaries' policies and practices related to climate change and fossil fuel production.

83.

ConocoPhillips is the world's largest independent pure-play exploration and production company ranking No. 77 in the 2022 Fortune 500 list of the largest United States corporations by total revenue.[66] ConocoPhillips is the fifth largest investor-owned greenhouse gas emitter.[67]

84.

Like Exxon, Shell, Chevron and BP, ConocoPhillips is a fully integrated oil company. ConocoPhillips was created through the merger of American oil companies Conoco

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[66] Fortune, Fortune 500 List, FORTUNE https://fortune.com/fortune500/ (last visited June 15, 2023).
[67] Paul Griffin, The Carbon Majors Database CDP Carbon Majors Report 2017, CDP (Jul. 2017) https://cdn.cdp.net/cdp-production/cms/reports/documents/000/002/327/original/Carbon-Majors-Report-2017.pdf?1501833772 (last visited June 15, 2023).

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Inc. and Phillips Petroleum Co. on August 30, 2002.[68] In 2012, ConocoPhillips spun off its downstream assets as a new, separate company, Phillips 66.[69]

85.

Phillips 66 is the fourth-largest lubricants supplier in the United States. Phillips 66 claims that, with its world-class research and development facilities and eight proprietary blending and packaging facilities, Phillips 66 lubricants are sold in more than 80 countries, including the United States under the brands of "Phillips 66," "Red Line" and "Kendall."[70]

86.

ConocoPhillips participates in chemicals and plastics production worldwide through a 50 percent interest in Chevron Phillips Chemical Company LLC (CPChem), one of the world's largest producers of olefins, polyolefins, aromatics and styrenics, piping, and proprietary plastics.[71]

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[68] ConocoPhillips, Form 8-K12G3, (Aug. 30, 2002), http://edgar.secdatabase.com/2323/89882202001082/filing-main.htm (last visited June 15, 2023).

[69] Christopher Helman, As ConocoPhillips Spins Off Refining Assets, Think Twice Before Buying The New Phillips 66, FORBES, (Apr. 30, 2012), https://www.forbes.com/sites/christopherhelman/2012/04/30/as-conocophillips-spins-off-refining-assets-should-you-own-the-new-phillips-66/?sh=230ec05b4eb7 (last visited June 15, 2023).

[70] Id.

[71] New York Encyclopedia, ConocoPhillips, NEW YORK ENCYCLOPEDIA, https://www.newworldencyclopedia.org/entry/ConocoPhillips (last visited June 15, 2023).

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87.

As of 2014, CP Chem has 5,000 employees worldwide, $9 billion in assets, and 36 manufacturing and research facilities in eight countries, including the United States, Belgium, China, Colombia, Qatar, Saudi Arabia, Singapore, and South Korea.[72]

88.

ConocoPhillips is registered with the SEC and is traded as "COP." ConocoPhillips markets and sells its products in Multnomah County and Oregon. ConocoPhillips conducts substantial fossil fuel product business in Oregon and purposefully avails itself of the rights, obligations, and privileges of Oregon's laws.

89.

ConocoPhillips is a major carbon emitter, and its concealment and misrepresentations about dangers of its emissions, as well as its emissions in Oregon. are individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff, for which it is individually and jointly and severally liable to Plaintiff.

90.

ConocoPhillips has engaged in an enterprise of misrepresentation about the effect its products would have on the climate, and that they could cause such an extreme heat event to occur. ConocoPhillips's misrepresentations and fraud were individually and collectively (with the other

[72] Chevron Phillips Chemical, Who We Are, CHEVRON PHILLIPS CHEMICAL, https://www.cpchem.com/who-we-are/company-history (last visited June 15, 2023).

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Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff.

91.

Defendant, Motiva Enterprises, LLC ("Motiva") is a wholly owned subsidiary of Saudi Arabia Refining Company ("Aramco"). Motiva has an interest in a joint-venture partnership with Shell and Texaco known as Motiva Enterprises, LLC, which refines and markets petroleum products in the eastern and Gulf Coast areas of the United States under the Texaco and Shell brands. Motiva Enterprises, LLC, is a fully owned affiliate of Aramco and is headquartered in Houston, Texas.[73]

92.

State-owned Saudi Aramco is one of the world's largest petrochemical companies, with 2018 sales of almost $356 billion. In 2019, Aramco announced plans to invest $15 billion to acquire a 20% stake in a Reliance Industries Ltd. unit that includes one of the world's largest polypropylene businesses.[74]

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[73] Aramco, Saudi Aramco and Shell Finalize Agreement to Separate Motiva Assets, ARAMCO (Mar. 7, 2017) https://www.aramco.com/en/news-media/news/2017/motiva-shell-aramco-separation (last visited June 15, 2023).

[74] Frank Esposito, Saudi Aramco continues growth with Texas acquisition, (Aug. 21, 2019, 1:25 PM), PLASTIC NEWS EUROPE, https://www.plasticsnews.com/news/saudi-aramco-continues-buying-spree-flint-hills-feedstocks-site-texas (last visited June 15, 2023).

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93.

In March, Aramco paid a little more than $69bn (€61bn) for a 70% stake in global commodity and engineering resins supplier Saudi Basic Industries Corp.[75] Saudi Aramco also has partnered with Dow Inc. on the Sadara plastics and petrochemicals joint venture in Saudi Arabia.

94.

In 2017, Aramco purchased Motiva Enterprises, LLC from Co-Defendant Shell, including the Port Arthur, Texas refinery and the right to sell Shell branded gasoline and diesel in numerous US states, including Oregon.

95.

SABIC (Saudi Arabia Basic Industries Corporation) is a public petrochemical company founded in 1976 and based in Riyadh, Saudi Arabia. SABIC is 70% owned by Aramco.[76]

96.

SABIC is active in chemicals and intermediates, industrial polymers, fertilizers, and metals. SABIC is the world's third-largest producer of polyethylene and the fourth-largest

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[75] On March 27, 2019, SABIC announced that state-owned energy company Saudi Aramco signed a share purchase agreement to acquire a 70% majority stake in SABIC from the Public Investment Fund of Saudi Arabia in a private transaction worth $69.1 billion. Aramco, Saudi Aramco Signs Share Purchase Agreement to Acquire 70% Majority Stake in SABIC from the Public Investment Fund of Saudi Arabia, ARAMCO (Mar. 27, 2019) https://www.aramco.com/en/news-media/news/2019/aramco-sabic (last visited June 15, 2023).

[76] Bloomberg, Saudi Basic Industries Corp. (SABIC: Saudi Arabia): Stock Quote & Company Profile - Businessweek, BLOOMBERG, https://www.bloomberg.com/quote/SABIC:AB?leadSource=uverify%20wall (last visited June 15, 2023).

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producer of polypropylene and polyolefins in general.[77] The company operates in more than 40 countries across the world, has 60 manufacturing sites and employs over 40,000 people. According to Forbes, SABIC generated about $35 billion in sales in 2017.[78]

97.

Motiva's products include diesel, gasoline, liquefied petroleum gas (LPG), aviation fuel, and lubricants, which are supplied to American states in the South, Mid-Atlantic, and the Northeast. Marketing outlets include 5200 Shell and 76-branded service stations, and 24 storage and distribution terminals.

98.

Motiva is registered to do business in Oregon. Motiva markets and sells its products in Oregon through its joint ventures with co-Defendants. Motiva conducts substantial fossil fuel product business in Oregon and purposefully avails itself of the rights, obligations, and privileges of Oregon's laws.

99.

Parent company Aramco is the world's largest contributor GHG and is responsible for substantial GHG emissions from 1965-2023.

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[77] Plastics Technology, Top 10 Largest Plastic Producing Companies, PLASTICS TECHNOLOGY https://www.plastics-technology.com/articles/top-largest-plastic-producing-companies (last visited June 15, 2023).

[78] Forbes, Saudi Basic Industries, Company Overview & News, FORBES, https://www.forbes.com/companies/saudi-basic-industries/#2aa3a7a073dc (last visited June 15, 2023).

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100.

Motiva is a major carbon emitter, and its concealment and misrepresentations about the dangers of its emissions, as well as its emissions in Oregon, are individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff.

101.

Motiva engaged in an enterprise of misrepresentation about the effect its products would have on the climate, and that they could cause such an extreme heat event to occur. Motiva's misrepresentations and fraud were individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff.

102.

Defendant, Occidental Petroleum F.K.A. Anadarko Petroleum Corp. (Anadarko) is an American Petroleum and natural gas exploration company headquartered in The Woodlands, Texas. Anadarko is ranked 257th on the Fortune 500[79] and is registered with the SEC and is traded

[79] Fortune 500, Anadarko Petroleum, FORTUNE, https://fortune.com/fortune500/2016/anadarko-petroleum/ (last visited June 15, 2023).

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as APC.

103.

Anadarko, in addition to exploration and production, engages in petroleum and natural gas gathering, processing, treating, and transportation. The company also participates in the hard minerals business through its ownership of non-operated joint ventures and royalty arrangements.

104.

As of December 31, 2018, the company had approximately 1.473 billion barrels of oil equivalent of proved reserves, 45% of which was oil reserves, 37% of which was natural gas, and 18% was natural gas liquids. In 2018, the company produced 666 thousand barrels of oil equivalent per day.[80]

105.

In 2019, Anadarko was acquired by Occidental Petroleum.

106.

Anadarko operates in the upstream, midstream, and downstream marketing of its oil-based

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[80] U.S. Securities and Exchange Commission, Anadarko Petroleum Corporation 2018 Form 10-K Annual Report, U.S. SECURITIES AND EXCHANGE COMMISSION, https://www.sec.gov/Archives/edgar/data/773910/000077391019000009/apc201810k-10k.htm (last visited June 15, 2023).

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products, including plastics.[81]

107.

The company's international operations accounted for 14% of total sales volumes during 2018 and 12% of total proved reserves at year-end 2018. The company has holdings in Algeria, Ghana, Mozambique, Colombia, and The Ivory Coast among others.[82]

108.

Anadarko markets and sells consumer products[83] worldwide, including in Oregon. Anadarko conducts substantial fossil fuel product business in Oregon and purposefully avails itself of the rights, obligations, and privileges of Oregon's laws.

109.

Anadarko is a major carbon emitter, and its concealment and misrepresentations about the dangers of its emissions, as well as its emissions in Oregon, are individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff.

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[81] Business Wire, Occidental Completes Acquisition of Anadarko, BUSINESS WIRE (Aug. 8, 2019, 11:21 AM) https://www.businesswire.com/news/home/20190808005586/en/Occidental-Completes-Acquisition-of-Anadarko (last visited June 15, 2023).

[82] Fortune 500, Anadarko Petroleum, FORTUNE, https://fortune.com/fortune500/2016/anadarko-petroleum/ (last visited June 15, 2023).

[83] Forbes, Anadarko Petroleum, FORBES https://www.forbes.com/companies/anadarko-petroleum/?sh=40dcb73c468c (last visited June 15, 2023).

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110.

Anadarko engaged in an enterprise of misrepresentation about the effect its products would have on the climate, and that they could cause such an extreme heat event to occur. Anadarko's misrepresentations and fraud were individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff.

111.

Defendant, Valero Energy Corporation, ("Valero") is a corporation organized under the laws of the state of Delaware, with its principal place of business at One Valero Way, in San Antonio, Texas.

112.

Valero Energy Corporation is the world's largest independent petroleum refiner. Through its subsidiaries, Valero Energy Corporation owns 15 petroleum refineries in the United States, Canada, and the United Kingdom which generate total throughput capacity of approximately 3.2 million barrels per day. Valero Energy Corporation and its subsidiaries supply approximately 7,000 independently owned fuel outlets carrying its family of brands in the United States, Canada, the U.K., Ireland, and Mexico, as well as rack and bulk markets in those countries and Peru.[84]

[84] Valero, Our History Advancing the Future of Energy Through the Years https://www.valero.com/about/our-history (last visited June 18, 2023).

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113.

Valero Energy Corporation determines and directs marketing, production, and/or distribution of fossil fuel products for itself and its subsidiaries in Oregon. Additionally, Valero Energy Corporation directs policy and procedures for itself and its subsidiaries regarding the marketing, advertising, climate change, and greenhouse gas emissions from fossil fuel products, and communications strategies concerning climate change and the link between fossil fuel use and climate-related impacts on the environment and communities.

114.

Valero Energy Corporation subsidiary, Valero Marketing and Supply Company, has been registered to do business in Oregon and has had a designated agent for service of process in Oregon from 1999 to the present. Valero Energy Corporation subsidiary, Valero Payment Services Company, has been registered to do business in Oregon and has had a designated agent for service of process in Oregon from 2015 to the present. Valero Energy Corporation subsidiary, Valero Refining Company-California, has been registered to do business in Oregon and has had a designated agent for service of process in Oregon from 2000 to the present.

115.

At times relevant herein, Valero Energy Corporation, individually, and through one or more of its subsidiaries, sold fossil fuel products including fuels, engine oils, lubricants, and/or greases at several gas stations owned and/or operated in Oregon including but not limited to stations located in the Oregon cities of Ashland, Bend, Eugene, Klamath Falls, and Medford. Valero Energy Corporation and the subsidiaries it controls conduct substantial fossil fuel product business in Oregon and purposefully avails itself of the rights, obligations, and privileges of Oregon's laws.

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116.

Valero is a major carbon emitter, and its concealment and misrepresentations about the dangers of its emissions, as well as its emissions in Oregon, are individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff.

117.

Valero engaged in an enterprise of misrepresentation about the effect its products would have on the climate, and that they could cause such an extreme heat event to occur. Valero's misrepresentations and fraud were individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff. Valero Energy Company refused to disclose the truth about the nature and degree to which its fossil fuel products, and those of the subsidiaries it controls, could super heat and thereby harm Multnomah County. This Defendant's deception is individually and collectively (with the other Defendants) a cause of enormous harm to the Plaintiff for which the Defendant is individually and jointly and severally liable to Plaintiff.

118.

Defendant, Koch Industries, Inc., ("Koch") is a corporation organized and existing under the laws of the State of Kansas with its headquarters located in Wichita, Kansas. Koch is the second largest privately held company in the United States and earned more than $120 billion in revenue

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in 2022.[85]

119.

Koch Industries, Inc. consists of multiple subsidiaries and affiliates, many of which are and have been involved in the exploration, extraction, production, manufacturing, refining, distribution, and/or marketing of petroleum products. Those subsidiaries unnamed in this Second Amended Complaint are DOES 1-25.

120.

One such subsidiary, Flint Hills Resources LP, formerly known as Koch Petroleum Group, is a wholly owned subsidiary of Koch Industries which sells gasoline, diesel, jet fuel, ethanol, polymers, intermediate chemicals, base oils, and asphalt. It operates refineries with a combined crude oil processing capacity of more than 700,000 barrels per day.[86] Additionally, it transports petroleum products through a network of over 4,000 miles of pipeline.[87]

121.

Koch Industries, Inc. has a substantial presence in the State of Oregon. According to the company website, Koch Industries, Inc. accounts for 1,617 jobs and $148,591,526 in wages and benefits in the State of Oregon.[88] One of its wholly owned subsidiaries, Georgia Pacific, has 4

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[85] Murphy, A., America's Largest Private Companies Forbes (December 1, 2022) https://www.forbes.com/lists/largest-private-companies/?sh=4d6a7d9cbac4 (last visited on June 18, 2023).
[86] Flint Hills Resources, The Rewards of Refining, https://www.fhr.com/products-services/fuels-and-aromatics (last visited on June 18, 2023).
[87] Id.
[88] Koch Industries, Driving Change Around the World – Locations https://www.kochind.com/about/locations (last visited on June 18, 2023).

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locations in Oregon, including one in Multnomah County, which account for total combined compensation and benefits, including direct and indirect jobs, of $450,000,000, and capital investments and acquisitions in Oregon since 2013 valued at $746,000,000.[89]

122.

Several Koch Industries, Inc. subsidiaries, including the petroleum refining, distributing, and transporting subsidiary, Flint Hills Resources LP, are registered to do business in the State of Oregon. Flint Hills Resources LP and its predecessor entities have been registered to do business in Oregon from 1995 to the present.

123.

Koch Industries, Inc. controls and has controlled companywide decision making about the amount and scope of its fossil fuel production and sales, including those of its subsidiaries. Koch Industries, Inc. determines and directs marketing, production, and/or distribution of fossil fuel products by its subsidiaries. Additionally, Koch Industries, Inc. controls and has controlled companywide decision making on matters including but not limited to marketing, advertising, climate change, and greenhouse gas emissions from its fossil fuel products, and communications strategies concerning climate change and the link between fossil fuel use and climate-related impacts on the environment and communities, on behalf of itself and its subsidiaries.

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[89] Georgia Pacific Our Locations https://www.gp.com/about-us/locations/oregon/ (last visited on June 18, 2023).

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124.

Defendant Koch Industries, Inc. and its predecessors, successors, parents, subsidiaries, affiliates, and/or divisions, are collectively referred to herein as "Koch."

125.

Koch is responsible for providing funding to many front groups, including the Heartland Institute, which has propagated false and misleading denials and downplays of the causal relationship between carbon pollution and extreme climate change in Oregon. Koch is alleged to have provided over $127 million to front groups whose role was to attack climate change science from 1997 to 2017.

126.

At times relevant herein, Koch, through one or more of its subsidiaries, sold fossil fuel products including fuels, engine oils, lubricants, and/or greases at several gas stations owned and/or operated in Oregon. Upon information and belief, Koch, and the subsidiaries it controls. conduct substantial fossil fuel product business in Oregon and Koch purposefully avails itself of the rights, obligations, and privileges of Oregon's laws.

127.

Koch is a major carbon emitter, and its concealment and misrepresentations about the dangers of its emissions, as well as its emissions in Oregon, are individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff.

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128.

Koch engaged in an enterprise of misrepresentation about the effect its products would have on the climate, and that they could cause such an extreme heat event to occur. Koch's misrepresentations and fraud were individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff. Koch refused to disclose the truth about the nature and degree to which its fossil fuel products, and those of the subsidiaries it controls, could super heat and thereby harm Multnomah County. Instead, Koch has funded a concerted effort to deceive the public through climate change denial campaigns. Koch's deception is individually and collectively (with the other Defendants) a cause of enormous harm to the Plaintiff for which the Defendant is individually and jointly and severally liable to Plaintiff.

129.

Defendant, TotalEnergies Marketing USA, Inc., is a wholly owned subsidiary of TotalEnergies, S.E. and/or its predecessor Total S.A. and, at times relevant herein, marketed, distributed, and sold the fossil fuel products of TotalEnergies, S.E. and/or its predecessor Total S.A.

130.

Defendant, TotalEnergies Marketing USA, Inc., f/k/a Total Specialties USA Inc., f/k/a Total Lubricants USA, Inc., f/k/a Total Fina ELF Lubricants USA, Inc., f/k/a ELF Lubricants North America, Inc., is and/or has been registered to do business in the State of Oregon and has and/or previously had designated an agent for service of process in Oregon.

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131.

Total Specialties USA Inc. does substantial fossil fuel product-related business in Oregon, and a substantial portion of its fossil fuel products are transported, distributed, marketed, and/or sold in Oregon. For instance, TotalEnergies Marketing USA, Inc., maintains regular sales or distribution relationships with Oregon distributors and sellers of Total fossil fuel products, including engine oils, lubricants, greases, and/or industrial petroleum products.

132.

Defendants TotalEnergies Marketing USA, Inc., and its predecessors, successors, parents, subsidiaries, affiliates, and divisions, are collectively referred to herein as “Total.”

133.

Total’s Oregon distributors or sellers include, but are not necessarily limited to, Mighty Auto Parts, which maintains one or more retail stores in Oregon, and Advance Auto Parts, which maintains several retail stores in Oregon, including multiple retail stores in Multnomah County. TotalEnergies Marketing USA, Inc., conducts substantial fossil fuel product business in Oregon and purposefully avails itself of the rights, obligations, and privileges of Oregon’s laws.

134.

Total is a major carbon emitter, and its concealment and misrepresentations about the dangers of its emissions, as well as its emissions in Oregon, are individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff.

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135.

Total engaged in an enterprise of misrepresentation about the effect its products would have on the climate, and that they could cause such an extreme heat event to occur. Total's misrepresentations and fraud were individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff. Total refused to disclose the truth about the nature and degree to which its fossil fuel products, and those of the subsidiaries it controls, could super heat and thereby harm Multnomah County. This Defendant's deception is individually and collectively (with the other Defendants) a cause of enormous harm to the Plaintiff for which the Defendant is individually and jointly and severally liable to Plaintiff.

136.

Defendant, Marathon Oil Corporation is incorporated under the laws of the State of Delaware with its corporate headquarters and principal place of business located in the Marathon Oil Tower in Houston, Texas.

137.

Marathon Oil Corporation consists of multiple subsidiaries and affiliates involved in the exploration, extraction, production, and marketing of fossil fuel products. As of December 31, 2020, the company had 972 million barrels of oil equivalent of estimated proven reserves. In 2020, the company sold 383 thousand barrels of oil equivalent per day.[90]

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[90] Marathon Oil Corporation Form 10-K, December 31, 2020

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138.

Defendant, Marathon Oil Company is an energy company incorporated in the State of Ohio with its principal place of business in Houston, Texas. Marathon Oil Company is a wholly owned subsidiary and/or corporate ancestor of Marathon Oil Corporation which acts on Marathon Oil Corporation's behalf and subject to Marathon Oil Corporation's control.

139.

Marathon Oil Corporation subsidiary, Marathon Oil Company, has been registered to do business in Oregon and has had a designated agent for service of process in Oregon from 1982 to the present.

140.

Defendant, Marathon Petroleum Corporation was a wholly owned subsidiary of Marathon Oil Corporation until was spun off from the operations of Marathon Oil Corporation in 2011.[91] Marathon Petroleum is a company organized and existing under the laws of the state of Delaware with its principal place of business in Findlay, Ohio.

141.

Marathon Petroleum Corporation operates the nation's largest refining system, with a crude oil refining capacity of approximately 2.9 million barrels per day from 13 refineries across the

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https://www.sec.gov/ix?doc=/Archives/edgar/data/101778/000010177821000018/mro-20201231.htm (last visited on June 18, 2023).

[91] Marathon Landing Page, Announcement that Marathon Oil and Marathon Petroleum Corporation are separate entities as of 2011, https://www.marathon.com/ (last visited on June 18, 2023).

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United States, including Anacortes, Washington.[92]

142.

Marathon Petroleum Corporation owns the general partner and majority limited partner interest in MPLX LP, a midstream company that owns and operates gathering, processing, and fractionation assets, as well as crude oil and light product transportation and logistics infrastructure.[93] MPLX LP subsidiary, Marathon Pipe Line LLC, operates pipelines, storage tanks, and marine facilities across the country, including a pipeline called the "Boise – Pasco 8"-6" Products" pipeline which runs through northeastern Oregon.[94]

143.

Marathon Petroleum Corporation maintains a coast-to-coast retail network of gas stations where Marathon Petroleum Corporation products are sold, including Marathon branded stations as well as stations bearing the ARCO brand which Marathon Petroleum Corporation acquired in 2018.[95] There are currently 41 ARCO stations in the State of Oregon, several of which are in Multnomah County.[96]

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[92] Marathon, Nation's Largest Refiner, MPC Refinery Locations in the US, https://www.marathonpetroleum.com/Operations/Refining/ (last visited on June 18, 2023).

[93] Marathon Petroleum Corporation, We are MPC - About Us, https://www.marathonpetroleum.com/About/ (last visited on June 18, 2023).

[94] Marathon Petroleum Corporation, Coast to Coast Retail Network https://www.marathonpetroleum.com/Operations/Retail/ (last visited on June 18, 2023).

[95] ARCO, Gas Station Locations https://www.arco.com/en-us/northwest/find-a-station/multnomah%20county,%20OR/ (last visited on June 18, 2023); Number of gas Stations in the United States in 2023, https://www.scrapehero.com/location-reports/ARCO-USA/ (last visited on June 18, 2023).

[96] Id.

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144.

Marathon Petroleum Corporation was registered to do business in Oregon from 1982 until on or after 2017 and has had a designated agent for service of process in Oregon from 1982 to the present. Marathon Petroleum Corporation subsidiary, Marathon Pipeline LLC has been registered to do business in Oregon and has had a designated agent for service of process in Oregon from 2019 to the present.

145.

Defendants Marathon Oil Corporation, Marathon Oil Company, and Marathon Petroleum Corporation and their predecessors, successors, parents, subsidiaries, affiliates, and divisions are collectively referred to herein as ("Marathon").

146.

Marathon conducts substantial fossil fuel product business in Oregon and purposefully avails itself of the rights, obligations, and privileges of Oregon's laws.

147.

According to the Oregon Department of Environmental Quality, Marathon is responsible for 46,231,812 metric tons of CO_2 e from 2010 to 2022 in Oregon.

148.

Marathon's public statements and proclamations made in furtherance of its campaign of deception and denial, and its repeated failure to warn the public and consumers of global warming-related hazards when it marketed, advertised, and sold its products, were intended to conceal, and mislead the public and consumers about the serious adverse consequences from continued use of Marathon's products. Said conduct was intended to reach and influence Multnomah County, as

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well as its residents, among others, to continue the unabated use of Defendants' fossil fuel products, resulting in Multnomah County's injuries.

149.

Marathon is a major carbon emitter, and its concealment and misrepresentations about the dangers of its emissions, as well as its emissions in Oregon, are individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff.

150.

Marathon engaged in an enterprise of misrepresentation about the effect its products would have on the climate, and that they could cause such an extreme heat event to occur. Marathon's misrepresentations and fraud were individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff. Marathon refused to disclose the truth about the nature and degree to which its fossil fuel products, and those of the subsidiaries it controls, could super heat and thereby harm Multnomah County. This Defendant's deception is individually and collectively (with the other Defendants) a cause of enormous harm to the Plaintiff for which the Defendant is individually and jointly and severally liable to Plaintiff.

151.

Defendant, Space Age Fuel, Inc. was organized under the laws of Oregon in 1982. Its principal place of business is 15525 SE For Mor Ct, Clackamas, OR 97015. Space Age Fuel, Inc. is a resident of the State of Oregon and purposefully avails itself of the rights, obligations, and privileges of the laws of Oregon.

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152.

Space Age Fuel is a fossil fuel marketer, and retail distributor in the Northwest United States including Oregon.

153.

Space Age Fuel owns a retail chain of fuel and convenience stores. Space Age Fuel operates predominately under the Space Age brand along with the Exxon and Union 76 brands.[97]

154.

Over the years Space Age Fuel Inc. has experienced rapid growth. Space Age Fuel Inc. is one of the largest independent marketers in the State of Oregon.

155.

Space Age Fuel consists of four divisions which are the company operated stations, commercial sales accounts, commercial freight deliveries and home heating oil deliveries. Currently Space Age Fuel currently operates nine truck and trailers in the Pacific Northwest.

156.

Space Age Fuel delivers its own fossil fuel and the fossil fuel of others in the state of Oregon. Space Age Fuel currently operates twenty-one locations and supplies another 60 retail and wholesale fueling facilities.

157.

Space Age Fuel also transports fuel for other Petroleum companies when the need arises.

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[97] Space Age, Retail, http://spaceagefuel.com/retail/ (last visited on June 18, 2023).

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Space Age Fuel sells both unbranded and branded products. Space Age Fuel's branded products are with Exxon and ConocoPhillips.

158.

During the years 2010 through 2022, Space Age Fuel contributed 8,194,765 metric tons of CO_2 greenhouse gas emissions in Oregon.[98] These numbers were self-reported to the Oregon Department of Environmental Quality.

159.

Space Age Fuel is a major carbon emitter, and its concealment and misrepresentations about the dangers of its emissions, as well as its emissions in Oregon, are individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff.

160.

Space Age Fuel engaged in an enterprise of misrepresentation about the effect its products would have on the climate, and that they could cause such an extreme heat event to occur. Space Age Fuel's misrepresentations and fraud were individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff. Space Age Fuel refused to disclose the truth about the nature and degree to which its fossil fuel products, and those of the subsidiaries it controls, could super heat and thereby harm Multnomah County. This Defendant's deception is individually and collectively

[98] Fuel Suppliers, 2010 – 2021 – Greenhouse Gas Emissions From Fuel Use, Oregon DEQ, https://www.oregon.gov/deq/ghgp/Pages/GHG-Emissions.aspx (last visited June 13, 2023).

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(with the other Defendants) a cause of enormous harm to the Plaintiff for which the Defendant is individually and jointly and severally liable to Plaintiff.

2. Gas Defendants

161.

Defendant, NW Natural F.K.A. Northwest Natural Gas Company ("NW Natural") is a publicly traded gas distributor incorporated in Portland, Oregon with its principal place of business in Portland, Oregon. NW Natural is the largest provider of gas to Western Oregon and Southwest Washington in the Pacific Northwest serving approximately two million people.

162.

Northwest Natural Holding Company is headquartered in Portland, Oregon and owns NW Natural. NW Natural Holdings Company is listed on the New York Stock Exchange (NWN).[99] NW Natural is Oregon's oldest and largest fossil fuel company, in terms of revenue and volumes of energy supplied. It was

163.

NW Natural contends that it is responsible as a single company for at least 9% of Oregon's emissions. Between the years 2010 to 2022, NW Natural contributed 72,145,570 metric tons of CO_2 greenhouse gas emissions in Oregon.[100]

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[99] Nasdaq, Northwest Natural Holding Company Common Stock, at https://www.nasdaq.com/market-activity/stocks/nwn (last visited August 28, 2024).

[100] Natural Gas Suppliers, 2010 – 2022 – Greenhouse Gas Emissions From Natural Gas Suppliers, Oregon DEQ, https://www.oregon.gov/deq/ghgp/Documents/ghgNatGasEms.xlsx (last visited August 23, 2023).

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164.

NW Natural is a major carbon and methane emitter, and its concealment and misrepresentations about the dangers of its emissions, as well as its emissions in Oregon, are individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff.

165.

NW Natural engaged in an enterprise of misrepresentation about the effects its products would have on the climate, and that the use of its products could cause an extreme heat event to occur. NW Natural's misrepresentations and fraud were individually and collectively (with the other Defendants) a cause of enormous harm to Plaintiff for which it is individually and jointly and severally liable to Plaintiff. NW Natural refused to disclose the truth about the nature and degree to which its fossil fuel products, and those of the subsidiaries it controls, could super heat and thereby harm Multnomah County. This Defendant's deception is individually and collectively (with the other Defendants) a cause of enormous harm to the Plaintiff for which the Defendant is individually and jointly and severally liable to Plaintiff.

166.

These Oil and Gas Defendants' (also called "Fossil Fuel Defendants") failures and/or refusals to warn Plaintiff about the climate impact of their fossil fuel activities were individually and collectively (with the other Defendant groups) a cause of the County's damages from extreme heat events, wildfires, and droughts described herein.

167.

The Oil and Gas Defendants listed above are collectively responsible for a substantial

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portion of all GHG emissions from 1965-2023, as well as in Oregon. Their direct emissions from their industry activities and end use of their product led to the County's harm.[101]

168.

Decades ago, the Fossil Fuel Defendants knew that their fossil fuel activities would substantially contribute to a dramatic rise in the concentration of GHG in the atmosphere and that the concentration of GHG in the atmosphere would lead to significant temperature changes, which would, in turn, lead to changes in the global climate, such as the increased frequency and intensity of extreme weather-related events like the heat dome and wildfires. They knew and should have known that immediate and sustained reductions in carbon pollution from their products were required to avoid a new normal of fossil fuel-induced climate catastrophes. However, Defendants knowingly concealed and misrepresented the climate impacts of their fossil fuel products and engaged in a sophisticated disinformation campaign to cast doubt on the science, causes, and effects of climate change, to increase fossil fuel consumption, thereby increasing greenhouse gas emissions. Had the Defendants *told the truth*, consumption would have decreased, along with emissions. Moreover, had Defendants disclosed that because of the mass consumption of Defendants' fossil fuel products, regions like Multnomah County would imminently experience high temperatures for a sustained period more than *35 ᵒ F* above normal, including highs of 116 degrees F in June, an environmentally conscious community and leadership structure like that in the County would have *been able to prepare* for such an extreme to occur now. The Defendants

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[101] Id.

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knew and foresaw that which the County did not: The climate change that the Defendants were causing did not just include the melting of distant ice caps, stranding of polar bears, rising of sea levels, and the diminishment of Greenland, but rather, could heat and smoke choke the County to a degree that was deadly to many of its inhabitants and unparalleled in its history.

169.

When an allegation is made in this Second Amended Complaint to an act or omission of the Defendants, unless specifically attributed or otherwise stated, such allegations assert that the officers, directors, agents, employees, or representatives of the Defendants committed or authorized such an act or omission, or failed to adequately supervise or properly control or direct their employees while engaged in the management, direction, operation or control of the affairs of Defendants, and did so while acting within the scope of their employment or agency. In addition, each Fossil Fuel Defendant acted individually, as well as in concerted or coordinated action with other Defendants, when causing economic harm and property damages to the Plaintiff, as well as in the negligent and/or intentional creation of a public nuisance in the County.

3. Carbon Footprint for Fossil Fuel Defendants

170.

Each Oil and Gas Defendant above is considered a major carbon emitter in Oregon. Each Defendant's carbon footprint, the amount of carbon dioxide (and other greenhouse gases) historically emitted from its operations and products is individually and collectively (with the other Defendants) a cause of the warming that is responsible for the occurrence, frequency and severity of the extreme weather events alleged by Plaintiff, including but not limited to the 2021 heat dome, the extreme heat of 2022 and beyond, the ongoing drought and the Oregon wildfires and wildfire-

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generated smoke.

171.

Plaintiff will show that the concealment and misrepresentation of the danger from each fossil fuel Defendant about the harms of the emissions, and the aggregated and cumulative greenhouse gas emissions in Oregon were individually and collectively (with the other Defendants) a cause of increasing the probability and severity of the heat dome, wildfires and drought identified and described herein. But for the Fossil Fuel Defendants' disinformation campaign and their carbon emissions in Oregon, the extreme heat events that have devastated the County since June 2021 would not have been as likely and/or as severe. Further, but for the Fossil Fuel Defendants' failures and/or refusals to warn about the climate harm that their fossil fuel emissions could cause, the County would have been better prepared and thereby experienced less harm from the Pacific Northwest Heat dome of 2021, and the extreme heat events that have subsequently struck the County.

4. Trade and Front Groups

172.

Defendant, the American Petroleum Institute ("API") is a national trade association representing the oil and gas industry, formed in 1919. API is headquartered in Washington, DC. In 2021, API reported total revenues of $228,789,035.

173.

The following Defendants and/or their predecessors in interest are and/or have been API members at times relevant to this litigation: Exxon, Shell, Chevron, BP, ConocoPhillips, Motiva,

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and Anadarko, all of whom have actively served on boards, committees and groups for API.[102]

174.

API is a nonprofit corporation registered to do business in Oregon during the period at issue in this lawsuit.

175.

With more than 600 members, API is the country's largest oil trade association.

176.

API asserts that it "speak[s] for the oil and gas industry to the public, Congress and the Executive Branch, state governments and the media."[103] API states that it "negotiate[s] with regulatory agencies, represent[s] the industry in legal proceedings, participate[s] in coalitions and work[s] in partnership with other associations to achieve [its] members' public policy goals."[104] API's purpose is to advance the individual members' collective business interests, which includes increasing consumers' consumption of oil and gas to Defendants' financial benefit. Among other

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[102] API's full membership is much more extensive, and includes predecessors to the Fossil Fuel Defendants named herein, American Standard of Indiana (BP), Asiatic (Shell), Ashland (Marathon), Atlantic Richfield (BP), British Petroleum (BP), Chevron Standard of California (Chevron), Esso Research (ExxonMobil), Ethyl (formerly affiliated with Esso, which was subsumed by ExxonMobil), Getty (ExxonMobil), Gulf (Chevron, among others), Humble Standard of New Jersey (ExxonMobil/Chevron/BP), Marathon, Mobil (ExxonMobil), Pan American (BP), Shell, Standard of Ohio (BP), Texaco (Chevron), Union (Chevron), Skelly (ExxonMobil), Colonial Pipeline (ownership has included BP, ExxonMobil, and Chevron entities, among others), Continental (ConocoPhillips), Dupont (former owner of Conoco), Phillips (ConocoPhillips), and Caltex (Chevron).

[103] About API, American Petroleum Institute, https://www.api.org/about (last visited on June 12, 2023).

[104] Id.

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functions, API coordinates among members of the petroleum industry and gathers information of interest to the industry and disseminates that information to its members.

177.

API has coordinated and participated in a deliberate misinformation and concealment campaign to downplay and/or outright deny the causal relationship between the GHG emissions of its members, the industry at large, and extreme weather events like those described herein. API's concealment and misrepresentation about the dangers of its members' emissions and emissions of the industry at large, is individually and collectively (with the other Defendants) a cause of enormous harm to the Plaintiff for which this Defendant is individually and jointly and severally liable to Plaintiff. Upon information and belief, API has directed its disinformation campaign and business activities into Oregon and purposefully availed itself of the rights, obligations, and privileges of the laws of Oregon.

178.

Defendant, the Western States Petroleum Association ("WSPA") is a non-profit trade association headquartered in Sacramento, California, representing Fossil Fuel Defendants' interests in Arizona, California, Nevada, Oregon and Washington. Its members include, and at times relevant to this matter, have included ExxonMobil, Shell, Chevron, Valero, Marathon, and BP.

179.

The Western States Petroleum Association was founded in 1907 and represents companies that account for the bulk of petroleum exploration, production, refining, transportation, and marketing in the five western states of Arizona, California, Nevada, Oregon, and Washington.

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180.

WSPA has engaged in a climate deception/misinformation campaign about the harms of fossil fuel use, in Oregon, to continue to further the business objectives of its carbon polluting members, including increasing the demand and consumption of their fossil fuel products. WSPA has conducted substantial business activities in Oregon and purposefully availed itself of the rights, obligations, and privileges of the laws of Oregon.

181.

WSPA has coordinated and participated in a deliberate misinformation and concealment campaign to downplay and/or deny the harms from the use of its members' fossil fuel products leading to an increase in the demand and consumption of fossil fuel products, and lack of preparedness for extreme weather events like the 2021 extreme heat event. WSPA's concealment and misrepresentation about the dangers of its members' emissions and industry's emissions, is individually and collectively (with the other Defendants) a cause of enormous harm to the Plaintiff for which this Defendant is individually and jointly and severally liable to Plaintiff.

182.

Defendant, Oregon Institute of Science and Medicine ("OISM") is a privately owned entity incorporated and registered to do business in Oregon since 1981 with its principal place of business and headquarters in Cave Junction, Oregon.

183.

Arthur B. Robinson is listed as OISM's CEO and has designated the entity's purpose is for research and education. Instead of providing an education, OISM, which is responsible for the Petition Project created a misinformation and deception campaign that is known as the "Oregon

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Petition." The Petition Project, received funding from Heartland, which has received funds from Exxon and Koch among other Defendants.

184.

Arthur Robinson and his son Noah E. Robinson were the co-directors of the Petition Project. Noah Robinson is also on the Board of Directors of the Heartland Institute.[105] On the latter's biography, the Petition Project is falsely touted as "signed by more than 31,000 scientists and engineers informing the U.S. Congress that human-produced carbon dioxide is beneficial to the Earth's plant and animal life and is not causing harmful global warming."

185.

In addition to the Oregon Petition discussed in paragraphs 404, 405, 406 and 407, OISM also disseminated a purportedly peer reviewed journal article authored by Art Robinson, Noah E. Robinson, and Willie Soon. The paper was created to read like a study published in a peer-reviewed journal, and even contained a cover letter by Frederick Seitz[106] who claimed to review the article and falsely asserted that the "[r]esearch data on climate change do not show that human use of hydrocarbons is harmful...to the contrary, there is good evidence that increased atmospheric carbon dioxide is environmentally helpful."[107]

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[105] Noah E. Robinson - The Heartland Institute, https://heartland.org/about-us/who-we-are/noah-e-robinson/ (last visited August 23, 2024).
[106] Letter from Frederick Seitz, Petition Project, http://www.petitionproject.org/seitz_letter.php (last visited on August 23, 2024).
[107] Id.

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186.

OISM published a paper that suggests that it analyzes the "Environmental Effects of Increased Atmospheric Carbon Dioxide."[108] The article is replete with disinformation, including the conclusion that states unequivocally, "[t]here are no experimental data to support the hypothesis that increases in human hydrocarbon use or in atmospheric carbon dioxide and other greenhouse gases are causing or can be expected to cause unfavorable changes in global temperatures, weather, or landscape. There is no reason to limit human production of CO2, CH4, and other minor greenhouse gases as has been proposed (82,83,97,123). We also need not worry about environmental calamities even if the current natural warming trend continues. The Earth has been much warmer during the past 3,000 years without catastrophic effects. Warmer weather extends growing seasons and generally improves the habitability of colder regions."[109]

187.

OISM has conducted substantial business activities in Oregon and purposefully availed itself of the rights, obligations, and privileges of the laws of Oregon.

188.

OISM has engaged in a climate deception/misinformation campaign in Oregon to continue to further the business objectives of its carbon polluting funders. OISM's concealment and misrepresentation about the dangers of its funders' emissions, are individually and collectively

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[108] A. Robinson, N. Robinson, W. Soon, Environmental Effects of Increased Atmospheric Carbon Dioxide, http://www.petitionproject.org/gw_article/GWReview_OISM600.pdf (last visited on August 28, 2024).
[109] *Id.*

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(with the other Defendants) a cause of enormous harm to Plaintiff for which this Defendant is individually as well as jointly and severally liable.

189.

OISM has coordinated and participated in a deliberate misinformation and concealment campaign to downplay and/or deny the harms from the use of its fossil fuel funders'—including Defendants—and the industry's products leading to an increase in the demand and consumption, and extreme weather events like those that have harmed the County. OISM's deception is individually and collectively (with the other Defendants) a cause of enormous harm to the Plaintiff for which this Defendant is individually and jointly and severally liable to Plaintiff.

5. Other Defendants

190.

McKinsey and Company, Inc. United States is a privately owned entity headquartered in New York, New York. McKinsey is registered to do business in Oregon and in all fifty states. At all relevant times, McKinsey has transacted business throughout Oregon, including in Multnomah County. McKinsey has conducted substantial business activities in Oregon and purposefully availed itself of the rights, obligations, and privileges of the laws of Oregon.

191.

Defendant McKinsey & Company, Inc. is a corporation organized under the laws of the state of New York. McKinsey's principal place of business is located at 711 Third Avenue, New York, NY 10017. It may be served with process via its registered agent, Corporation Service Company, at 80 State Street, Albany, NY 12207.

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192.

Defendant McKinsey Holdings, Inc. is a Delaware corporation with its principal place of business is located at 711 Third Avenue, New York, NY 10017. It may be served with process via its registered agent, Corporation Service Company, 251 Little Falls Drive, Wilmington, DE 19808.

193.

Upon information and belief, McKinsey & Company, Inc. is the parent company of McKinsey Holdings, Inc., which is itself the parent company of both McKinsey & Company, Inc. United States and McKinsey & Company, Inc. Washington D.C. Upon information and belief, each subsidiary corporation is wholly owned by its parent. to as (collectively "McKinsey").

194.

McKinsey is one of the world's largest and most influential consulting companies. McKinsey prides itself on learning the intimacies of its clients' businesses, embedding itself in management, and evolving "transformational partnerships" with actual boots on the ground. McKinsey's work with fossil fuel entities dates back several decades. Though McKinsey promotes itself as being "committed to protecting the planet," McKinsey counts at least seventeen mining and fossil fuel companies among its biggest clients. McKinsey's claims of commitment to environmental protectionism stand in stark contrast to the millions of dollars it has earned assisting its fossil fuel and mining company clients in promoting themes to deny the existence and/or gravity of ACC.

195.

Since 2010, McKinsey has worked for at least forty-three of the hundred companies that have pumped substantial tons of carbon dioxide into the atmosphere since 1965.

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196.

Those forty-three companies, when accounting for the customers who use their products, were responsible for a substantial share of the greenhouse gas emissions from the fossil fuel industry, including Defendants, in the past several decades.

197.

Chevron is one of McKinsey's biggest clients, generating at least $50 million in consulting fees in 2019. Saudi Aramco, number one on the list, has been a McKinsey client since at least the 1970s. During that half a century, Chevron's total emissions were approximately 43.7 gigatons (43 billion tons) of carbon dioxide. In 2019, energy-related emissions for the entire planet amounted to about 33 gigatons, according to the International Energy Agency.

198.

Other top McKinsey fossil fuel clients include ExxonMobil, BP, Royal Dutch Shell, Russia's Gazprom, and Qatar Petroleum.

199.

McKinsey has coordinated and participated in a deliberate misinformation campaign to downplay and/or outright deny the causal relationship between the use of its fossil fuel clients' products and climate harms, thereby leading to an increase in the demand and consumption of the fossil fuel products, and the severity of extreme weather events like those described herein. McKinsey's contribution to, and deception is individually and collectively (with the other Defendants) a cause of enormous harm to the Plaintiff for which this Defendant is individually and jointly and severally liable to Plaintiff.

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200.

DOES 25-250, are heretofore unnamed entities, organizations or persons actively engaged in the GHG emissions, or in the deceptive enterprise that have harmed Multnomah County.

C. Venue

201.

Venue is proper in Multnomah County under ORS 14.080(1) because a substantial portion of the causes of action asserted by Plaintiff herein arose in Multnomah County.

III. FACTUAL ALLEGATIONS

A. Anthropogenic Climate Change (ACC) is Scorching the Planet

202.

Contrary to Defendants' public position, emissions from fossil fuels are a primary cause of global warming. This is the consensus among the world's leading scientists.[110] Present-day concentrations of atmospheric carbon dioxide (CO_2) are at higher levels than at any time in at least the past two million years.[111]

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[110] Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6), Chapter 2.1, (2023) ("Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850-1900 in 2011-2020. Global greenhouse gas emissions have continued to increase over 2010-2019, with unequal historical and ongoing contributions arising from unsustainable energy use…"). https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

[111] Gulev, S. K. et al. Changing State of the Climate System. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (eds. Masson-Delmotte, V. et al.)(Cambridge University Press Cambridge, United Kingdom and New York, NY, USA, 287–422), (2021) https://doi.org/10.1017/9781009157896.004.

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203.

ACC is already affecting many weather and climate extremes in every region across the globe, including in the Pacific Northwest and Multnomah County.[112] In 1960, the atmospheric concentration of CO_2 was measured at 317 ppm. Today it is 425 ppm, and steadily rising.

204.

The fossil fuel products that Defendants marketed, distributed, extracted, refined, transported, and sold, when used as intended, release greenhouse gases, including carbon dioxide (CO_2) and methane, which trap atmospheric heat.

205.

The earth's temperature depends on the balance between energy entering and leaving the planet's system. When sunlight reaches the planet surface, it can either be reflected into space or absorbed by the earth. Incoming energy that is absorbed by the earth warms the planet. Once absorbed, the planet releases some of the energy back into the atmosphere as heat (also called infrared radiation). Greenhouse gases trap atmospheric heat, warming the earth. Solar energy that is reflected to space does not warm the earth.

206.

Global temperatures have warmed by at least 1.1°C to 1.2°C since 1900, with most of that occurring in the last 35 years.[113] Global warming has destabilized the planet's climate patterns, as

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[112] Id.
[113] Id.

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well as the climate in Oregon, and has caused an increased frequency and intensity of extreme weather events, like the 2021 PNW heat dome.

207.

The scientific community has determined and declared that because of rising greenhouse gas emissions, planet Earth is facing an unprecedented and accelerating climate emergency. Scientists have warned that ACC has substantially contributed to rising land, air and oceanic temperatures, the melting of the polar ice sheets, and the increased frequency and severity of extreme heat events, wildfires, drought, floods, and storms.[114] In sum, scientists have declared that unabated climate change presents a "code red" danger to humanity.[115]

208.

Change in Oregon's climate is being harshly felt and growing worse at a rapid pace. Nine of Oregon's hottest years in recorded history have occurred since the year 2000 and seven have come since 2010.[116]

209.

Multiple scientific studies have found that climate change is already contributing to extreme heat waves, widespread drought conditions, severe wildfires, coastal erosion, and other

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[114] Fleishman, Erica, and Oregon Climate Change Research Institute. 2023. Sixth Oregon Climate Assessment. : [Corvallis, Oregon] : Oregon Climate Change Research Institute, Oregon State University, https://energyinfo.oregon.gov/blog/2023/1/11/occris-sixth-climate-assessment-outlines-climate-change-effects-on-oregon (last visited June 13, 2023).
[115] Id.
[116] Id.

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erratic weather conditions in Oregon. [117] Unless carbon emissions decline considerably, these impacts will intensify over the coming decades.[118]

210.

According to the Oregon Climate Change Research Institute, if greenhouse gas emissions continue at current levels, the annual temperature in Oregon is projected to increase by 5°F by the 2050s and 8.2°F by the 2080s, with the greatest seasonal increases in summer.[119]

211.

The Oregon Climate Change Research Institute has found that ACC poses a significant threat to Oregon's forestry, agriculture, fisheries, water supplies, and coastal resources. In addition to extreme heat events, the OCCRI predicts that other likely ACC-related impacts include winter flooding, summer droughts, loss of shoreline, forest fires, worsening air quality, diminished fish and wildlife habitat, retreating glaciers, decreased snowpack, and increased disease vectors and invasive species.

212.

Increased temperatures are projected to contribute to: (i) decreased winter snowpack and changes in the timing and volume of streamflow fed by snowmelt; (ii) increased summer water demand, especially during more intense and longer summer droughts; (iii) increased risk of flooding due to more intense snow events and sea level rise; (iv) increased risk of fire in forest

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[117] Id.
[118] Id.
[119] Id.

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lands, open space, and in areas where forest and residential lands overlap; (v) increased risk of heat-related morbidity and mortality during more intense summer heat waves like the extreme heat event of June 2021; (vi) increased summer air pollution and related health impacts; (vii) decreased summer hydropower production and increased summer energy demand, especially from air conditioning; (viii) increased harm to aquatic wildlife because of warmer water temperatures in streams, rivers, lakes; and (ix) increased shifts in habitat, invasive species, and insects affecting forest health, agriculture, and ecosystem function.

B. Oregonians Died and Multnomah County Suffered Damages Because of Defendants' Fossil Fuel Activities – 2021 PNW Heat Dome

213.

In June of 2021, the Pacific Northwest experienced an extreme weather event unlike any the region has ever experienced. The extreme weather event occurred earlier in the summer, before residents could naturally acclimate to warmer temperatures.[120] Additionally, the heat dome brought a prolonged period of heat intensity never experienced in the region.[121]

214.

Multnomah County, known for its traditionally mild climate, was unprepared for the devastation the heat dome unleashed on its citizens. Although extreme heat is one of the leading causes of weather-related deaths in the United States[122] — in some years killing more people than

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[120] Multnomah County, Preliminary Review on Excessive Heat Deaths, https://www.multco.us/preliminary-review-excessive-heat-deaths-multnomah-county-june-2021 (last visited June 12, 2023).
[121] Id.
[122] CDC, Extreme Heat and Your Health,

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all other weather hazards (except hurricanes) combined — the severity of these conditions and their impacts was new for customarily cool and wet Multnomah County.[123]

215.

On June 25, 2021, the high temperature in Multnomah County was **95° F.** The average high temperature for this date prior to 2021 was 76° F.[124]

216.

On June 26, 2021, the high temperature in Multnomah County was **108° F.** The average high temperature for this date prior to 2021 was 76.4° F.[125]

217.

On June 27, 2021, the high temperature in Multnomah County was **112 ° F.** The average high temperature for this date prior to 2021 was 76.7° F.[126]

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https://www.cdc.gov/nceh/features/trackingheat/index.html#:~:text=Extreme%20heat%20events%2C%20or%20heat,inability%20to%20cool%20down%20properly. ("Extreme heat events, or heat waves, are one of the leading causes of weather-related deaths in the United States. When temperatures rise in the summer, extremely hot weather can cause sickness or even death. Heat stress is heat-related illness caused by your body's inability to cool down properly.").

[123] Multnomah County, Preliminary Review on Excessive Heat Deaths, https://www.multco.us/preliminary-review-excessive-heat-deaths-multnomah-county-june-2021 (last visited June 12, 2023).

[124] This average is calculated from temperature readings from 1991 to 2020 for June 25. https://www.extremeweatherwatch.com/cities/portland-or/day/june-25 (last visited on June 12, 2023).

[125] This average is calculated from temperature readings from 1991 to 2020 for June 26. https://www.extremeweatherwatch.com/cities/portland-or/day/june-26 (last visited on June 12, 2023).

[126] This average is calculated from temperature readings from 1991 to 2020 for June 27. https://www.extremeweatherwatch.com/cities/portland-or/day/june-27 (last visited on June 12, 2023).

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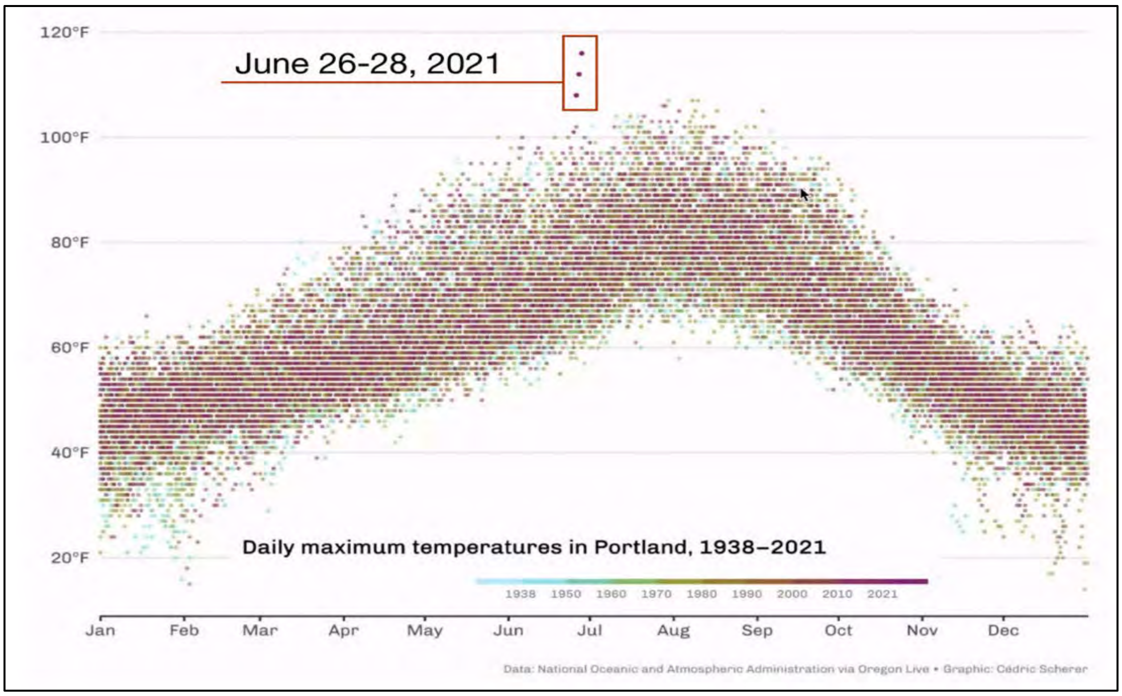
218.

On June 28, 2021, the high temperature in Multnomah County was **116° F.** The average high temperature for this date prior to 2021 was 77° F.[127]

219.

The temperature readings on June 26, 27, and 28 were so far outside the normal distribution of temperatures that this heat event was classified as an extreme weather event—and perhaps the most extreme in history.[128] The graph below shows how outside of the mean temperatures were:



[127] This average is calculated from temperature readings from 1991 to 2020 for June 28. https://www.extremeweatherwatch.com/cities/portland-or/day/june-28 (last visited on June 12, 2023).

[128] Multnomah County, June 2021 Extreme Heat Event, Preliminary Findings and Action Steps https://www.multco.us/file/june-2021-heat-event-preliminary-findings-and-action-steps (last visited June 12, 2023).

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220.

The occurrence of the heat dome was "virtually impossible" without ACC caused by Defendants' fossil fuel related activities and enterprise.[129]

221.

Another study that evaluated the 2021 PNW heat dome concluded, "[i]t is clear… that anthropogenic warming of the planet contributed to the severity of this event."[130]

222.

Yet another study determined that "while the extreme heat was unprecedented, it was nevertheless mechanistically linked to regional climate change.[131]

223.

Defendants' conduct was individually and collectively a cause of the lack of preparedness for dramatic warming of the region's surface temperature, the decrease in atmospheric moisture and the desiccation of the region's soil, all as a result of ACC. Defendants' collective conduct combined to cause the massive damages caused by the 2021 PNW heat dome.

224.

Defendants' GHG emissions, in Oregon, were individually and collectively (with the other Defendants) a cause of the occurrence and severity of the heat dome. The heat dome would have

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[129] Philip, *et al.*, *supra* note 4.

[130] White, R.H., Anderson, S., Booth, J.F. et al. The unprecedented Pacific Northwest heatwave of June 2021. Nat Commun 14, 727 (2023). https://doi.org/10.1038/s41467-023-36289-3.

[131] Bartusek, S., Kornhuber, K. & Ting, M. 2021 North American heatwave amplified by climate change-driven nonlinear interactions. Nat. Clim. Chang. **12**, 1143–1150 (2022). https://doi.org/10.1038/s41558-022-01520-4.

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been less likely to occur without Defendants' high levels of GHG emissions and the warming it caused. Even if the heat dome would have occurred absent a Defendant's GHG contributions or had Defendants' GHG contributions been lower, it would have been less severe and less catastrophic in and to Multnomah County. Had Defendants been truthful, about the harmful impacts of their GHG contributions, to the County, to the public, and others, the County could have adequately prepared to withstand the extreme heat.

225.

The 2021 PNW heat dome event was responsible for approximately 619 heat-related deaths in Canada, a 95% increase over the number reported for late-June in prior years. The State of Washington recorded 196 heat-related deaths. Oregon recorded 100 deaths, 69 of which occurred in Multnomah County, which the coroner ruled were caused by hyperthermia. These deaths were

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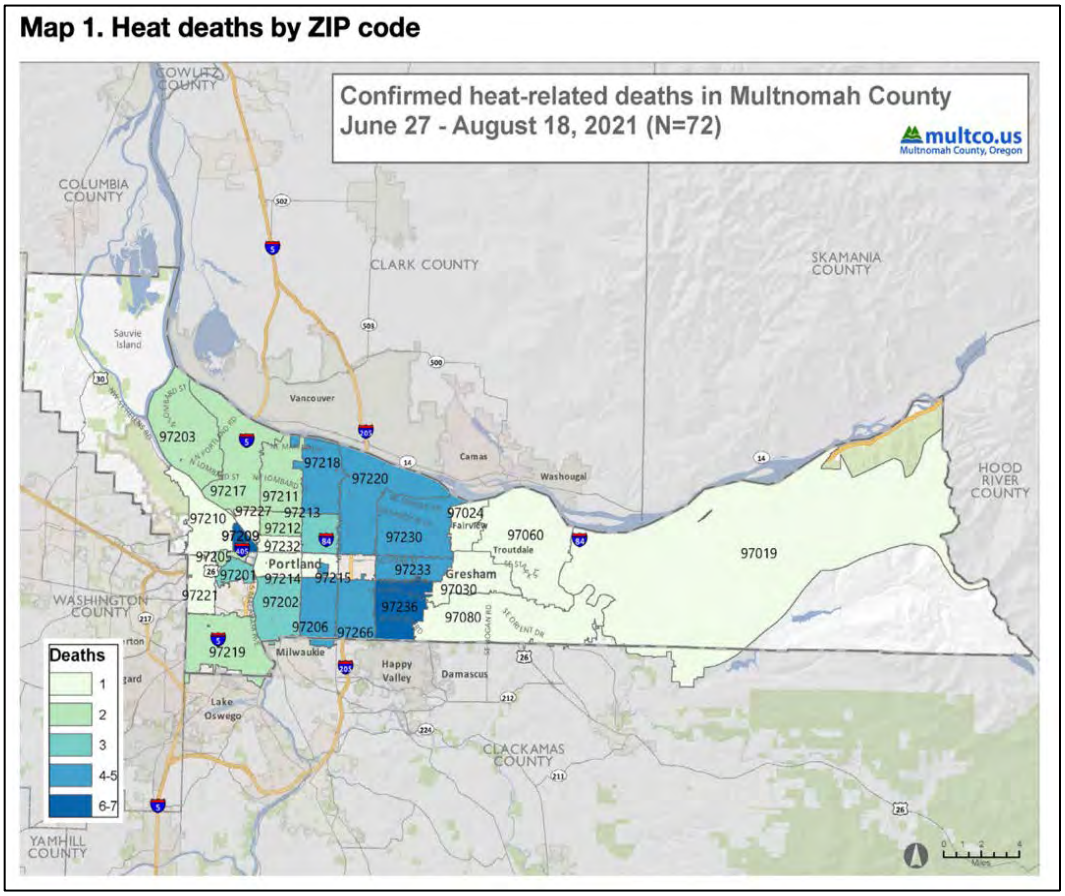
in virtually every zip code of Multnomah County.



226.

In prior years, the County reported zero heat-related deaths. Elderly persons living alone in muti-family buildings without air conditioning in densely populated parts of the region accounted for a large percentage of those who perished.

227.

In a typical year, there are about 95 deaths from all causes in the last week of June. In 2021 there were 186, nearly double the average during the previous three years.

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228.

In addition to casualties and injuries, the heat dome's impacts were far-reaching. Roads, rails, bridges, power stations, utilities, hardscapes, parks, levees, greenscapes, and buildings were impacted. Asphalt melted. Businesses shuttered. Tourists fled. Marine life perished. Circuits fried. Productivity plummeted as the heat drove the outdoor labor force indoors, away from their jobs, simply to survive. Multnomah County incurred immediate costs by treating people with heat-related symptoms and establishing air-conditioned emergency shelters, among other costs. The County recorded 257 emergency visits for heat illness, compared to a typical volume of 83 visits for that same time of the year.

229.

To the North, the heat dome sparked wildfires, which in turn generated smoke-related health impacts, as well as eventual floods and mudslides.

230.

Long term global warming and soil drying transformed the heat dome from "virtually impossible" to a more than likely a 10 yearly reoccurrence if the climate continues to warm from the current 1.2ºC to 2°C over pre-industrial times.[132]

231.

"Global warming caused a ~0.8°C–1°C increase in heatwave temperatures. Future

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[132] Bartusek, S., Kornhuber, K. & Ting, M. 2021 North American heatwave amplified by climate change-driven nonlinear interactions. Nat. Clim. Chang. **12**, 1143–1150 (2022). https://doi.org/10.1038/s41558-022-01520-4.

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warming would lead to a ~5°C increase in heatwave temperature by the end of the 21st century."[133]

232.

"Climate model projections indicate a rapidly increasing risk of the PNW regularly experiencing 2021-like extreme summer temperatures, with a 50% chance of yearly occurrence by 2050. The 2021 summer temperatures experienced across the PNW provide a benchmark and impetus for communities in historically temperate climates to account for extreme heat-related impacts in climate change adaptation strategies."[134]

233.

In light of the 2021 PNW extreme heat wave, "policymakers and governments need to prepare for events beyond current records – particularly with trends caused by ACC enhancing the probability of extremes. Heatwaves are deadly—but better preparation can save lives. Planning ahead can reduce mortality from climatic extremes. For example, city heat plans that include actions such as establishing cooling centers or reducing hours of work for outdoor workers can reduce heat impacts. Policy changes following the 2003 European heatwave led to fewer deaths after the similar magnitude 2006 event.[135]

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[133] Emily Bercos-Hickey, et al. "Anthropogenic contributions to the 2021 Pacific Northwest heatwave." Geophysical Research Letters 49 (2022).
[134] Id.
[135] Thompson, V., Mitchell, D., Hegerl, G.C. et al. The most at-risk regions in the world for high-impact heatwaves. Nat Commun 14, 2152 (2023). https://doi.org/10.1038/s41467-023-37554-1 (last visited on June 18, 2023).

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234.

During Summer 2021, the number of Heat-Related Illness Emergency Department or urgent care clinic (ED) visits were over twice those observed in past years (2016-2019). Multnomah County recorded 266 heat-related Emergency Department visits in 2021. In 2020, the County recorded 55 visits. In 2021, Multnomah County recorded 52 heat related hospitalizations. In the prior three years, from 2018 to 2019, the County averaged 4 hospitalizations.

235.

Increasing CO_2 emissions and global temperatures are expected to create more extreme heat events more often in Multnomah County in the future, in the form of heatwaves, wildfires, and storms. Damage from extreme weather events restricts access to essential services, including clean water, food, basic sanitation, and health care. Trauma from the loss of friends, family, and community also creates stress and affects mental health. This stress grows over time if limited resources are available for mental and physical care, recovery, and reconstruction efforts.

C. ACC Has Caused Deadly Fires and Smoke Plumes that Have Harmed the Public Health of Multnomah County

236.

On September 7th and 8th of 2020 several fires inundated Oregon. Five of these fires were megafires—which are greater than 100,000 acres in size.[136] These fires became known as the Labor

[136] Report, Oregon Forest Resources Institute, Economic Impacts to Oregon's Forest Sector September 2021, 1.0 Executive Summary at p. 8 https://oregonforests.org/sites/default/files/2021-09/OFRI-LaborDayFiresEconomicReport_Final%20Sept%202021.pdf.

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Day 2020 fires.[137] There were 12 other fires ranging from 112 to 50,951 acres.[138]

237.

Multnomah County was inundated with smoke from these fires. On Monday September 7, 2020, the Oregon Department of Environmental Quality (DEQ) issued an air quality alert for Multnomah County.[139]

238.

Multnomah County remained under a dense smoke warning from September 12-17, 2020. This smoke intrusion incident resulted in the most hazardous air quality in the world for a period of time and the worst ever recorded in Multnomah County.[140]

239.

In response, Multnomah County was required to provide KN95 masks, emergency services, shelters, and fire response management. In the wake of the smoke intrusion incident, the County replaced 1,200 air filters and provided extensive HVAC maintenance.

D. ACC is Contributing to the Frequency and Severity of Deadly Wildfires and Smoke

240.

Anthropogenic climate change, induced by the burning of fossil fuels, has caused an

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137 Id.
138 Id.
139 Report, Wildfire Threat and Smoke Intrusion Incident, After Action Report/Improvement Plan (AAR/IP) Multnomah County, Oregon May 8, 2021, p. 4.
140 Id. at 5.

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increase in the frequency and severity of wildfires in Oregon, which not only destroy lives, property and natural resources, but also generate plumes of toxic smoke which in the last ten years has damaged the health and property of residents of Multnomah County.

241.

Wildfire-generated plumes of smoke inject fine particulate matter (PM2.5) at high altitudes, increasing long-range transport of PM2.5 from locations outside of the County where they have caused a health hazard.

242.

Excessive PM2.5, pollution from wildfires cause numerous human health problems, including chronic obstructive pulmonary disease, acute lower respiratory illness, asthma, ischemic heart disease, and lung cancer that disproportionately affect vulnerable populations, such as children with respiratory ailments, the elderly, people of color, and the economically disadvantaged[141]

243.

The health problems are amplified in airsheds closest to a specific fire event, but impacts can extend over vast distances depending on wind patterns and other factors. The particulates are dangerous to human health.

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[141] Reid CE, Maestas MM. Wildfire smoke exposure under climate change: impact on respiratory health of affected communities. CURR OPIN PULM MED. Mar 25, 2019, pp 179-187. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6743728/.

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244.

Wildfire-generated particulate matter has increased dramatically in Oregon, which has directly impacted the health of people in Multnomah County. From 1979 through 2019, the duration of the fire weather season in forests in Oregon has increased by 43 percent, and the annual number of days when fire danger was extreme increased by 166 percent. Widespread drought has led to increased fire danger.

245.

The Oregon Global Warming Commission stated its 2023 report to the legislature that:

> "Climate change is already having a measurable impact on Oregon's landscape, communities and economy. Oregon is experiencing increased temperatures, changing precipitation patterns, reduced snowpack, drier summers, and more frequent and damaging wildfires. Since the 2020 Report to the Legislature, extreme heat events, severe drought conditions, shifting precipitation patterns, and high-intensity wildfires have continued to inflict significant damage on Oregonians, communities, the environment, and the economy. These impacts are projected to become more frequent and severe as temperatures increase and global climate conditions become more extreme and unpredictable."

246.

The report further predicted, "Warmer temperatures and drier conditions increase the risk of more frequent and severe wildfires."

247.

The total area of land burned by wildfire each year has increased in Oregon over the past 35 years, and wildfires have grown larger and spread into higher elevations during this period. In the Pacific Northwest, the number of days with extreme wildfire danger have more than doubled since 1979. Drought, increased aridity, and reductions in relative humidity contribute to the

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growing fire risk in Oregon. As global temperatures increase, wildfires are expected to become larger and fire seasons increasingly extreme in Oregon and across the West.

248.

ACC, induced by the burning of fossil fuels, has substantially contributed to hotter, drier conditions that generate more toxic smoke from wildfires. ACC has substantially contributed to diminished air quality and increased levels of harmful ground level ozone. Wildfire-generated smoke triggers asthma symptoms.

249.

ACC, induced by the burning of fossil fuels, has substantially contributed to air quality related respiratory illness visits at hospital emergency departments and urgent care clinics in the County. In 2022, a total of 84,081 visits in Multnomah, Washington and Clackamas Counties were due to air quality-related illness, most of which occurred in Multnomah County. From 2016 to 2022, Multnomah County recorded steadily increased visits each year except in 2021, which recorded a level similar to 2017.

250.

In September of 2020, Multnomah County experienced a spike in medical visits for asthma caused by poor air quality as a result of ACC-related wildfire smoke. Asthma-related emergency room visits in Multnomah County increased by nearly one-third in the four weeks during and after wildfires in 2020.

251.

The Labor Day fires of 2020 produced extreme smoke levels resulting in unhealthy air quality in Multnomah County.

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252.

The air quality index in Multnomah County from September 10th through the 13th repeatedly broke records during the Labor Day 2020 fires (215, 287, 288 and 477 AQI, respectively).[142] AQI above 200 is considered "very unhealthy."[143] Before 2015, Portland did not have a single day with air quality ≥ Unhealthy for Sensitive Groups (USG) from wildfire smoke since air quality monitoring began in 1985.[144] From 2015 to 2022, Portland had 26 ≥ USG days or 3.3 ≥ USG days/year.[145] In 2020, Portland had its first days over the unhealthy AQI level with 3 very unhealthy and 5 hazardous days.[146] In 2022, Portland had 3 ≥ USG days.[147]

253.

AQI categories from wildfire smoke have been increasing since around 2012, with more frequent days at more "unhealthy" or worse levels, including the record-breaking events of September 2020.[148] Scientists expect this trend will continue and worsen. More acreage in Oregon has burned by wildfires in 2024 than any previous year on record.

254.

The Labor Day 2020 fires were among the worst ever in Oregon history, scorching nearly

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[142] State of Oregon Department of Environmental Quality, *Wildfire Smoke Trends and the Air Quality Index* (May 2023) https://www.oregon.gov/deq/wildfires/Documents/WildfireSmokeTrendsReport.pdf (last visited June 21, 2023).
[143] Id.
[144] Id.
[145] Id.
[146] Id.
[147] Id.
[148] Id.

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1,500 square miles of mainly forested areas, the largest area in the state's recorded history. Strong and dry winds, combined with desiccated vegetation, drove the rapid growth of the fires. A key driver of the wildfires was unusually high aridity (the drop in atmospheric water vapor), a trend to which fossil fuel induced climate change substantially contributed.

255.

The Labor Day fires are also part of a regional trend. Total annual area burned in Oregon has increased during the last 35 years.[149] As aridity has increased, wildfires have spread into higher elevations that previously were cool and moist enough to deter fire expansion.[150]

256.

The United Nations Environment Programme Report, authored by 52 international scientists, linked global spread of landscape-scale wildfires to global overheating that is "turning landscapes into tinderboxes, while more extreme weather means stronger, hotter, drier winds to fan the flames."[151]

257.

More than a dozen rigorous peer-reviewed studies and meta-analyses (synthesis studies) confirm the presence of a consistent pattern of increased wildfire events and severity in Oregon

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[149] Oregon Department of Energy, *OCCRI's Sixth Climate Assessment Outlines Climate Change Effects On Oregon* https://energyinfo.oregon.gov/blog/2023/1/11/occris-sixth-climate-assessment-outlines-climate-change-effects-on-oregon (last visited on June 21, 2023).
[150] Id.
[151] United Nations Environmental Program, Spreading like Wildfire: The Rising Threat of Extraordinary Landscape Fires (2022) https://www.unep.org/resources/report/spreading-wildfire-rising-threat-extraordinary-landscape-fires (last visited June 20, 2023).

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that is attributable to fossil fuel induced ACC.[152]

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[152] *See* Dennison, P. E., Brewer, S. C., Arnold, J. D., & Moritz, M. A. (2014). Large wildfire trends in the western United States, 1984–2011. *Geophysical Research Letters*, *41*(8), 2928-2933. https://doi.org/10.1002/2014GL059576 (increased Western wildfire attributed in part to warmer and drier summer conditions (drought severity). For all ecoregions combined, the number of large fires increased at a rate of seven fires per year, while total fire area increased at a rate of 355 km^2 per year."); Westerling, A. L. (2016) Increasing western US forest wildfire activity: sensitivity to changes in the timing of spring *Phil. Trans. R. Soc. B* 371: 2015017820150178 http://doi.org/10.1098/rstb.2015.0178 (reaffirmed the tight association between wildfire activity and the relatively high cumulative warm-season actual evapotranspiration and early spring snow melt. Notably, there was a +1000% increase in wildfire activity from 2003-2012 and the increase was attributed to spring and summer temperature increases.); Abatzoglou, J. T., & Williams, A. P. (2016). Impact of anthropogenic climate change on wildfire across western US forests. *Proceedings of the National Academy of Sciences*, *113*(42), 11770-11775. https://doi.org/10.1073/pnas.1607171113 ("anthropogenic increases in temperature and vapor pressure deficit significantly enhanced fuel aridity across western forests during 2000–2015, contributing to 75% more forested area experiencing high fire-season fuel aridity and an average of 9 additional days per year of high fire potential. ACC accounted for ~55% of observed increases in fuel aridity and wildfire potential in recent decades."); Holden, Z. A., *et al*. (2018) Decreasing fire season precipitation increased recent western US forest wildfire activity. *Proceedings of the National Academy of Sciences*, *115*(36), E8349-E8357. https://doi.org/10.1073/pnas.1802316115 (declines in summer precipitation and rain days associated with GHG increases are the primary driver of increases in wildfire area in the West.); Abatzoglou, J. T., Rupp, D. E., & Sadegh, M. (2021). Compound Extremes Drive the Western Oregon Wildfires of September 2020. *Geophysical Research Letters*, *48*(8), e2021GL092520. https://doi.org/10.1029/2021GL092520 ("the 2020 Labor Day fires in Oregon exceeded the area burned in any single year for at least the past 120 years, contributing to hazardous air quality and massive smoke plumes. Unusually warm conditions with limited precipitation occurred in the 60-days prior to the fires. Exceptionally strong winds and dry air drove rapid rates of fire spread. The concurrence of these drivers created conditions unmatched in the observational record."); Mass, C. F., *et al*. (2021). The September 2020 Wildfires over the Pacific Northwest. Wea. Forecasting, 36, 1843–1865. https://doi.org/10.1175/WAF-D-21-0028.1 ("the Labor Day fires of 2020 were driven by strong … highly unusual winds. Wildfires produced dense smoke that initially moved westward over the Willamette Valley and eventually covered the entire region. Air quality rapidly degraded to hazardous levels, representing the worst levels in recent decades."); Hawkins, L. R., *et al*. (2022). Anthropogenic Influence on Recent Severe Autumn Fire Weather in the West Coast of the United States. *Geophysical Research Letters*, *49*(4), e2021GL095496. https://doi.org/10.1029/2021GL095496 ("ACC factors (fuel aridity, warmer temperatures during dry wind events) increased fuel aridity and likelihood of extreme fire weather by 40% in northern

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258.

Anthropogenic climate change, induced by the burning of fossil fuels, has caused and exacerbated wildfires in Oregon that harmed Multnomah County. ACC has increased the vapor pressure deficit and the summer temperatures dramatically, two conditions that influence the frequency and severity of wildfires. Other ACC factors contributing to increasing wildfire activity include unusually strong winds, a higher incidence of lightning, longer fire seasons, and decreased snowpack.

California and Oregon."); Dahl, K., *et al*. (2023) *Environ. Res. Lett.* **18** 064011. https://doi.org/10.1088/1748-9326/acbce8 (linked increases in burned forest area across the West and southwestern Canada to the vapor pressure deficit, meaning drier atmospheric conditions produced drought-stressed plants and soils that readily burned. The study used a robust global energy balance carbon-cycle model and a suite of downscaled climate models to "attribute emissions to vapor pressure deficit from 1901–2021 and cumulative forest fire area from 1986–2021. Emissions were responsible for 48% of long-term rise in vapor pressure deficit and, correspondingly, 37% of the cumulative area burned. Emissions also contributed to nearly half the increase in drought- and fire-danger since 1901."); MacDonald, G., *et al*. (2023). Drivers of California's changing wildfires: a state-of-the-knowledge synthesis. *International Journal of Wildland Fire* **32**, 1039-1058. https://doi.org/10.1071/WF22155 (Synthesizing the literature on climate-wildfire attribution studies finding that there was a "striking increase in annual area burned in the West related to increasing temperatures and the atmospheric vapor pressure deficit. ACC was the main driver behind wildfire activity. The trend is projected to increase without reductions in GHGs.); Marc Turco, M., *et al*. (2023). Anthropogenic climate change impacts exacerbate summer forest fires in California. *Proceedings of the National Academy of Sciences*, *120*(25), e2213815120. https://doi.org/10.1073/pnas.2213815120 (Used the latest simulations for climate change attribution and detection studies showing that nearly all observed increases in burned area in California over the past half-century was attributed to ACC (summer temperature increases, dryness). Model simulations using ACC factors alone accounted for 172% (range 84 to 310%) more area burned than simulations with natural forcing only (no ACC in the model). Their results indicate that observed increases in burned area was primarily due to greater fuel aridity (from drying and summer temperatures).

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259.

The vapor pressure deficit and summer temperatures are likely to further increase in the decades ahead, meaning even more extreme wildfire events are forecasted.

260.

Since 2020, wildfires have cost Oregon $3 billion in structure losses in this decade alone. The 2020 Labor Day wildfires were the most destructive urban-wildland fires on record, killing 11 people, destroying 4300 homes, and triggering $422 million in federal aid.[153] All told, there were 21 fires in Oregon in summer/fall of 2020, 12 of which started over the Labor Day weekend, producing "smoke waves" which detrimentally impacted smoke and air quality levels in Multnomah County.

261.

Wildfire-generated toxic smoke plumes have caused damage to Multnomah County, its residents, and its property. As carbon emissions continue, and global temperatures increase Multnomah, County will suffer more extreme heat days, more poor air quality days, larger wildfires, and more "smoke waves."

262.

GHGs from Fossil Fuel Defendants' emissions caused the fires to burn more severely and more intensely, which in turned caused smoke penetration and related harm in and to Multnomah

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[153] Eckert, T, *$422M federal grant approved to assist 2020 Oregon wildfire survivors,* OPB, Oct. 6, 2022 https://www.opb.org/article/2022/10/06/federal-assistance-for-2020-oregon-wildfires-survivors/#:~:text=The%20U.S.%20Department%20of%20Housing,fires%20throughout%20Oregon%20in%202020. (last visited on June 21, 2023).

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County. Drought conditions are linked to climate-driven temperature increases across wide swaths of the western United States, which evaporates soil of moisture which in turn makes heatwaves more severe. Changes in climate will affect future fire frequency and severity.[154] Climate change will result in longer wildfire seasons, increased wildfire frequency, larger burn zones, and increased wildfire severity.[155]

263.

Wildfires were sparked during the 2021 heat dome and thereafter.[156] Because of Defendants' acts or omissions related to the burning of fossil fuels, Multnomah County will suffer harm from smoke penetration, including adverse health impacts on its citizens from the intense smoke. As one climatologist described the matter, "it's like someone poured gasoline on the forest."[157]

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[154] Halofsky, J.E., Peterson, D.L. & Harvey, B.J. Changing wildfire, changing forests: the effects of climate change on fire regimes and vegetation in the Pacific Northwest, USA. fire ecol 16, 4 (2020). https://doi.org/10.1186/s42408-019-0062-8 (According to projections based on historical records, current trends, and simulation modeling, protracted warmer and drier conditions will drive lower fuel moisture and longer fire seasons in the future, likely increasing the frequency and extent of fires…).

[155] USDA Northwest Climate Hub, How do Climate and Wildfire Relate? https://www.climatehubs.usda.gov/hubs/northwest/topic/climate-change-and-wildfire-idaho-oregon-and-washington (last visited June 13, 2023);

[156] Bartusek, S., Kornhuber, K. & Ting, M. 2021 North American heatwave amplified by climate change-driven nonlinear interactions. Nat. Clim. Chang. **12**, 1143–1150 (2022). https://doi.org/10.1038/s41558-022-01520-4.

[157] Burns, J, We know climate change set the conditions for Oregon fires. Dis it stoke the flames, too? Sept. 21, 2020 https://www.opb.org/article/2020/09/21/oregon-wildfires-climate-change-role/ (last visited on June 18, 2023); Abatzoglou, J. T., Rupp, D. E., O'Neill, L. W., & Sadegh, M. (2021). Compound extremes drive the western Oregon wildfires of September 2020. Geophysical Research Letters, 48 https://doi.org/10.1029/2021GL092520 ("studies suggest that climate change has contributed to increased fuel aridity and longer fire seasons and the

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E. Extreme Heat is Here to Stay and Is Caused By Defendants' Activities – 2022 Heatwave

264.

Since the heat dome of 2021, additional extreme heat events have occurred. In 2022, Multnomah County experienced seven consecutive days of temperatures above 95 F from July 25 through July 31.[158]

265.

The 2022 heatwave took the lives of five Multnomah County residents.[159]

266.

In 2022, the County recorded 172 heat-related illness Emergency visits, which was 40% greater than the number of visits between 2016 and 2019.

267.

Defendants' tortious conduct has caused unprecedented and excessive heat to plague

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probability of compound hot-dry extremes and climate projections suggest continued warming with slight decreases in summer precipitation in the Pacific Northwest over the 21st century.").

[158] Ehrlich, A., Portland breaks record for consecutive days of temperatures 95 or higher July 31, 2022, https://www.opb.org/article/2022/07/31/portland-breaks-record-for-consecutive-days-of-temperatures-95-or-higher/ (last visited on June 18, 2023).

[159] Multnomah County, Medical Examiner confirms five heat deaths during summer 2022, March 7, 2023, https://www.multco.us/multnomah-county/news/news-release-medical-examiner-confirms-five-heat-deaths-during-summer-2022 (last visited June 21, 2023).

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F. ACC Has Caused Droughts that Will Continue to Wreak Havoc on Multnomah County

268.

Defendants misleading Over the last three years, a severe drought linked to the regional shift in climate caused by the burning of Defendants' fossil fuel products has strained the water supply to communities, agriculture, and ecosystems. Water availability is central to the state's economy, contributing significantly to the resilience of agricultural and livestock production, public health, urban environments, energy supply, fisheries, and industry.[160]

269.

Virtually all of Oregon is in a multiple-year drought, defined as drought that persists for more than one water year. Impacts on human and natural systems become more severe in each consecutive year of drought as groundwater, soils, and surface-water bodies continually dry without normal recharge.[161]

270.

In 17 of the last 23 water years, Oregon's precipitation was below normal. In terms of precipitation, water years 2001 and 2020 ranked as the third and fifth driest water years in Oregon

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[160] Oregon Climate Assessment, January 2023, Fleischman, Editor, Oregon State University, https://ir.library.oregonstate.edu/concern/technical_reports/gt54kw197) (last visited June 20, 2023).

[161] Id.

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since 1895.[162]

271.

The average temperature in Oregon also was warmer than normal in 18 of the last 23 water years, which contributed to increases in evapotranspiration and drought frequency.[163]

272.

For 2020, the drought was the most severe in Oregon's recorded history. The 2020 drought was driven by a combination of low precipitation and high evapotranspiration, which in turn produced well above normal temperatures.[164]

273.

Yearly estimates of soil moisture from tree rings suggested that the years 2000–2021 were the driest in Oregon since at least 800 CE. These years were characterized by low snowpack, decreased summer streamflow, low precipitation during all seasons, and steadily rising evaporative demand due to climate change-induced aridification.[165]

274.

Persistent and severe droughts have occurred in Oregon since 2000. These droughts were driven by ACC, which substantially contributed to low winter precipitation and snowpack and low summer precipitation and high winter temperature. Low precipitation contributed to each drought, but temperature and snowpack also affected drought severity and impacts. An estimated 19 percent

[162] Id.
[163] Id.
[164] Id.
[165] Id.

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of the soil moisture deficits in the West from 2000–2021 were caused by fossil fuel induced ACC.[166]

275.

Evaporation is expected to increase in Oregon as temperatures increase. Warm air holds more moisture than cool air, so projected increases in total evaporation are driven by projected increases in vapor pressure deficit. Even if the net water balance (precipitation minus evaporation) increases on average, the likelihood of drought, particularly during summer, increases as precipitation becomes more intense and seasonal. The severity and duration of droughts are projected to increase across most of Oregon. Droughts are projected to be 11–33 percent longer and at least 40 percent more severe by the end of the century.[167]

G. Defendants Had Knowledge on the Impact of Their Fossil Fuel Activities—But Chose Windfall Profits Over Humanity

276.

The connection between burning fossil fuels and atmospheric CO_2 pollution was first suspected in the scientific literature in 1856.[168] The connection was confirmed in 1930.[169] In 1954, scientists at the California Institute of Technology ("Cal Tech") proposed to the API to commission a study that would differentiate carbon molecules released from the burning of fossil fuels versus

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[166] Id.
[167] Id.
[168] Franta, B. Early oil industry knowledge of CO_2 and global warming. Nature Clim Change **8**, 1024–1025 (2018). https://doi.org/10.1038/s41558-018-0349-9.
[169] Id.

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natural sources.[170] Cal Tech had already determined from tree ring studies that fossil fuels had caused the atmospheric concentrations of CO_2 to rise by 5% in the past 100 years or so.[171] In 1955, the API funded the Cal Tech study, received the results, but never published the same.[172] In 1959, the renown physicist Edward Teller appeared at an API meeting and warned that the combustion of fossil fuels was contaminating the atmosphere, and would soon raise global temperatures sufficiently to melt the polar ice caps and raise the sea level.[173]

277.

On March 29, 1958, Charles Keeling began recording daily carbon in the Earth's atmosphere at the Mauna Loa observatory in Hawaii.[174] Keeling's first reading on March 29, 1958, measured the atmospheric CO_2 concentration at 313 ppm.[175]

278.

By the 1950s, the Fossil Fuel Defendants (herein also called "Oil Defendants") discovered that climate change would present dangerous risks to the world's population.[176] In response, they

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[170] Id.
[171] Id.
[172] Id.
[173] Id.
[174] Britannica, Keeling Curve, BRITANNICA, https://www.britannica.com/science/Keeling-Curve (last visited June 18, 2023).
[175] ACS, The Keeling Curve: Carbon Dioxide Measurements at Mauna Loa, ACS, https://www.acs.org/content/acs/en/education/whatischemistry/landmarks/keeling-curve.html (last visited June 18, 2023).
[176] American Institute of Physics. The discovery of Global Warming, AMERICAN INSTITUTE OF PHYSICS, (2022) https://history.aip.org/climate/index.htm#contents (last visited June 20, 2023); Craig Harmon, The Natural Distribution of Radiocarbon and the Exchange Time of Carbon Dioxide Between Atmosphere and Sea, Tellus, 1-17 (9TH Ed. 1957); Roger Revelle & Hans E.

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engaged in decades-long concerted effort to keep Multnomah County, and the rest of the United States in the dark about those risks, while they reaped profits by false and deceptive consumer advertising misinformation.

279.

In 1967, Shell, with assistance from Exxon, Chevron and BP, gathered ocean data concerning its oil platforms in the Gulf of Mexico and studied wave, wind, barometric pressure, storms, sea level, and current changes and trends on its six platforms in the Gulf of Mexico.[177] The report was necessary to develop and calibrate environmental forecasting theories to protect the industry's platforms. What they found out guided their marketing strategies for the next five decades. There is also evidence that they built their offshore platforms higher to contend with ocean rise from warming.

280.

Thus, more than fifty years ago, scientists for the Fossil Fuel Defendants concluded that "doubling in CO_2 could increase average global temperature 1°C to 3°C by 2050….10°C predicted at poles." In the 1968 report for the American Petroleum Institute (API), attached as Exhibit 1, the scientists stated:

a) "Significant temperature changes are almost certain to occur by the year 2000 and these could bring about climatic change…if the Earth's temperature increases significantly, a number of events might be

Seuss, Carbonates and carbon dioxide, Memoirs of the Geological Society of America 239–295 (1957).

177 M. Patterson, An Ocean Data Gathering Program for the Gulf of Mexico, Society of Petroleum Engineers (1969), (Available at: https://www.onepetro.org/conference-paper/SPE-2638-MS.) (last visited June 20, 2023).

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> expected to occur including the melting of the Antarctic ice cap, a rise in sea levels, warming of the oceans and an increase in photosynthesis."
>
> b) "It is clear that we are unsure as to what our long-lived pollutants are doing to our environment; however, there seems to be no doubt that the potential damage to our environment could be severe."[178]

281.

A 1969 supplemental report by scientists for API, projected that based on current fuel usage at the time, atmospheric CO_2 concentrations would reach 370 ppm by the turn of the century.[179] They proved to be ominously correct. It was 369.34 ppm in 2000.[180]

282.

API's scientists connected the rise in atmospheric CO2 concentrations to the use of fossil fuels, warning that the temptations and consequences of ignoring CO_2 as a pollutant could be of global importance as a factor that could change man's environment.[181] This report was disseminated to the oil industry through API, including to Oil Defendants Exxon, Shell, BP,

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[178] E. Robinson & R.C. Robbins, Final Report, Sources, Abundance, and Fate of Gaseous. Atmospheric Pollutants, SRI Project PR-6755, prepared for American Petroleum Institute, at 109-110.

[179] E. Robinson & R.C. Robbins, Sources, Abundance, and Fate of Gaseous Atmospheric Pollutants Supplement, Stanford Research Institute (June 1969).

[180] NASA Goddard Institute for Space Studies, Global Mean CO_2Mixing Ratios (ppm): Observations, NASA GODDARD INSTITUTE FOR SPACE STUDIES, https://data.giss.nasa.gov/modelforce/ghgases/Fig1A.ext.txt (last visited June 20, 2023).

[181] Elmer Robinson and R.C. Robbins, Sources, Abundance, and Fate of Gaseous Atmospheric Pollutants Supplement, STANFORD RESEARCH INSTITUTE (Jun. 1969), http://chr.gov.ph/wp-content/uploads/2019/11/Exhibit-3I-Sources-Abundance-and-Fate-of-Gaseous-Atmospheric-Pollutants-Supplement.pdf (last visited June 20, 2023).

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ConocoPhillips, Motiva and Anadarko (or their predecessors in interest) in a 1972 status report.[182]

283.

In clandestine fashion, the oil industry began to prepare for climate change. In 1973 and 1974, Exxon obtained a patent for a cargo ship capable of breaking sea ice and for an oil tanker designed specifically for use in previously unreachable areas of the Arctic.[183] Chevron also obtained a patent for a mobile arctic drilling platform designed to withstand significant interference from lateral ice masses,[184] allowing for drilling in areas with increased ice flow movement due to elevated temperature.

284.

Norske Shell, Royal Dutch Shell's Norwegian subsidiary[185] factored rising sea levels into plans for its "Troll A platform" to account for higher anticipated average sea levels and increased storm intensity due to global warming over the platform's 70-year operational life[186] at a cost of

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[182] Committee for Air and Water Conservation American Petroleum Institute, Environmental Research, A Status Report, Committee for Air and Water Conservation, AMERICAN PETROLEUM INSTITUTE (Jan.1972), https://files.eric.ed.gov/fulltext/ED066339.pdf (last visited Nov 15, 2022).
[183] ExxonMobil Research Engineering Co., Icebreaking cargo vessel, GOOGLE PATENTS (Apr. 17, 1973), https://patents.google.com/patent/US3727571A/en (last visited June 20, 2023); ExxonMobil Research Engineering Co., Tanker vessel, GOOGLE PATENTS (Jul. 17, 1973), (last visited June 20, 2023).
[184] Chevron Research & Technology Co., Arctic offshore platform, GOOGLE PATENTS (Aug. 27, 1974) https://patents.google.com/patent/US3831385A/fi (last visited June 20, 2023).
[185] N.Y. Times, Greenhouse Effect: Shell Anticipates A Sea Change, N.Y. TIMES (Dec. 20, 1989), http://www.nytimes.com/1989/12/20/business/greenhouse-effect-shell-anticipates-a-sea-change.html (last visited June 20, 2023).
[186] Id.; Amy Lieberman and Susanne Rust, Big Oil braced for global warming while it fought regulations, L. A. TIMES (Dec. 31, 2015), https://graphics.latimes.com/oil-operations/ (last visited June 20, 2023).

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nearly $40 million.

285.

Exxon's Henry Shaw stated in a memo to David Edward, Jr. in 1978, attached as Exhibit 2, that Exxon needed to understand the "CO_2 problem" and wanted to "assess the possible impact of the greenhouse effect on Exxon business. Exxon must develop a credible scientific team that can critically evaluate the information generated on the subject and be able to carry bad news, if any, to the corporation."[187]

286.

From 1979 to 1982, the Exxon Research and Engineering (ER&E) Company pursued major global warming-based projects.[188] Exxon's described the projects thusly: "Establish a scientific presence through research program in climate modeling; selective support of outside activities;

[187] Henry Shaw, Memo from Henry Shaw to Edward David Jr., The "Greenhouse Effect," EXXON RESEARCH AND ENGINEERING COMPANY (Dec. 7, 1978), https://www.climatefiles.com/exxonmobil/1978-exxon-memo-on-programs-developed-to-measure-co2-uptake-and-request-credible-scientific-team/ (last visited June 20, 2023).

[188] G.H. Long, Atmospheric CO_2 Scoping Study, EXXON RESEARCH AND ENGINEERING COMPANY (Feb. 5, 1981), https://www.climatefiles.com/exxonmobil/1981-exxon-report-potential-climate-change-research-programs/ (last visited June 20, 2023); A.M. Natkin, Memo Summarizing Climate Modeling and CO2 Greenhouse Effect Research, EXXON RESEARCH AND ENGINEERING COMPANY, (Sept. 2, 1982), https://www.climatefiles.com/exxonmobil/1982-exxon-memo-summarizing-climate-modeling-and-co2-greenhouse-effect-research/ (last visited June 20, 2023).

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maintain awareness of new scientific developments."[189]

287.

At a presentation for Exxon's Corporation Management Committee in 1978, attached as Exhibit 3**,** Exxon was warned that CO_2 concentrations were building in the Earth's atmosphere at an increasing rate, that CO_2 emissions attributable to fossil fuels were retained in the atmosphere, and that CO_2 was contributing to global warming.[190] An Exxon executive expressed the concern that humans have a "window of five to ten years before the need for hard decisions regarding changes in energy strategies might become critical."[191] That was **55 years ago**.

288.

Steve Knisely was a summer intern at Exxon Research and Engineering in 1979 when Exxon asked him to analyze how global warming might affect fuel use.[192] Knisley's report, attached as Exhibit 4**,** predicted that if nothing was done and that if fossil fuel use was not limited, there would be noticeable temperature changes and 400 ppm of CO_2 in the atmosphere by 2010. His prediction was remarkably accurate. There was 388.61 ppm carbon in the atmosphere on

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[189] A.J. Callegari, Corporate Research Program in Climate/CO_2-Greenhouse, EXXON CORPORATE RESEARCH PROGRAM (Feb. 2, 1984), https://www.climatefiles.com/exxonmobil/1984-exxon-report-on-climate-modeling-and-co2-effects/ (last visited June 20, 2023).

[190] Id.

[191] Id.

[192] Lisa Song, Neal Banerjee and David Hasemyer, Exxon Confirmed Global Warming Consensus in 1982 with In-House Climate Models, INSIDE CLIMATE NEWS (Sept. 22, 2015), https://insideclimatenews.org/news/22092015/exxon-confirmed-global-warming-consensus-in-1982-with-in-house-climate-models/ (last visited June 20, 2023).

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January 16, 2010, per NASA data.[193]

289.

Knisely even concluded that the fossil fuel industry might need to leave 80% of its recoverable reserves in the ground to avoid doubling CO_2 concentrations.[194]

290.

At this time, Exxon scientists expressed grave concern about the potential impacts of fossil fuel-driven global warming and advocated internally for additional fossil fuel industry-generated research considering the growing consensus that consumption of fossil fuel products was changing the planet's climate.[195]

291.

Indeed, on November 19, 1979, Exxon's Henry Shaw, the company's lead climate researcher at the time, wrote an inter-office memorandum concerning "Research in Atmospheric Science", attached as Exhibit 5**,** wherein he stated:

> We should determine how Exxon can best participate in all these [atmospheric science research] areas and influence possible legislation on environmental controls. It is important to begin to anticipate the strong intervention of environmental groups and be prepared to respond with reliable and credible data. It behooves [Exxon] to start a very aggressive defensive program in the indicated areas of atmospheric science and climate because there is a good probability that legislation affecting our business will be passed. Clearly, it is in our interest for such legislation to be based on hard scientific data. The data obtained from research

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[193] NASA, Vital Signs, NASA GLOBAL CLIMATE CHANGE, https://climate.nasa.gov/vital-signs/carbon-dioxide/ (last visited June 20, 2023).
[194] *See* Exhibit 4.
[195] Id.

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> on the global damage from pollution, e.g., from coal combustion, will give us the needed focus for further research to avoid or control such pollutants.[196]

292.

That same year, Exxon's W.L. Ferrall summarized Exxon's internal findings in a memo concerning "Controlling Atmospheric CO_2," [Exhibit 4] concluding that:

> a) the increase [in CO_2 concentration] is due to fossil fuel combustion,
>
> b) increasing CO_2 concentration will cause a warming of the earth's surface.
>
> c) present trend of fossil fuel consumption will cause dramatic environmental effects before the year 2050."[197]

293.

Doubling of CO_2 concentration (using 1860 as a baseline), Ferrall predicted that "ocean levels would rise four feet" and the "Arctic Ocean would be ice free for at least six months each year, causing major shifts in weather patterns in the northern hemisphere."[198]

294.

In 1977, upon information and belief, a publication by Marathon Oil titled Marathon World publication described with accuracy what global temperature rise linked to industrial expansion

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[196] Henry Shaw, Memo to H.N. Weinberg about Research in Atmospheric Science, Inter-Office Correspondence, EXXON CORP. (Nov. 19, 1979), https://www.climatefiles.com/exxonmobil/1979-exxon-memo-on-atmospheric-science-research-to-influence-legislation/ (last visited June 20, 2023).

[197] W.L. Ferrall, Memo to R.L. Hirsch Controlling Atmospheric CO_2, EXXON RESEARCH AND ENGINEERING COMPANY (Oct. 16, 1979). https://www.climatefiles.com/exxonmobil/1979-exxon-memo-on-potential-impact-of-fossil-fuel-combustion/ (last visited June 20, 2023).

[198] Id.

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could on day lead to "social and economic calamities."

295.

The periodical went on to state, "[a]lthough climatologists disagree on the underlying reasons, many see a future climate of greater variability, bringing with it areas of extreme drought." Marathon informed its publication recipients about the true dangers of the continued use of fossil fuels but provided no warnings or disclosures to the populous in the State of Oregon that purchased, used, and sold its products.

296.

The American Petroleum Institute and scientists from Exxon, Mobil, Amoco (now BP), Phillips (now ConocoPhillips), Texaco (now, Shell, Sunoco, Sohio (now BP)) as well as Standard Oil (now BP) and Gulf Oil (now Chevron), began the "CO_2 and Climate Task Force" to monitor and to freely share industry knowledge on climate research between 1979 and 1983.[199]

297.

In 1979, API sent its members a background memo related to API's CO_2 and Climate Task Force's efforts, stating that CO_2 concentrations were rising steadily in the atmosphere, and predicting when the first clear effects of climate change might be felt.[200]

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[199] Id.

[200] Neela Banerjee, Exxon's Oil Industry Peers Knew About Climate Dangers in the 1970s, Too, INSIDE CLIMATE NEWS (Dec. 22, 2015), https://insideclimatenews.org/news/22122015/exxon-mobil-oil-industry-peers-knew-about-climate-change-dangers-1970s-american-petroleum-institute-api-shell-chevron-texaco/ (last visited June 20, 2023).

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298.

In 1980, API's CO_2 Task Force members discussed the oil industry's responsibility to reduce CO_2 emissions by changing refining processes and developing fuels that emit less CO_2. The minutes from the Task Force's meeting on February 29, 1980 included a summary of a presentation on "The CO_2 Problem," which identified the "scientific consensus on the potential for large future climatic response to increased CO_2 levels" as a reason for API members to have concern with the "CO_2 problem" and informed attendees that there was "strong empirical evidence" that rise in CO_2 concentration was caused by anthropogenic release of CO_2, mainly from fossil fuel combustion (emphasis added).[201] Those minutes are attached as Exhibit 6.

299.

Dr. Laurman warned the Fossil Fuel Defendants that the amount of CO_2 in the atmosphere could double by 2038, which he said would likely lead to a 2.5° C (4.5º F) rise in global average temperature, resulting in "major economic consequences." He then told the task force that climate models predicted a 5°C (9º F) rise by 2067, with "globally catastrophic effects."[202] A Texaco (now Chevron) representative posited that the API CO_2 Task Force should develop ground rules for energy release of fuels and the cleanup of fuels as they relate to CO_2 creation.

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[201] American Petroleum Institute, AQ-9 Task Force Meeting Minutes, attached as Exhibit 6. AQ-9 refers to the "CO_2 and Climate" Task Force.

[202] Id.

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300.

In 1980, the API CO_2 Task Force also discussed a potential area for investigation: alternative energy sources as a means of mitigating CO_2 emissions from Defendants' fossil fuel products. These efforts called for research and development to "Investigate the Market Penetration Requirements of Introducing a New Energy Source into Worldwide Use." Such investigation was to include the technical implications of energy source changeover, research timing, and requirements.

301.

These Meeting Minutes from the February 29, 1980, meeting of the CO_2 and Climate Task Force, reflected a dire prediction:

CLIMATE MODELING – CONCLUSIONS

- GLOBAL AVERAGED 2.5º C RISE EXPECTED BY 2038 AT A 3% p.a. GROWTH RATE OF ATMOSPHERIC CO_2 CONCENTRATION
- LARGE ERROR IN THIS ESTIMATE - 1 IN 10 CHANCE OF THIS CHANGE BY 2005
- NO REGIONAL CLIMATE CHANGE ESTIMATES YET POSSIBLE
- LIKELY IMPACTS:

1º C RISE (2005):	BARELY NOTICEABLE
2.5º C RISE (2038):	MAJOR ECONOMIC CONSEQUENCES, STRONG REGIONAL DEPENDENCE
5º C RISE (2067):	GLOBALLY CATASTROPHIC EFFECTS

302.

The Climate Task Force estimated that the Earth would warm up by 2.5° C by 2038. The February 29, 1980, meeting of API's CO_2 and Climate Task Force concluded with the following warning:

CONCLUSIONS

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AT A 3% PER ANNUM GROWTH RATE OF CO_2, **A 2.5ºC RISE BRINGS WORLD ECONOMIC GROWTH TO A HALT IN ABOUT 2025**.[203]

303.

Exxon scientist Roger Cohen warned his colleagues in a 1981 internal memorandum, attached as Exhibit 7, that "future developments in global data gathering and analysis, along with advances in climate modeling, may provide strong evidence for a delayed CO_2 effect of a truly substantial magnitude," and that under certain circumstances it would be "very likely that we will unambiguously recognize the threat by the year 2000.[204] Cohen previously expressed concern that the memorandum mischaracterized potential effects of unabated CO_2 emissions from Defendants' fossil fuel products: "[I]t is distinctly possible that the . . . [Exxon Planning Division's] scenario will produce effects which will indeed be catastrophic (at least for a substantial fraction of the world's population)."[205]

304.

In 1981, Exxon's Henry Shaw prepared a summary of Exxon's current position on the greenhouse effect, attached as Exhibit 8**,** for Edward David Jr., president of Exxon Research and Engineering, stating in relevant part that: "Atmospheric CO_2 will double in 100 years if fossil fuels grow at 1.4%"… there will be a "3° Celsius global average temperature rise and 10° Celsius at

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[203] Id. (emphasis added).
[204] Roger W. Cohen, Exxon Memo to W. Glass about possible "catastrophic" effect of CO_2, Inter-Office Correspondence, EXXONMOBIL CORP. (Aug. 18, 1981), https://www.mass.gov/files/documents/2016/10/tp/exxon-appendix-memo-support.pdf (last visited (last visited June 20, 2023).
[205] Id.

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poles if CO_2 doubles" and there will be "major shifts in rainfall/agriculture" and "polar ice may melt."[206]

305.

In 1982, another report prepared for API by scientists at the Lamont-Doherty Geological Observatory at Columbia University, attached as Exhibit 9, recognized that atmospheric CO_2 concentration had risen significantly compared to the beginning of the industrial revolution from about 290 parts per million to about 340 parts per million in 1981 and acknowledged that despite differences in climate modelers' predictions, all models indicated a temperature increase caused by anthropogenic CO_2 within a global mean range of 4º C (7.2° F).

306.

Roger W. Cohen of Exxon Memo, summarizing findings of research in climate modeling, Exxon Research Engineering Co. dated Sept. 2, 1982, report advised that there was scientific consensus that "a doubling of atmospheric CO_2 from pre-industrial revolution value would result in an average global temperature rise of (3.0 ± 1.5)° C [5.4 ± 2.7° F]." It went further, warning that "[s]uch a warming can have serious consequences for man's comfort and survival since patterns of aridity and rainfall can change, the height of the sea level can increase considerably, and the world food supply can be affected."[207]

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[206] Henry Shaw, Exxon Memo to E. E. David, Jr. about "CO_2Position Statement, Inter-Office Correspondence, EXXONMOBIL CORP. (May 15, 1981), https://docs.house.gov/meetings/GO/GO28/20190409/109294/HMTG-116-GO28-20190409-SD007.pdf (last visited June 20, 2023).

[207] American Petroleum Institute, Climate Models and CO_2 Warming: A Selective Review and Summary, Lamont-DOHERTY GEOLOGICAL OBSERVATORY (COLUMBIA UNIVERSITY) (Mar. 1982),

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307.

Also, in 1982, Exxon's Environmental Affairs Manager, M.B. Glaser, distributed a primer on climate change, attached as Exhibit 10**,** to a "wide circulation [of] Exxon management…. intended to familiarize Exxon personnel with the subject."[208] The primer also was "restricted to Exxon personnel and not to be distributed externally."[209]

308.

Glaser submitted a chart to Exxon which reflected CO_2 in the atmosphere, and how the temperature would increase by year:[210]

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https://insideclimatenews.org/wp-content/uploads/2016/02/API-1982-Climate-models-and-CO2-warming.pdf (last visited June 20, 2023).

[208] M.B. Glaser, Exxon Memo to Management about "CO_2 'Greenhouse' Effect", Exxon Research and Engineering Co. (Nov. 12, 1982), https://www.climatefiles.com/exxonmobil/1982-memo-to-exxon-management-about-co2-greenhouse-effect/ (last visited June 20, 2023).

[209] Id.

[210] Id. at 7.

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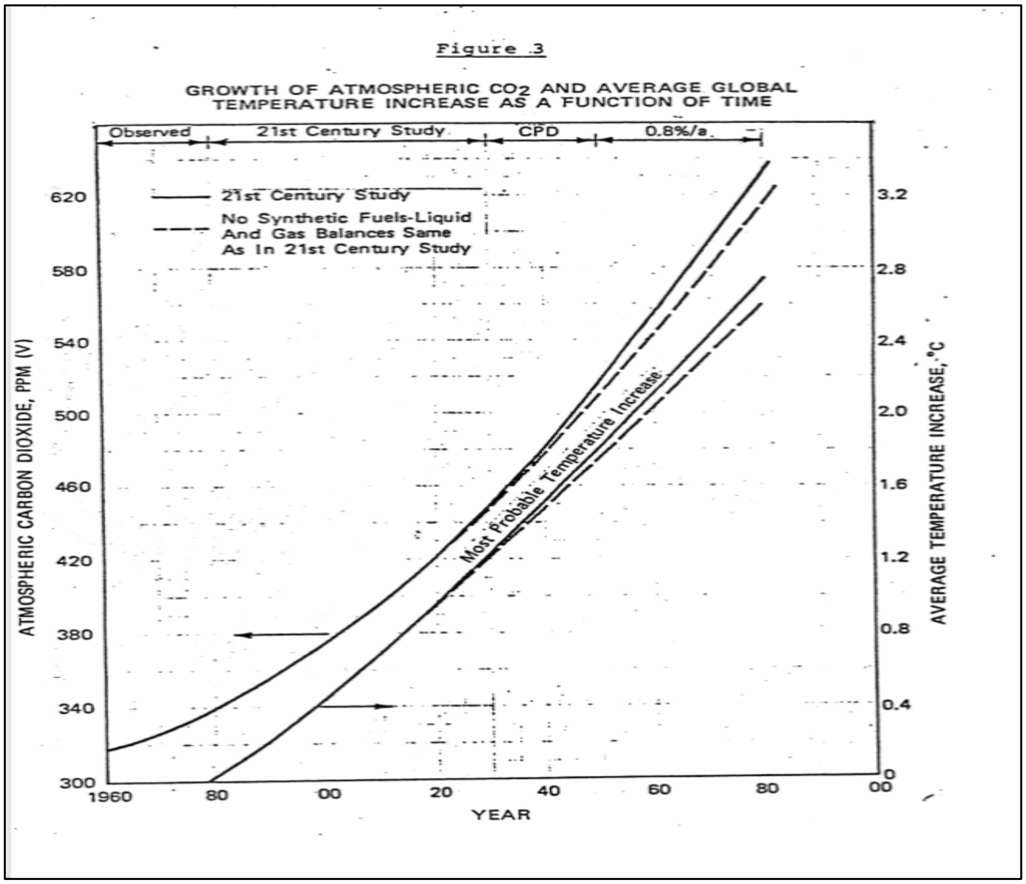

309.

Glaser's primer collected science on climate change available at the time and confirmed fossil fuel combustion as a primary anthropogenic contributor to global warming. The report estimated a CO_2 doubling around 2090 based on Exxon's long-range modeled outlook.

310.

Glaser warned that "there are some potentially catastrophic events that must be considered," including increased sea surface temperatures, and the loss of Antarctic ice sheets.[211]

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[211] Id.

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It noted that some scientific groups were concerned "that once the effects are measurable, they might not be reversible."[212]

311.

During the time the Task Force was in effect, the development of shale oil was of paramount concern to API. It was discussed that the production of oil shale may generate 3-5 times more carbon emissions.[213]

312.

Director of Exxon's Theoretical and Mathematical Sciences Laboratory Roger Cohen agreed and wrote that "the time required for doubling of atmospheric CO_2 depends on future world consumption of fossil fuels." Cohen concluded that Exxon's own results were "consistent with the published predictions of more complex climate models" and "in accord with the scientific consensus on the effect of increased atmospheric CO_2 on climate."[214]

313.

In October 1982, attended by members of API, Exxon Research and Engineering Company president E.E. David delivered a speech titled: "Inventing the Future: Energy and the CO_2 'Greenhouse Effect.'"[215] His remarks, attached as Exhibit 11**,** included the following statement:

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[212] Id.

[213] Id.

[214] Cohen, *supra* note 204.

[215] Dr. E. E. David, Jr., Inventing the Future: Energy and the CO_2 Greenhouse Effect: Remarks at the Fourth Annual Ewing Symposium, Tenafly, NJ, EXXON RESEARCH AND ENGINEERING COMPANY, (Oct. 26, 1982), https://www.climatefiles.com/exxonmobil/inventing-future-energy-co2-greenhouse-effect/ (last visited June 20, 2023).

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"[F]ew people doubt that the world has entered an energy transition away from dependence upon fossil fuels and toward some mix of renewable resources that will not pose problems of CO_2 accumulation." He went on, discussing the human opportunity to address anthropogenic climate change before the point of no return:

> It is ironic that the biggest uncertainties about the CO_2 buildup are not in predicting **what the climate will do, but in predicting what people will do**. . .. [It] appears we still have time to generate the wealth and knowledge we will need to invent the transition to a stable energy system.[216]

314.

Throughout the early 1980s, at Exxon's direction, Exxon climate scientist Henry Shaw forecasted emissions of CO_2 from fossil fuel use. Those estimates were incorporated into Exxon's 21st century energy projections, attached as Exhibit 12, and were distributed among Exxon's various divisions.

315.

Shaw's conclusions included an expectation that atmospheric CO_2 concentrations would double in 2090 per the Exxon model, with an attendant 2.3–5.6º F average global temperature increase. Shaw compared his model results to those of the U.S. EPA, the National Academy of Sciences, and the Massachusetts Institute of Technology, indicating that the Exxon model predicted a longer delay than any of the other models, although its temperature increase prediction was in

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[216] Id. (emphasis added).

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the mid-range of the four projections.[217]

316.

During the 1980s, these Defendants additionally formed their own research units focused on climate modeling. The API, including the API CO_2 Task Force, provided a forum for Defendants to share their research efforts and corroborate their findings related to anthropogenic greenhouse gas emissions.[218]

317.

James J. Nelson, the former director of the task force, was interviewed by Inside Climate News' Neela Banerjee and said that by 1983, the CO_2 and Climate Task Force was maneuvered by API into lobbying against regulation. "They (API) were less interested in pushing the envelope of science and more interested in how to make it more advantageous politically or economically for the oil industry."[219]

318.

By the early 1980s the Defendants had initiated a five-point plan in response to their unique knowledge of the danger faced by the world's population, as a result of the ever-increasing sale and use of their products. First, hide or obfuscate the dangers of climate change; second, increase

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[217] Neela Banerjee, More Exxon Documents Show How Much It Knew About Climate 35 Years Ago, INSIDE CLIMATE NEWS (Dec. 1, 2015), https://insideclimatenews.org/news/01122015/documents-exxons-early-co2-position-senior-executives-engage-and-warming-forecast (last visited June 20, 2023).
[218] Banerjee, *supra* note 200.
[219] Id.

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supply and production; third, decrease prices; fourth, prevent non-carbon energy sources from developing; and fifth, stop or deter regulation of the carbon industry.

319.

During this time, the Fossil Fuel Defendants' statements express an understanding of their obligation to consider and mitigate the externalities of unabated promotion, marketing, and sale of their fossil fuel products, but they failed to do so, leaving our planet exposed to dangers.

320.

Fossil Fuel Defendants have long understood grim truths about the global harm caused by their products and expressed them in insular circles before working to sow public doubt about their veracity. For example, in 1988, Richard Tucker, then president of Mobil Oil, observed to industry colleagues:

> [H]umanity, which has created the industrial system that has transformed civilizations, is also responsible for the environment, which sometimes is at risk because of unintended consequences of industrialization…. Maintaining the health of this life-support system is emerging as one of the highest priorities…. [W]e must all be environmentalists. The environmental covenant requires action on many fronts…the low-atmosphere ozone problem, the upper-atmosphere ozone problem and the greenhouse effect, to name a few…. Our strategy must be to reduce pollution before it is ever generated – to prevent problems at the source. Prevention means engineering a new generation of fuels, lubricants and chemical products…. Prevention means designing catalysts and processes that minimize or eliminate the production of unwanted byproducts…. Prevention on a global scale may even require a dramatic reduction in our dependence on fossil fuels—and a shift towards solar, hydrogen, and safe nuclear power. It may be possible that—just possible—that the energy industry will transform itself so completely that observers will declare it a new industry….

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> Brute force, low-tech responses and money alone won't meet the challenges we face in the energy industry.[220]

321.

Also, in 1988, the Shell Greenhouse Effect Working Group issued a confidential internal report, "The Greenhouse Effect," attached as Exhibit 13, which acknowledged global warming's anthropogenic nature: "Man-made carbon dioxide released into and accumulated in the atmosphere is believed to warm the earth through the so-called greenhouse effect." The authors also noted the burning of fossil fuel as a primary driver of CO_2 buildup and warned that ocean warming would impact marine species populations and that "shifts in ranges and migration patterns could result in local losses of food source revenues and could require [fishing] operations in other (more distant) grounds."[221]

322.

In addressing "Socio-economic implications" of climate change, the authors noted that, "[w]hile the greenhouse effect is a global phenomenon, the consequences and many of the socio-economic implications will be regional and local …." The authors went on to address specific impacts including "Changing air temperature."[222]

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[220] Richard E. Tucker, High Tech Frontiers in the Energy Industry: The Challenge Ahead, AICHE NATIONAL MEETING (Nov. 30, 1988).

[221] Shell Internationale Petroleum, Greenhouse Effect Working Group, The Greenhouse Effect, SHELL INTERNATIONALE PETROLEUM (May 30, 1988) https://www.climatefiles.com/shell/1988-shell-report-greenhouse/ (last visited June 20, 2023).

[222] Id.

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323.

Local temperature change, the report stated, may necessitate local adaptation of the buildings in which people live and work, technologies for heating or cooling, energy sources for heating and cooling, new food preparation technologies, new cultivation techniques, etc. All such adaptations are costly, and some would drastically change the way people live and work.[223]

324.

Given these and other socio-economic implications, the Shell Greenhouse Effect Working Group advocated for a plan in which industry would work with governments to address the problem:

> With fossil fuel combustion being the major source of CO_2 in the atmosphere, a forward-looking approach by the energy industry is clearly desirable, seeking to play its part with governments and others in the development of appropriate measures to tackle the problem.[224]

325.

Like early warnings by Exxon scientists, the Shell report notes that "by the time the global warming becomes detectable it could be too late to take effective countermeasures to reduce the effects or even to stabilize the situation." The authors mention the need to consider policy changes on multiple occasions, noting that "the potential implications for the world are…so large that policy options need to be considered much earlier" and that research should be "directed more to

[223] Id. at 27-28.
[224] Id. at 1.

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the analysis of policy and energy options than to studies of what we will be facing exactly."[225]

326.

The Fossil Fuel Defendants Exxon, Shell, BP, ConocoPhillips, Motiva, Valero, Total and Anadarko (and their predecessors in interest) were at the forefront of carbon dioxide research for much of the latter half of the 20th century. Collectively, they studied and developed cutting edge and innovative technology, working with top researchers to produce exceptionally sophisticated greenhouse gas studies and climate change models.

327.

The Fossil Fuel Defendants actively participated in committees, boards and groups for the American Petroleum Institute, Western States Petroleum Association (and others) and received numerous studies and updates from various committees regarding industry wide knowledge.

328.

The largest Fossil Fuel Defendants worked with McKinsey to create strategies that allowed for exponential increase in the use of their products, artificial creation of energy dependence, and control climate messaging to create doubt.

329.

Defendants failed to act reasonably to mitigate or avoid the dire adverse impacts their scientists carefully predicted. Defendants instead adopted the position, as described below, that the absence of meaningful regulations on the consumption of their fossil fuel products was the

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[225] Id.

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equivalent of a social license to continue the unfettered pursuit of profits from those products. This position was an abdication of Defendants' obligation to consumers and the public, including Multnomah County, to act on their unique knowledge of the hazards of unabated production and consumption of their fossil fuel products.

330.

By 1988, Defendants had amassed a compelling body of knowledge about the role of anthropogenic greenhouse gases—specifically those emitted from the normal use of Defendants' fossil fuel products—in causing global warming, increased mean surface temperature, heatwaves, and the attendant consequences for human communities and the environment.

331.

The Fossil Fuel Defendants possessed actual knowledge that their products were causing global climate change and predicted dire effects on the planet. The Fossil Fuel Defendants were faced with the decision of whether to take steps to limit the damages their fossil fuel products were causing and would continue to cause for virtually every area of the globe, including Multnomah County.

332.

It was also during this time that the Fossil Fuel Defendants were investing in offshore platforms and needed to study climate change to protect their own assets from rising sea levels. These investments included (among others), raising offshore oil platforms to protect against sea level rise; reinforcing offshore oil platforms to withstand increased wave strength and storm severity; and developing and patenting designs for equipment intended to extract crude oil and/or

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natural gas in areas previously unreachable because of the presence of polar ice sheets.[226] The Defendants understood that to effectuate their conspiracy and enterprise, they must find more oil and gas, produce more, maintain low prices, and stifle the alternative energy source companies and the governmental regulators.

333.

Ordinary care required Defendants to have taken any of several steps to mitigate the damages caused by their fossil fuel products, and their own comments reveal an awareness of the steps they were required to take.

334.

Ordinary care required Defendants to have made reasonable warnings to consumers, the public, and regulators of the dangers known to them of the unabated consumption of their fossil fuel products and were required to have taken reasonable steps to limit the potential greenhouse gas emissions arising out of those products.

335.

The Defendants acted carelessly and recklessly, rather than reasonably or with ordinary care. They mobilized with the coal and fossil fuel dependent industries to manufacture and spread propaganda and deception about climate science, contrary to their own internal scientific

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[226] Amy Lieberman and Suzanne Rust, Big Oil braced for global warming while it fought regulations, L.A. TIMES (Dec. 31, 2015), https://graphics.latimes.com/oil-operations/ (last visited June 20, 2023).

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conclusions, to ensure the sale of their products to consumers worldwide and in Multnomah County.

336.

Exxon instructed Duane Levine, Exxon's manager of science and strategy development, to give a primer to the company's board of directors on February 22, 1989, which is attached as Exhibit 14.

337.

Levine told the board of directors what they already knew ten years prior: There was general consensus among scientists that the burning of fossil fuels could raise global temperatures significantly by the middle of the 21st century — between 2.7 and 8.1° F — causing glaciers to melt and sea levels to rise."[227] Speaking of impending regulation, Exxon's LeVine warned "arguments that we can't tolerate delay and must act now can lead to irreversible and costly Draconian steps."[228]

338.

Levine quoted from the 1983 "Changing Climate Report" from the Natural Research Council. [229]

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[227] Katie Jennings, Dino Grandoni and Susanne Rust, How Exxon went from leader to skeptic on climate change research, L. A. TIMES (Oct. 23, 2015), https://graphics.latimes.com/exxon-research/ (last visited June 20, 2023).
[228] Id.
[229] *See*, Exhibit 15.

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339.

In a 1989 internal newsletter, attached as Exhibit 15, Exxon's resident climate expert Brian Flannery confirmed that regulatory efforts to reduce the risk of climate change, would "alter profoundly the strategic direction of the energy industry." And he warned that the impact on the company from those efforts "will come sooner … than from climate change itself."[230]

340.

Reiterating the position taken a decade earlier, Joseph M. Carlson, Exxon Memo on "The Greenhouse Effect" dated Aug. 3, 1988, attached as Exhibit 16, described the "Exxon Position," which included among others, two important tenets:

> a) **emphasize the uncertainty** in scientific conclusions regarding the potential enhanced Greenhouse Effect; and
>
> b) **resist** the overstatement and sensationalization (sic) of potential greenhouse effect which could lead to noneconomic development of non-fossil fuel resources.[231]

H. The Global Climate Coalition: The Propaganda Machine

341.

Though the Fossil Fuel Defendants are market competitors in some respects, they share a common purpose to sell as many of their polluting products as possible and to deceive or

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[230] Id.

[231] Joseph M. Carlson, Exxon Memo on "The Greenhouse Effect", EXXONMOBIL CORP. (Aug. 3, 1988). https://www.climatefiles.com/exxonmobil/566/#:~:text=In%20the%20document%2C%20Carlson%20states,can%20have%20disastrous%20environmental%20impacts (last visited June 20, 2023).

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overwhelm those who may wish to modify that behavior. In furtherance of that shared objective, the Fossil Fuel and Coal Defendants converged and formed the "Global Climate Coalition" ("GCC") to fund and coordinate a multi-year, multi-million-dollar, multi-organization misinformation campaign designed explicitly to undermine climate science and further their business interests.

342.

Multnomah County alleges a pattern of conduct that includes the Defendants' conscious efforts to hide behind third parties, touted as "green" or "pro-environment." This practice is a form of greenwashing, sometimes referred to as "green sheen." Greenwashing is a public relations spin to promote the public's perception that an organization's products, aims, or policies are environmentally friendly.[232] Greenwashing was used when forming the Global Climate Coalition and became a repetitive and effective scheme to deceive consumers.

343.

The GCC was formed in 1989 as a public relations and international lobbyist group of businesses that opposed action to reduce greenhouse gas emissions and publicly challenged the science behind global warming, even though the founders knew otherwise. The following is a list of the founding members of the GCC on November 16, 1989: [233]

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[232] The Age of Persuasion, Season 5: It's Not Easy Being Green: Green Marketing, CBC RADIO (Jan. 8, 2011).

[233] Global Climate Coalition, Global Climate Coalition Membership, GLOBAL CLIMATE COALITION (Nov. 16, 1989), https://www.climatefiles.com/denial-groups/global-climate-coalition-collection/1989-membership/ (last visited June 20, 2023).

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Global Climate Coalition Membership

Aluminum Association
American Electric Power Service Corporation
American Gas Association
American Iron & Steel Institute
American Mining Congress
American Nuclear Energy Council
American Paper Institute
American Petroleum Institute
Amoco Corporation
ARCO
Armco, Inc.
Association of Home Appliance Manufacturers
Automobile Importers of America
BHP - Utah International, Inc.
Business Roundtable
Chemical Manufacturers Association
Chrysler Corporation
Clean Air Working Group
Coalition Opposed to Energy Taxes
Consolidation Coal Company
Consumers Power Company
Council of Industrial Boiler Owners
Dow Chemical Company
E.I. Dupont de Nemours & Company, Inc.
Eastman Kodak
Edison Electric Institute
Electricity Consumers Resource Council
Ford Motor Company
General Motors Corporation
Georgia Pacific Corporation
Hercules Inc.
IBM
Jefferson Energy Foundation
Maytag Corporation
Motor Vehicle Manufacturers Association
National Association of Manufacturers
National Coal Association
National Steel Corporation
Occidental Chemical Corporation
Pacific Gas & Electric Company
Peabody Holding Company, Inc.
Petrochemical Energy Group
Petroleum Marketers Association of America
Phillips Petroleum Company
Portland Cement Association
PPG Industries
Process Gas Consumers Group
Rubber Manufacturers Association
Shell Oil Company
Society of the Plastics Industry, Inc.
Southern Company Services, Inc.
Texaco, Inc.
Union Carbide Corporation
UNOCAL Corporation
U.S. Chamber of Commerce
U.S. Council for Energy Awareness
U.S. Council for International Business

344.

The GCC, on behalf of Fossil Fuel Defendants and other fossil fuel companies, funded advertising campaigns and distributed material to misinform the public about climate change, with the specific purpose of preventing U.S. adoption of the Kyoto Protocol—an international treaty that commits state parties to reduce greenhouse gas emissions, based on the scientific

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consensus that global warming is occurring—despite the leading role that the U.S. had played in the Protocol negotiations.[234]

345.

From the outset, the corporate interests that controlled the central components of the GCC were fossil fuel producers, including coal mining interests, oil and gas companies, and fossil fuel dependent industries, including coal-burning utilities, railroads who moved coal, automobiles, and chemical companies. Approximately 53% of membership in the GCC centered around fossil fuel activities, namely coal, oil, and auto companies. These companies also represented approximately 38% of board membership.[235] The Oil and Gas Defendants were integral to the foundation and purpose of the GCC.

346.

The GCC was "reorganized" in 1992 by Phillips Petroleum (now ConocoPhillips), BHP (now BP), Ford, National Mining Association, Shell, Texaco (now Chevron), Exxon, Chrysler (now FCA), General Motors, the National Association of Manufacturers, the American Petroleum Institute (Oil and Gas Defendants), the National Coal Association, among many other fossil fuel

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[234] Id.

[235] The Global Climate Coalition, Big Business Funds Climate Change Denial and Regulatory Delay, CLIMATE INVESTIGATIONS CENTER (Mar. 25, 2019), https://climateinvestigations.org/wp-content/uploads/2019/04/The-Global-Climate-Coalition-Denial-and-Delay.pdf (last visited June 20, 2023).

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dependent companies.[236]

347.

The GCC, including its member corporations and member trade associations, represented hundreds of thousands of businesses and was managed by Ruder Finn, a public relations firm.[237]

348.

Despite an internal primer stating that various "contrarian theories"—i.e., climate change skepticism—do not "offer convincing arguments against the conventional model of greenhouse gas emission induced climate change," GCC excluded this section from the public version of the backgrounder (talking points) and instead funded efforts to promote those same contrarian theories. It does so to this day.[238]

349.

The GCC's financial information is not publicly available, though some has been uncovered by researchers. GCC's advocacy activities including political lobbying, aggressive and

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[236] Ian McGregor, *Organizing to Influence the Global Politics of Climate Change,* AUSTRALIAN AND NEW ZEALAND ACADEMY OF MANAGEMENT CONFERENCE (2008), https://opus.lib.uts.edu.au/bitstream/10453/11492/1/2008000811OK.pdf (last visited June 20, 2023).

[237] Wendy E. Franz, Science, skeptics, and non-state actors in the greenhouse, BELFER CENTER FOR SCIENCE AND INTERNATIONAL AFFAIRS (Sept. 1998), https://www.belfercenter.org/sites/default/files/legacy/files/Science%20Skeptics%20and%20Non-State%20Actors%20in%20the%20Greenhouse%20-%20E-98-18.pdf (last visited June 20, 2023).

[238] Gregory J. Dana, Memo to AIAM Technical Committee Re: Global Climate Coalition (GCC) – Primer on Climate Change Science – Final Draft, ASSOCIATION OF INTERNATIONAL AUTOMOBILE MANUFACTURERS (Jan. 18, 1996), https://www.ucsusa.org/sites/default/files/attach/2015/07/Climate-Deception-Dossier-7_GCC-Climate-Primer.pdf (last visited June 20, 2023).

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misleading promotion of promotion of climate change denialism, criticism of the processes of international climate organizations, critiques of reliable but ominous climate models, and personal attacks on scientists and environmentalists whose work confirms that GHGs are warming the planet and thereby inducing devastating weather events.

350.

The effort included promoting their hazardous products through advertising campaigns and the initiation and funding of climate change denialist organizations, designed to influence consumers to continue using Defendants' fossil fuel products regardless of those products' damage to communities and the environment.

351.

The Fossil Fuel Defendants took affirmative steps to conceal from the Multnomah County, its residents, and the public, the foreseeable impacts of the use of their fossil fuel products on the planet's climate and associated harms to people and communities. Using the GCC, these Defendants embarked on a public relations campaign and colluded with Fossil Fuel Defendants, among others, to deceive the public about the science connecting global climate change to fossil fuel products and greenhouse gas emissions, to influence public perception of the existence of anthropogenic global warming. Under the guise of the GCC, the Fossil Fuel Defendants were able to collude with other members to accomplish what it could not fully do on their own: discredit scientific consensus and foster deception. In doing so, they exponentially increased the sales of their products, expanded consumer demand for them, and built an energy monopoly.

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352.

A key strategy in Defendants' efforts to discredit scientific consensus on climate change, including the Intergovernmental Panel on Climate Change ("IPCC"), a body of scientists from every major country created by the United Nations, was to bankroll and hide behind scientists who, although sometimes accredited, held fringe opinions that were even more suspect given the sources of their research funding, which was not publicly disclosed and contrary to the insiders' own conclusions about their consumer products. These scientists obtained part or all their research budget from Defendants directly or through Defendant-funded organizations like API,[239] but failed to disclose their fossil fuel industry underwriters in violation of common law fraud and consumer protections laws.[240]

353.

In 1991, the Defendants were a part of another greenwashed front group, Information Council on the Environment ("ICE"), with the express purpose of deceiving the public about climate science. ICE was a U.S. organization created by the National Coal Association, the Western Fuels Association, and Edison Electrical Institute.

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[239] Willie Soon & Sallie Baliunas, Proxy Climatic and Environmental Changes of the Past 1000 Years, 23 Climate Research at 88,105 (Jan. 31, 2003) https://www.jstor.org/stable/24868339 (last visited June 20, 2023).

[240] Smithsonian, *Smithsonian Statement: Dr. Wei-Hock (Willie) Soon*, LEGISTORM (Feb. 26, 2015). https://www.legistorm.com/stormfeed/view_rss/529271/organization/36823/title/smithsonian-statement-dr-wei-hock-willie-soon.html (last visited June 20, 2023).

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354.

ICE launched a $500,000 advertising and public relations campaign to determine if their deceptive "science approach sells" [241] and, in ICE's words, "reposition global warming as theory (not fact)" a framing that makes clear that by 1991 global warming was an accepted scientific fact, and that the group's objectives to "reposition global warming as a theory" were pure propaganda, not based in science. Patrick Michaels, Robert Balling and Sherwood B. Idso all lent their names in 1991 to its scientific advisory panel.[242]

355.

The Defendants' publicity plan called for placing these three scientists, along with fellow climate change denier S. Fred Singer, in broadcast appearances, op-ed pages, and newspaper interviews by its public relations firm.[243]

356.

Another company was contracted to conduct opinion polls, which identified "older, less-educated males from larger households who are not typically active information-seekers" and "younger, lower-income women" as "good targets for radio advertisements" that would "directly attack the proponents of global warming …. through comparison of global warming to historical

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[241] *See* May 7, 1991, correspondence from E. Erie to O. Mark DeMichele.

[242] Kathy Mulvey & Seth Shulman, The Climate Deception Dossier Internal Fossil Fuel Industry Memos Reveal Decades of Corporate Disinformation, UNION OF CONCERNED SCIENTISTS (July 2015), at 20, https://www.ucsusa.org/sites/default/files/attach/2015/07/The-Climate-Deception-Dossiers.pdf (last visited June 20, 2023).

[243] Matthew L. Wald, Pro-Coal Ad Campaign Disputes Warming Idea, N. Y. TIMES (Jul. 8, 1991), https://www.nytimes.com/1991/07/08/business/pro-coal-ad-campaign-disputes-warming-idea.html (last visited June 20, 2023).

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or mythical instances of gloom and doom."[244]

357.

ICE used print campaigns to influence public opinion. One such campaign showed a sailing ship about to drop off the edge of a flat world into the jaws of a waiting dragon. The headline read: "Some say the earth is warming. Some also said the earth was flat." Another featured a cowering chicken under the headline, "Who Told You the Earth Was Warming . . . Chicken Little?" Another ad was targeted at Minneapolis readers and asked, "If the earth is getting warmer, why is Minneapolis getting colder?"

358.

The images appearing below are some examples of ICE-funded print advertisements challenging the validity of climate science and intended to obscure the scientific consensus on anthropogenic climate change and reduce political inertia to address it.[245]

[244] Id.
[245] Mulvey & Shulman, *supra* note 242.

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359.

The goals of ICE's advertising campaign were to undermine the science, manufacture deception and dupe public opinion regarding the realities of global warming. A memo from Richard Lawson, president of the National Coal Association, asked members to contribute to the ICE campaign with the justification that policymakers are prepared to act on global warming, noting that opinion polls revealed 60% of Americans believed global warming was a serious

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environmental problem and that "our industry cannot sit on the sidelines in this debate."[246] The ICE propaganda strategy is attached as Exhibit 17.

360.

In December 1992, the Global Climate Coalition's Executive Director, John Shales, wrote in a letter to *The New York Times*: "...there is considerable debate on whether or not man-made greenhouse gases (produced primarily by burning fossil fuels) are triggering a dangerous 'global warming' trend." The letter in full:

> **To the Editor:**
>
> "Cheapest Protection of Nature May Lie In Taxes, Not Laws" (Science Times, Nov. 24) echoes the theme that bad taxes become good taxes (alias "green fees") when they tax "bad" things. According to the article, these include fossil fuels, traffic and household garbage.
>
> While tax policy can affect behavior, misguided tax policy can dampen economic prosperity in attempting to solve problems that might not exist or that could be solved in less onerous ways. The World Resources Institute study you cite asks Americans to pay higher energy prices to prevent catastrophic global warming.
>
> But there is considerable debate on whether or not man-made greenhouse gases (produced primarily by burning fossil fuels) are triggering a dangerous "global warming" trend. At an international meeting of climate experts in 1990, an intergovernmental panel on climate change concluded that "it is impossible to prove a cause-and-effect relationship" between man-made emissions and global warming. In the 1992 supplement to that report, the scientists stated, "It is still not

[246] Naomi Oreskes, My Facts Are Better Than Your Facts: Spreading Good News about Global Warming, in Peter Howlett et al., How Well Do Facts Travel? The Dissemination of Reliable Knowledge, CAMBRIDGE UNIVERSITY PRESS (2011), at 136–66, https://doc.lagout.org/Others/Cambridge.University.Press-How.Well.Do.Facts.Travel.2010.RETAiL.EBook.pdf (last visited June 19, 2023).

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> possible to attribute with high confidence all, or even part of, the observed global warming to the enhanced greenhouse effect."
>
> We know that climate change over the last 100 years is well within the planet's natural variation (the global climate has never been "stable"). If scientists don't agree that man-made global warming is a problem, does the United States want to pay the costs incurred from an energy tax, including a diminished competitive position with our trading partners? A major Japanese Government agency has backed away from a carbon tax because of its impact on industry. You cite a $5 trillion price tag in the study.
>
> The American business community has made significant improvements in energy efficiency and now spends approximately $100 billion a year complying with environmental regulations. These improvements have resulted in a substantial reduction in greenhouse gas emissions.
>
> A green fee is a carbon tax, and a carbon tax is an energy tax. That translates into higher prices, lost jobs, reduced paychecks and slower growth.[247]

361.

That year, in 1992, the GCC distributed a video entitled *The Greening of Planet Earth,*[248] to media, policy makers and its competitors, several Middle Eastern oil-producing countries, which claimed that increasing atmospheric carbon dioxide could boost crop yields and solve world

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[247] John Schlaes, What Global Warming?, N.Y. TIMES (Dec. 22, 1992), https://www.nytimes.com/1992/12/22/opinion/l-what-global-warming-250692.html (last visited June 20, 2023).

[248] A sequel, entitled, The Greening of Planet Earth Continues, was released in 1998. The video was narrated by Sherwood Idso. The Greening Earth Society, now defunct, was a public relations organization which denied the effects of climate change and the impacts of increased levels of carbon dioxide. The Society published the World Climate Report, a newsletter edited by Patrick Michaels of the Cato Institute.

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hunger. These claims were inconsistent with climate models by the Fossil Fuel Defendants that predicted global climatic catastrophe.[249]

362.

Amidst this propaganda to muddy the waters of climate change facts, the United Nations began preparation for the 1992 Earth Summit in Rio de Janeiro, Brazil. The Summit was a major, newsworthy gathering of 172 world governments, of which 116 sent their heads of state. On May 9, 1992, the United Nations Framework Convention on Climate Change ("UNFCCC") adopted an international environmental treaty providing protocols for future negotiations aimed at "stabiliz[ing] greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." The treaty was opened for signature at the Earth Summit in Rio de Janeiro on June 14, 1992.

363.

Candace Crandall of Science & Environmental Policy Project ("SEPP") registered at the IPPC's Rio Earth Summit as a "publicist" for the "science team" while the GCC ran an industry-wide collaborative delay and disinformation program to try to block decisions being taken at the Summit. These actions were coordinated by public relations giant Burson-Marsteller. The main anti-IPPC operation in Rio at the 1992 Earth Summit was run by the Global Climate Coalition.[250]

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[249] Amy Lieberman and Susanne Rust, Big Oil braced for global warming while it fought regulations, L. A. TIMES (Dec. 31, 2015), https://graphics.latimes.com/oil-operations/ (last visited June 19, 2023).

[250] The Center for Media and Democracy, Candace C. Crandall, CENTER FOR MEDIA AND DEMOCRACY (CMD) https://www.sourcewatch.org/index.php/Candace_C._Crandall (last visited June 19, 2023).

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364.

These world events marked a shift in public discussion of climate change, and the initiation of international efforts to curb anthropogenic greenhouse emissions—developments that had stark implications for, and would have diminished the profitability of, Defendants' fossil fuel products.

365.

The GCC's indoctrination, which focused on concealing, discrediting, and/or misrepresenting information that tended to support restricting consumption of (and thereby decreasing demand for) Defendants' fossil fuel products, enabled Defendants to accelerate their business practice of exploiting fossil fuel reserves, and concurrently externalize the social and environmental costs of their fossil fuel products.

366.

These activities stood in direct contradiction to the Fossil Fuel Defendants' prior recognition that the science of anthropogenic climate change was clear and that the greatest uncertainties involved responsive human behavior, not scientific understanding of the issue.

367.

A 1994 Shell report titled "The Enhanced Greenhouse Effect: A Review of the Scientific Aspects", attached as Exhibit 18**,** warned of the potentially dramatic economic effects of "ill-advised policy measures" relating to climate change. While this 1994 report recognized the IPCC conclusions as the mainstream view, the author emphasized scientific uncertainty and that the "evolution of energy systems indicates that policies to curb greenhouse gas emissions beyond 'no regrets' measures could be premature, divert resources from more pressing needs and further

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distort markets."[251]

368.

When the GCC became a standalone organization in 1995, independent from the National Association of Manufacturers, the membership grew, adding at least eight new utilities and seven new oil and gas corporations as members. At the same time, the budget tripled, with tax documents showing three million dollars in corporate and trade association dues in tax years 1996 and 1997, compared to one million dollars in dues from the years 1994 and 1995.[252]

369.

In 1995, GCC assembled an advisory committee of scientific and technical experts to compile an internal, 17-page report on climate science entitled *Predicting Future Climate Change: A Primer*, attached as Exhibit 19, which stated: "The scientific basis for the Greenhouse Effect and the potential impact of human emissions of greenhouse gases such as CO_2 on climate is well established and cannot be denied."

370.

But that is not the message Defendants, and their co-conspirators promoted to consumers, investors, or the public. Even though these GCC members knew that their products caused catastrophic effects, including extreme changes in heat, GCC disseminated climate denial claims

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[251] P. Langcake, The Enhanced Greenhouse Effect: A review of the Scientific Aspects, ROYAL DUTCH SHELL (Dec. 1994), https://www.climatefiles.com/shell/1994-shell-enhanced-greenhouse-effect-review-scientific-aspects/ (last visited June 19, 2023).

[252] Climate Investigations Center, Global Climate Coalition Documents: Big Business Funds Climate Change Denial and Regulatory Delay, CLIMATE INVESTIGATIONS CENTER, https://climateinvestigations.org/global-climate-coalition-documents/ (last visited June 19, 2023).

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that relied largely on the *World Climate Review* and its successor, the *World Climate Report*, which was edited by Patrick Michaels, funded by the Western Fuels Association[253] and promoted by the Greening Earth Society, purportedly debunking the catastrophic effects of their products on our atmosphere.

371.

The Greening Earth Society ("GEC") was a public relations organization which promoted a thesis that there was considerable scientific doubt about the effects of climate change and increased atmospheric accumulation of carbon dioxide. The Western Fuels Association created the GEC and shared office space with it. The GEC promoted the views of climate skeptics such as Patrick Michaels, Fred Singer, and Richard Lindzen.[254] In 1996, the GEC published a report titled "Changing Weather? Facts and Fallacies about Climate Change", attached as Exhibit 20. The GEC publicly opposed IPCC's scientific consensus to further the business objectives of its fossil fuel benefactors rather than for intellectually honest or science-based reasons.

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[253] Wendy E. Franz, Science, skeptics, and non-state actors in the greenhouse, BELFER CENTER FOR SCIENCE AND INTERNATIONAL AFFAIRS (Sept. 1998), https://www.belfercenter.org/sites/default/files/legacy/files/Science%20Skeptics%20and%20Non-State%20Actors%20in%20the%20Greenhouse%20-%20E-98-18.pdf (last visited June 19, 2023).

[254] David Levy and Sandra Rothenberg, Corporate Strategy and Climate Change: Heterogeneity and Change in the Global Automobile Industry, BELFER CENTER FOR SCIENCE AND INTERNATIONAL AFFAIRS (Sept. 30, 1999), https://www.belfercenter.org/publication/corporate-strategy-and-climate-change-heterogeneity-and-change-global-automobile (last visited June 19, 2023).

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372.

In July 1996, at a Washington, D.C. press conference on the eve of the second United Nations Climate Change conference in Geneva, GEC's executive director said, "The time for decision is not yet now."[255]

373.

In 1996, Exxon released a publication, attached as Exhibit 21, titled "Global Warming: Who's Right? Facts about a debate that's turned up more questions than answers." Exxon CEO Lee Raymond stated that "taking drastic action immediately is unnecessary since many scientists agree there's ample time to better understand the climate system."

374.

In the publication, another article described the greenhouse effect as "unquestionably real and definitely a **good thing**," while ignoring the severe consequences that would result from the influence of the increased CO_2 concentration on Earth's climate. Exxon downplayed the greenhouse effect as simply "what makes the earth's atmosphere livable."

375.

In this 1996 publication, Exxon contradicted its own internal reports and peer reviewed science, attributing the rise in temperature since the late 19th century to "natural fluctuations that occur over long periods of time" rather than to the anthropogenic emissions that Exxon and other

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[255] John H Cushman Jr., Report says global warming poses threat to public health. N. Y. TIMES, (Jul. 8, 1996) https://www.nytimes.com/1996/07/08/world/report-says-global-warming-poses-threat-to-public-health.html (last visited June 20, 2023).

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scientists had confirmed were responsible. The article also falsely and cynically challenged the accuracy of computer models that projected the future impacts of unabated fossil fuel product consumption, including those developed by Exxon's own employees for the company's use.

376.

Exxon's article contradicted the numerous reports circulated among Exxon's staff, and by the API, by stating that "the indications are that a warmer world would be far more benign than many imagine . . . moderate warming would reduce mortality rates in the US, so a slightly warmer climate would be more healthful." Raymond concluded his preface by attacking advocates for limiting the use of his company's fossil fuel products as "drawing on bad science, faulty logic, or unrealistic assumptions"—despite the important role that Exxon's own scientists had played in compiling those same scientific underpinnings.[256]

377.

Joining with Exxon, API published a report in the 1996 titled "Reinventing Energy: Making the Right Choices", attached as Exhibit 22**,** warning against concern over CO_2 buildup and any need to curb consumption or regulate the industry. The same API that less than 20 years earlier had concluded that global warming from fossil fuel emissions could cause "globally catastrophic" effects now wrote that "there is no persuasive basis for forcing Americans to dramatically change their lifestyles to use less oil." The authors discouraged the further development of certain

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[256] Exxon Corp., Global warming: who's right? (1996), EXXON CORP, https://www.climatefiles.com/exxonmobil/global-warming-who-is-right-1996/ (last visited June 20, 2023).

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alternative energy sources, writing that "government agencies have advocated the increased use of ethanol and the electric car, without the facts to support the assertion that either is superior to existing fuels and technologies" and that "policies that mandate replacing oil with specific alternative fuel technologies freeze progress at the current level of technology, and reduce the chance that innovation will develop better solutions." The report denies the human connection to climate change, saying that no "scientific evidence exists that human activities are significantly affecting sea levels, rainfall, surface temperatures or the intensity and frequency of storms," concluding that "facts don't support the arguments for restraining oil use."[257]

378.

Every Thursday from 1985 to 2000, Mobil bought a full-page in the *New York Times* and used its ad space to publish what appeared to be scientific articles.[258] At the same time, in 1996, Exxon, while publicly denying the threat of global warming, designed its drilling rigs off the Nova Scotia coast to account for a 0.5-meter anthropogenic rise in sea levels that climate models predicted would likely occur during the expected 25-year lifespan of the structures.[259]

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[257] American Petroleum Institute, Reinventing Energy, AMERICAN PETROLEUM INSTITUTE (1996) https://www.climatefiles.com/trade-group/american-petroleum-institute/1996-reinventing-energy/ (last visited June 20, 2023).

[258] Connor Gibson, How Exxon Used the New York Times to Make You Question Climate Science, ECOWATCH (Sept. 2, 2017) https://www.ecowatch.com/exxon-new-york-times-2479595376.html (last visited June 20, 2023).

[259] Amy Lieberman and Susanne Rust, Big Oil braced for global warming while it fought regulations, L. A. TIMES (Dec. 31, 2015), https://graphics.latimes.com/oil-operations/ (last visited June 20, 2023).

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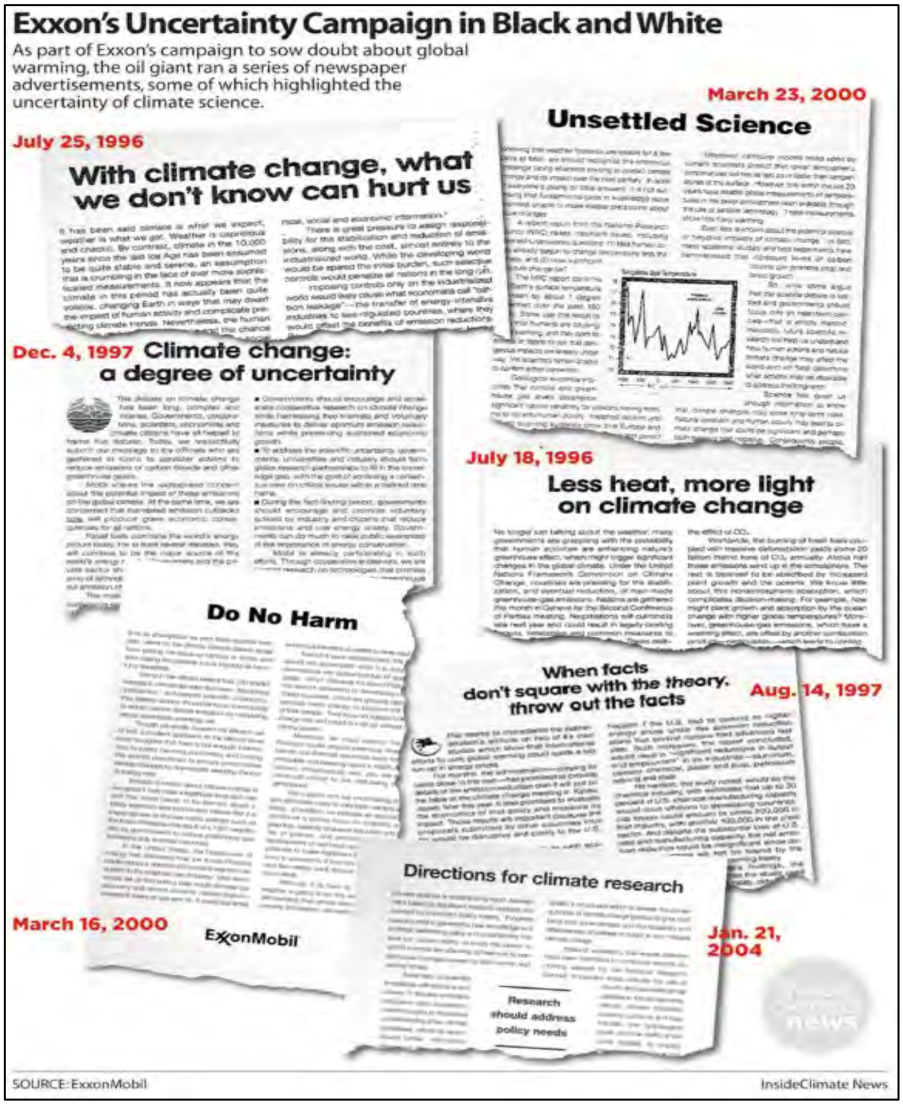
379.

Mobil's advertorials continued until 2000, and Exxon continued to publish multiple 'Advertorials', again, designed to 'misinform' the public:[260]



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[260] NPR, Climate Change Is 'Greatest Challenge Humans Have Ever Faced,' Author Says, NPR (Apr. 16, 2019 1:59 PM) https://www.npr.org/2019/04/16/713829853/climate-change-is-greatest-challenge-humans-have-ever-faced-author-says (last visited June 20, 2023). Photo source: Inside Climate News.

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380.

In 1997, Mobil paid for an ad/article published in the *New York Times* proclaiming:

> Let's face it: The science of climate change is too uncertain to mandate a plan of action that could plunge economies into turmoil…We still don't know what role man-made greenhouse gases might play in warming the planet.[261]

381.

In a speech presented at the World Petroleum Congress in Beijing in 1997 at which many of the Fossil Fuel Defendants were present, Exxon CEO Lee Raymond reiterated these views. This time, he presented a false dichotomy between stable energy markets and abatement of the marketing, promotion, and sale of fossil fuel products known to Defendants to be hazardous. He stated:

> Some people who argue that we should drastically curtail our use of fossil fuels for environmental reasons…my belief [is] that such proposals are neither prudent nor practical. With no readily available economic alternatives on the horizon, fossil fuels will continue to supply most of the worlds and this region's energy for the foreseeable future... Governments also need to provide a stable investment climate…They should avoid the temptation to intervene in energy markets in ways that give advantage to one competitor over another or one fuel over another. We also have to keep in mind that most of the greenhouse effects comes from natural sources.…Leaping to radically cut this tiny sliver of the greenhouse pie on the premise that it will affect climate defies common sense and lacks foundation in our current understanding of the climate system. Let's agree there's a lot we really don't know about how climate

[261] Dino Grandoni, ExxonMobil asked people to 'read the documents' it produced on climate change. So, these Harvard researchers did. THE WASHINGTON POST (Aug. 24, 2017) *https://www.washingtonpost.com/news/powerpost/wp/2017/08/24/exxonmobil-asked-people-to-read-the-documents-it-produced-on-climate-change-so-these-harvard-researchers-did* (last visited June 20, 2023).

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> will change in the 21st century and beyond.…It is highly unlikely that the temperature in the middle of the next century will be significantly affected whether policies are enacted now or 20 years from now. It's bad public policy to impose very costly regulations and restrictions when their need has yet to be proven.[262]

382.

In 1997, the GCC launched an advertising campaign in the US against any agreement aimed at reducing greenhouse gas emissions internationally. This was run through an organization called the Global Climate Information Project ("GCIP"), which was sponsored by the GCC and the American Association of Automobile Manufacturers, among others. The GCIP was represented by Shandwick Public Affairs, the second-largest PR firm in the United States.[263]

383.

The GCIP's ads were produced by Goddard Claussen/First Tuesday, a California-based PR firm, which falsely claimed "It's Not Global and It Won't Work." Among other things, the ads indicated that "Americans will pay the price ... 50¢ more for every gallon of gasoline," even though there was no proposal for such a tax. There was no treaty at that point, and no government

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[262] Lee R. Raymond, Energy – Key to growth and a better environment for Asia-Pacific nations, WORLD PETROLEUM CONGRESS (Oct. 13, 1997), *https://www.climatefiles.com/exxonmobil/1997-exxon-lee-raymond-speech-at-world-petroleum-congress/* (last visited June 20, 2023).

[263] Shandwick Public Affairs is a division of Weber Shandwick Worldwide (WSW) was, in 2004, the world's largest public relations company. A subsidiary of the Interpublic Group, it was formed as the product of the mergers of Weber Public Relations and Shandwick Worldwide in late 2000. In 2001, Weber Shandwick merged with BSMG to become the largest PR operation in the world. Other Shandwick clients include Browning-Ferris Industries, Central Maine Power, Georgia-Pacific Corp., Monsanto Chemical Co., New York State Electric and Gas Co., Ciba-Geigy, Ford Motor Company, Hydro-Quebec, Pfizer, and Procter & Gamble. SourceWatch, Weber Shandwick, THE CENTER FOR MEDIA AND DEMOCRACY, *https://www.sourcewatch.org/index.php/Weber_Shandwick* (last visited June 20, 2023).

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proposals, then or now, that have suggested a "50 cent gallon gas tax." The ads are attached hereto as Exhibit 23.

384.

In August 1997, a few months before the Kyoto Conference on Climate Change, the GCC helped launch a massive advertising campaign designed to prevent the United States from endorsing any meaningful agreement to reduce global carbon emissions. This group, including in its ranks these Defendants, some of the world's most powerful corporations and trade associations involved with fossil fuels, concentrated its efforts on a series of television ads that attempted to confuse and frighten Americans.

385.

In the 1990s, Defendant Koch began funding Climate Denial Groups including those named herein. By estimates, Koch spent $145,556,729 from 1997 to 2018 on directed campaigns to spread doubt and continue to amass profits.[264]

386.

Mobil's 1997 advertorial below[265] argued that economic analysis of emissions restrictions was faulty and inconclusive and therefore a justification for delaying action on climate change.

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[264] Greenpeace, Koch Industries: Secretly Funding the Climate Denial Machine, *https://www.greenpeace.org/usa/fighting-climate-chaos/climate-deniers/koch-industries/* (last visited on June 19, 2023).

[265] Mobil, When Facts Don't Square with the Theory, Throw Out the Facts, N.Y. TIMES, (Aug. 14, 1997) at A31, https://www.documentcloud.org/documents/705550-mob-nyt-1997-aug-14-whenfactsdontsquare.html? (last visited June 19, 2023).

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When facts don't square with the theory, throw out the facts

That seems to characterize the administration's attitude on two of its own studies which show that international efforts to curb global warming could spark a big run-up in energy prices.

For months, the administration—playing its cards close to the vest—has promised to provide details of the emission reduction plan it will put on the table at the climate change meeting in Kyoto, Japan, later this year. It also promised to evaluate the economics of that policy and measure its impact. Those results are important because the proposals submitted by other countries thus far would be disruptive and costly to the U.S. economy.

Yet, when the results from its own economic models were finally generated, the administration started distancing itself from the findings and models that produced them. The administration's top economic advisor said that economic models can't provide a "definitive answer" on the impact of controlling emissions. The effort, she said, was "futile." At best, the models can only provide a "range of potential impacts."

Frankly, we're puzzled. The White House has promised to lay the economic facts before the public. Yet, the administration's top advisor said such an analysis won't be based on models and it will "preclude . . . detailed numbers." If you don't provide numbers and don't rely on models, what kind of rigorous economic examination can Congress and the public expect?

We're also puzzled by ambivalence over models. The administration downplays the utility of economic models to forecast cost impacts 10–15 years from now, yet its negotiators accept as gospel the 50–100-year predictions of global warming that have been generated by climate models—many of which have been criticized as seriously flawed.

The second study, conducted by Argonne National Laboratory under a contract with the Energy Department, examined what would happen if the U.S. had to commit to higher energy prices under the emission reduction plans that several nations had advanced last year. Such increases, the report concluded, would result in "significant reductions in output and employment" in six industries—aluminum, cement, chemical, paper and pulp, petroleum refining and steel.

Hit hardest, the study noted, would be the chemical industry, with estimates that up to 30 percent of U.S. chemical manufacturing capacity would move offshore to developing countries. Job losses could amount to some 200,000 in that industry, with another 100,000 in the steel sector. And despite the substantial loss of U.S. jobs and manufacturing capacity, the net emission reduction could be insignificant since developing countries will not be bound by the emission targets of a global warming treaty.

Downplaying Argonne's findings, the Energy Department noted that the study used outdated energy prices (mid-1996), didn't reflect the gains that would come from international emissions trading and failed to factor in the benefits of accelerated developments in energy efficiency and low-carbon technologies.

What it failed to mention is just what these new technologies are and when we can expect their benefits to kick in. As for emissions trading, many economists have theorized about the role they could play in reducing emissions, but few have grappled with the practicality of implementing and policing such a scheme.

We applaud the goals the U.S. wants to achieve in these upcoming negotiations—namely, that a final agreement must be "flexible, cost-effective, realistic, achievable and ultimately global in scope." But until we see the details of the administration's policy, we are concerned that plans are being developed in the absence of rigorous economic analysis. Too much is at stake to simply ignore facts that don't square with preconceived theories.

Mobil The energy to make a difference.

http://www.mobil.com

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387.

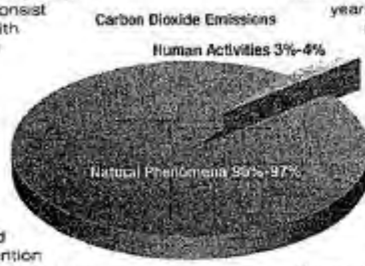
An example of one of Mobil's advertisements in the *New York Times*, published on November 7, 1997, is reproduced below:

Display Ad 26 -- No Title
New York Times (1923-Current file); Nov 6, 1997;
ProQuest Historical Newspapers: The New York Times (1851-2008) with Index (1851-1993)
pg. A31

Science: what we know and don't know

As the debate over climate change heats up, science is being upstaged by the call for solutions. At stake is a complex issue with many questions. Some things we know for certain. Others are far from certain.

First, we know greenhouse gases account for less than one percent of Earth's atmosphere. The ability of these gases to trap heat and warm Earth is an important part of the climate system because it makes our planet habitable. Greenhouse gases consist largely of water vapor, with smaller amounts of carbon dioxide (CO_2), methane and nitrous oxide and traces of chlorofluorocarbons (CFCs).



The focus of concern is CO_2. While most of the CO_2 emitted by far is the result of natural phenomena—namely respiration and decomposition, most attention has centered on the three to four percent related to human activities—burning of fossil fuels, deforestation. The amount of carbon dioxide in the atmosphere has risen in the last 100 years, leading scientists to conclude that the increase is a result of man-made activities.

Although the linkage between the greenhouse gases and global warming is one factor, other variables could be much more important in the climate system than emissions produced by man.

The UN-sponsored Intergovernmental Panel on Climate Change (IPCC) thought it had found the magic bullet when it concluded that the one-degree Fahrenheit rise in global temperatures over the past century may bear a "fingerprint" of human activity. The fingerprint soon blurred when an IPCC lead author conceded to the "uncertainty inherent in computer climate modeling."

Nonetheless, nations at Kyoto are being asked to embrace proposals that could have potentially huge impacts on economies and lifestyles. Nations are being urged to cut emissions without knowing either the severity of the problem—that is, will Earth's temperature increase over the next 50–100 years?—or the efficacy of the solution—will cutting CO_2 emissions reduce the problem?

Within a decade, science is likely to provide more answers on what factors affect global warming, thereby improving our decision-making. We just don't have this information today.

Answers to questions on climate change will require more reliable measurements of temperature at many places on Earth, better understanding of clouds and ocean currents along with greater computer power.

This process shouldn't be short-circuited to satisfy an artificial deadline, like the conference in Kyoto. Whatever effect increased concentrations of man-made gases may have, it will develop slowly over decades. Thus, there is time for scientists to refine their understanding of the climate system, while governments, industry and the public work to find practical means to control greenhouse gases, if such measures are called for. Adopting quick-fix measures at this point could pose grave economic risks for the world.

Mobil The energy to make a difference.

http://www.mobil.com/climatechange

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388.

The GCC had an active subcommittee named the "Global Climate Coalition Science and Technology Assessment Committee" (STAC). In 1996, members of this subcommittee on science and technology were represented by Ford, Exxon, API, the NMA, BHP, and many others.

389.

At STAC's June 20, 1996 meeting, which was held at the API headquarters, notes were prepared and distributed by the Association of International Automobile Manufacturers (AIAM), released talking points from Bronson Gardner to Jim Pinto and distributed to the STAC committee for addressing whether 1995 was "really that much hotter than normal or whether the data was 'blown out of proportion'" giving STAC and the GCC talking points for downplaying record setting temperatures.[266]

390.

In 1997 alone, the GCC spent $13 million opposing the Kyoto Protocol.[267]

1. The GCSCT Action Plan--Double Down on Deception

391.

Members of the GCC created a task force which met at a "workshop" held at the API

[266] Howard J. Feldman, 1996 GCC STAC June Meeting Minutes, GLOBAL CLIMATE CHANGE COALITION (Jun. 20, 1996), https://www.documentcloud.org/documents/5689156-AIAM-051229.html (last visited June 20, 2023).
[267] Maggie Farley, Showdown at Global Warming Summit, L. A. TIMES (Dec. 7, 1997), https://www.latimes.com/archives/la-xpm-1997-dec-07-mn-61743-story.html (last visited June 20, 2023).

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headquarters in late March of 1998.[268] A memorandum titled the "Global Climate Science Communication Team Action Plan" ("GCSCT" Action Plan) and written by API's Joe Walker memorializing the workshop's goals, strategies and tactics was emailed to the GCSCT team members on April 3, 1998, and is attached hereto as Exhibit 24.

392.

The email from Joe Walker with the GCSCT Action Plan which detailed a scheme on how the GCC would achieve "Victory" by duping consumers through front groups, promoters, and media strategists:

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[268] The e-mail is undated but refers to a workshop that occurred the Friday before. As the attachment is dated April 3, 1998.

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Joe Walker

To: Global Climate Science Team
Cc: Michelle Ross; Susan Moya
Subject: Draft Global Climate Science Communications Plan

As promised, attached is the draft Global Climate Science Communications Plan that we developed during our workshop last Friday. Thanks especially to those of you who participated in the workshop, and in particular to John Adams for his very helpful thoughts following up our meeting, and Alan Caudill for turning around the notes from our workshop so quickly.

Please review the plan and get back to me with your comments as soon as possible.

As those of you who were at the workshop know, we have scheduled a follow-up team meeting to review the plan in person on Friday, April 17, from 1 to 3 p.m. at the API headquarters. After that, we hope to have a "plan champion" help us move it forward to potential funding sources, perhaps starting with the global climate "Coordinating Council." That will be an item for discussion on April 17.

Again, thanks for your hard work on this project. Please e-mail, call or fax me with your comments. Thanks.

Regards,
Joe Walker

393.

The cover page of the GCSCT Action Plan, setting forth its goals, current reality, and when **"victory"** would be achieved, is infamously known as the "Victory Memo:"

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Global Climate Science Communications

Action Plan

Project Goal

A majority of the American public, including industry leadership, recognizes that significant uncertainties exist in climate science, and therefore raises questions among those (e.g. Congress) who chart the future U.S. course on global climate change.

Progress will be measured toward the goal. A measurement of the public's perspective on climate science will be taken before the plan is launched, and the same measurement will be taken at one or more as-yet-to-be-determined intervals as the plan is implemented.

Victory Will Be Achieved When

- Average citizens "understand" (recognize) uncertainties in climate science; recognition of uncertainties becomes part of the "conventional wisdom"
- Media "understands" (recognizes) uncertainties in climate science.
- Media coverage reflects balance on climate science and recognition of the validity of viewpoints that challenge the current "conventional wisdom"
- Industry senior leadership understands uncertainties in climate science, making them stronger ambassadors to those who shape climate policy
- Those promoting the Kyoto treaty on the basis of extant science appear to be out of touch with reality.

Current Reality

Unless "climate change" becomes a non-issue, meaning that the Kyoto proposal is defeated and there are no further initiatives to thwart the threat of climate change, there may be no moment when we can declare victory for our efforts. It will be necessary to establish measurements for the science effort to track progress toward achieving the goal and strategic success.

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394.

The GCSCT Action Plan named the following members, a who's who of fossil fuel industry insiders and advocates, as having contributed to the Plan's development: John Adams, John Adams Associates; Candace Crandall, Science and Environmental Policy Project;[269] David Rothbard, Committee for A Constructive Tomorrow; Jeffrey Salmon, The Marshall Institute;[270] Lee Garrigan, Environmental Issues Council;[271] Lynn Bouchey and Myron Ebell, Frontiers of Freedom;[272] Peter

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[269] Candace Crandall was the wife of S. Fred Singer and registered for the Rio conference as a "publicist" for a science team at the Rio Conference where GCC participated in 1992.

[270] Also known as "The George C. Marshall Institute" (GMI) is a "non-profit" organization funded by the profits from oil and gas interests and co-founded by Frederick Seitz in 1984. It has received substantial funding from Exxon's Exxon Education Foundation. SourceWatch, *George C. Marshall Institute,* THE CENTER FOR MEDIA AND DEMOCRACY, https://www.sourcewatch.org/index.php/George_C._Marshall_Institute (last visited June 20, 2023).

[271] The Environmental Issues Council (EIC) was established in 1993 by a number of leading U.S. industry trade associations to serve as a "new ally against ill-conceived environmental regulation." SourceWatch, *Environmental Issues Council*, THE CENTER FOR MEDIA AND DEMOCRACY, https://www.sourcewatch.org/index.php/Environmental_Issues_Council (last visited June 20, 2023). Environmental Issues Council website no longer active. The EIC included membership of the Independent Petroleum Association of America (IPAA) "has represented independent oil and natural gas producers for three-quarters of a century."
United States Environmental Protection Agency (EPA), *Oil and Gas, Resources,* UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA) https://archive.epa.gov/sectors/web/html/oilandgas.html#:~:text=IPAA%20is%20a%20national%20trade,three%2Dquarters%20of%20a%20century (last visited June 20, 2023).

[272] According to a 2003 *New York Times* report, Frontiers of Freedom, which has about a $700,000 annual budget, received $230,000 from Exxon in 2002, up from $40,000 in 2001, according to Exxon documents. George Landrith, Frontiers of Freedom's President told the *New York Times* "They've determined that we are effective at what we do" and that Exxon essentially took the attitude, "We like to make it possible to do more of that."
Jennifer Lee, *Exxon Backs Groups That Question Global Warming,* THE NEW YORK TIMES (May 28, 2003), https://www.nytimes.com/2003/05/28/business/exxon-backs-groups-that-question-global-warming.html (last visited June 20, 2023).

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Cleary, Americans for Tax Reform;[273] Randy Randol, Exxon Corp.; Robert Gehri, The Southern Company;[274] Sharon Kneiss, Chevron Corp.; Steve Milloy, The Advancement of Sound Science Coalition;[275] and Joseph Walker, American Petroleum Institute.

395.

Defendants borrowed propagandist strategies right out of the playbook of prior denialist campaigns. This team mirrored a front group created by the tobacco industry, known as "The Advancement of Sound Science Coalition," whose purpose was to *mislead consumers* that cigarette smoke was not carcinogenic.

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[273] ATR is a member of the American Legislative Exchange Council ("ALEC"). Noble Ellington, *National Chairman Of ALEC Responds To Report,* Interview with Terry Gross in Fresh Air, NPR (Jul. 21, 2011), https://www.npr.org/2011/07/21/138575665/national-chairman-of-alec-responds-to-report (last visited June 20, 2023).

[274] Southern Company has been a corporate funder of the American Legislative Exchange Council (ALEC) Clearinghouse on Environmental Advocacy and Research, project of the Environmental Working Group. Information of the American Legislative Exchange Council archived organizational profile by Wayback Machine, (Dec. 2, 2000).

[275] The Advancement of Sound Science Coalition ("TASSC") is a now-defunct, industry-funded PR front group run by the APCO Worldwide public relations firm. It worked to hang the label of "junk science" on environmentalists and health activists. TASSC was created in 1993 as a front for Philip Morris which was attempting to discredit ETS (Environmental Tobacco Smoke) research as a long-term cause of increased cancer and heart problems in the community -- especially among office workers and children living with smoking parents. APCO billed the tobacco company $25,000 a month to run the operation. Chevron, Exxon and GM were all funders of TASSC which promoted climate change denial. Bob Burton and Sheldon Rampton, *Thinking Globally, Acting Vocally: The International Conspiracy to Overheat the Earth,* PR WATCH (1997) https://www.prwatch.org/files/pdfs/prwatch/prwv4n4.pdf (last visited June 20, 2023).

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396.

The GCSCT's membership included Steve Milloy (a key player on the tobacco industry's front group) for Exxon. Between 2000 and 2004, Exxon donated $110,000 to Milloy's efforts and another organization, the Free Enterprise Education Institute, and $50,000 to the Free Enterprise Action Institute, both registered to Milloy's home address.[276]

397.

The GCSCT Action Plan set out its goals: sow confusion for consumers, make global warming into a "non-issue," defeat the Kyoto Protocol, and ensure "there are no further initiatives to thwart the threat of climate change."[277]

2. Climate Science Messaging without Scientists or Science

398.

There were no **scientists** on the "Global Climate **Science** Communications Team." (GCSCT). The GCSCT Action Plan's purpose was clear---keep consumers buying their products and further industry objectives by directing the future of US global climate change policy.

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[276] Seth Shulman et al. Smoke, Mirrors & Hot Air: How ExxonMobil Uses Big Tobacco's Tactics to Manufacture Uncertainty on Climate Science, UNION OF CONCERNED SCIENTISTS, (Jan. 2007), at 19, https://www.ucsusa.org/sites/default/files/2019-09/exxon_report.pdf (last visited Nov. 15, 2022).

[277] Joe Walker, Global Climate Science Communications Action Plan, GLOBAL CLIMATE SCIENCE COMMUNICATIONS TEAM (GCSCT) (Apr. 3, 1998), https://insideclimatenews.org/wp-content/uploads/2015/12/Global-Climate-Science-Communications-Plan-1998.pdf (last visited Nov 15, 2022).

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399.

The GCSCT Action Plan allocated an initial budget of $7.9 million, most of which would fund efforts to inject fake science and bold-faced lies into the global climate debate.[278] From 1998 to 2008, Exxon alone invested more than $20 million to think tanks that dedicated a large amount of effort to undermining the scientific consensus on climate change in fulfillment of the purpose of the GCSCT Action Plan.[279]

400.

Naomi Oreskes and Erik M. Conway, authors of *Merchants of Doubt*, similarly note:

> In 2005…Chris Mooney documented how in just a few years Exxon Mobil had channeled more than $8 million to forty different organizations that challenged the scientific evidence of global warming. The organizations did not just include probusiness and conservative think tanks, but also "quasi-journalistic outlets like TechCentralStation.com (a website providing 'news, analysis, research, and commentary' that received $95,000 from ExxonMobil in 2003), a *FoxNews.com* columnist, and even religious and civil rights groups". Mooney also noted how former ExxonMobil chairman and CEO Lee Raymond served as vice-chairman of the board of trustees for the American Enterprise Institute, which received $960,000 in funding from ExxonMobil, and how in 2002, ExxonMobil explicitly earmarked $60,000 for "legal activities" by the Competitive Enterprise Institute.
>
> Mooney described what happened when scientists released the comprehensive *Arctic Climate Impact Assessment*, which concluded that the Arctic was warming at twice the rate of the rest of the world…The report was blasted in a column by Steve Milloy, now working as a columnist for *FoxNews.com* and serving as an adjunct

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278 Id.

279 Global Climate Science Communications Team, Global Climate Science Communications Action Plan, GLOBAL CLIMATE SCIENCE COMMUNICATIONS TEAM, https://insideclimatenews.org/wp-content/uploads/2015/12/Global-Climate-Science-Communications-Plan-1998.pdf (last visited June 20, 2023).

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> scholar at the Cato Institute, which received $75,000 from ExxonMobil….Milloy had received money from ExxonMobil: $40,000 to The Advancement of Sound Science Center and $50,000 to the Free Enterprise Action Institute–both of which are registered to Milloy's home address.[280]

401.

GCC members, through its GCSCT Action Plan, doubled down on disseminating these contrarian theories, particularly through ghostwriters, front groups and think tanks. It needed to flood the public with false science, media blitzes, advertorials, and doubt. The multi-million-dollar, multi-year proposed budget included public outreach and the dissemination of educational materials to schools to begin to erect a barrier against further efforts to impose Kyoto-like measures in the future.[281]

402.

Imperial Oil (now Exxon) CEO Robert Peterson also falsely denied the established connection between Defendants' fossil fuel products and ACC in the Summer 1998 Imperial Oil Review, attached as Exhibit 25, "A Cleaner Canada":

> [Climate change] has absolutely nothing to do with pollution and air quality. Carbon dioxide is not a pollutant but an essential ingredient of life on this planet…. [T]he question of whether or not the trapping of 'greenhouse' gases will result in the planet's getting warmer…has no connection whatsoever with our day-to-day weather. There is absolutely no agreement among climatologists on whether or not the planet is getting warmer, or, if it is, on whether the warming is the result of man-made factors or natural variations in the climate…. I feel very safe in

[280] Naomi Oreskes & Erik M. Conway, Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming, BLOOMSBURY PRESS (2010), at 246-247.
[281] Global Climate Science Communications Team, *supra* note 279.

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> saying that the view that burning fossil fuels will result in global climate change remains an unproved hypothesis.[282]

403.

In the early 1990s, both API and Exxon funded and promoted the work of Fred Seitz,[283] Fred Singer, and Singer's Science and Environmental Policy Project[284] ("SEPP"). Singer's wife, Candace Crandall, the Executive Director at SEPP, registered at the Rio conference as a 'publicist' for a "science team" in 1992.[285] Neither Seitz nor Singer was trained in climate science, but both had previously been hired by industry, including tobacco companies, to create doubt in the public mind—again, where there should have been none.[286]

404.

The GCSCT Action Plan went into high gear. Taking money from the GCC and its

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[282] Robert Peterson, A Cleaner Canada, IMPERIAL OIL REVIEW (1998), https://www.climatefiles.com/exxonmobil/imperial-oil/1998-imperial-oil-article-a-cleaner-canada-by-robert-peterson/ (last viewed June 20, 2023).

[283] George C. Marshall Institute, Recent Founders, GEORGE C. MARSHALL INSTITUTE, http://web.archive.org/web/20000823170917/www.marshall.org/funders.htm (last visited June 20, 2023).

[284] Exxon Education Foundation, Corporate Giving Source: Dimensions, EXXONMOBIL (1997); ExxonMobil, Foundation Form 990, DEPARTMENT OF THE TREASURY INTERNAL REVENUE SERVICE (IRS) (2000), https://www.documentcloud.org/documents/1019871-2000-exxonmobil-foundation-form-990 (last visited June 20, 2023).

[285] The Center for Media and Democracy, Candace C. Crandall, CENTER FOR MEDIA AND DEMOCRACY (CMD) https://www.sourcewatch.org/index.php/Candace_C._Crandall (last visited June 20, 2023).

[286] D. Hevesi, Frederick Seitz, 96, Dies; Physicist Who Led Skeptics of Global Warming, THE NEW YORK TIMES (Mar. 03, 2008), https://www.nytimes.com/2008/03/06/us/06seitz.html#:~:text=Frederick%20Seitz%2C%20a%20renowned%20physicist,confirmed%20by%20his%20son%2C%20Joachim (last visited June 20, 2023).

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members, Seitz, Singer, and SEPP were used to attack climate science, and specifically the IPCC conclusions and process. In 1998, Seitz helped organize and distribute the "The Global Warming Petition Project" (also known as the "Oregon Petition" or "Petition Project"). Launched from Oregon, by Defendant, the Oregon Institute of Science and Medicine the Oregon Petition was created to misinform and deceive the public about the scientific results and the consensus of climate change, urging the United States government to reject the global warming Kyoto Protocol of 1997 and similar policies.[287] OISM receives funding from the Heartland Institute that is funded by Exxon, Koch and others.

405.

The petition, attached as Exhibit 26**,** was formatted to appear sanctioned by the National Academy of Scientists and sent to thousands of American scientists. Supposedly signed by 17,000 "scientists," the petition claimed to find "no convincing scientific evidence that human release of greenhouse gases is causing or will, in the foreseeable future, cause catastrophic heating of the Earth's atmosphere and disruption of the Earth's climate." The list of signatories was filled not with 17,000 actual scientists, but fictitious names, deceased persons, and celebrities.[288]

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[287] Sander van der Linden et al., Inoculating the Public against Misinformation about Climate Change, GLOBAL CHALLENGES (2017), https://onlinelibrary.wiley.com/doi/epdf/10.1002/gch2.201600008 (last visited June 20, 2023).
[288] Michael E. Mann. The Hockey Stick and the Climate Wars. Columbia University Press (2012), at 66.

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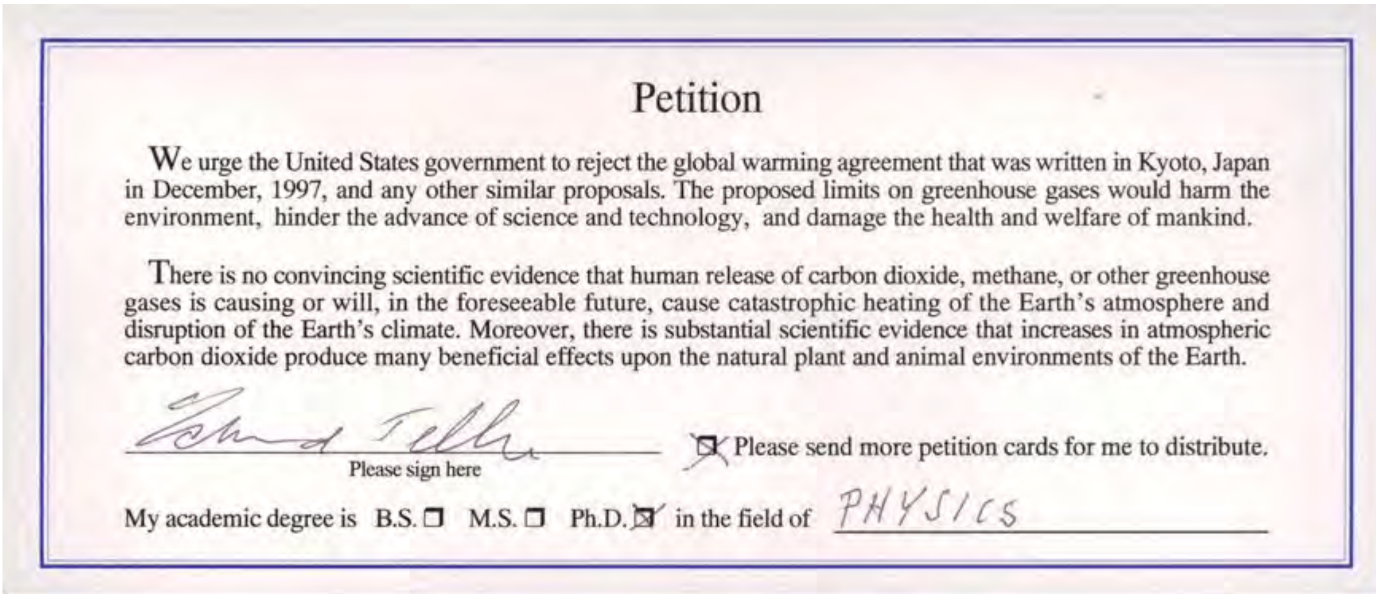
406.

The petition:[289]


Petition

We urge the United States government to reject the global warming agreement that was written in Kyoto, Japan in December, 1997, and any other similar proposals. The proposed limits on greenhouse gases would harm the environment, hinder the advance of science and technology, and damage the health and welfare of mankind.

There is no convincing scientific evidence that human release of carbon dioxide, methane, or other greenhouse gases is causing or will, in the foreseeable future, cause catastrophic heating of the Earth's atmosphere and disruption of the Earth's climate. Moreover, there is substantial scientific evidence that increases in atmospheric carbon dioxide produce many beneficial effects upon the natural plant and animal environments of the Earth.

Please sign here ☒ Please send more petition cards for me to distribute.

My academic degree is B.S. ☐ M.S. ☐ Ph.D. ☒ in the field of PHYSICS

407.

The petition was organized and circulated by Arthur B. Robinson, president of the Oregon Institute of Science and Medicine (described as "a small independent research group") in 1998, and again in 2007.[290]

[289] Global Warming Petition Project website, http://www.petitionproject.org/ (last visited Nov. 14, 2022). Note: on June 20, 2023, the website claims that 31,487 American scientists have signed this petition, including 9,029 with PhDs.

[290] Devin Henry, Climate change petition pits scientists against each other, THE MINNESOTA DAILY (May 28, 2008), https://mndaily.com/222080/news/world/climate-change-petition-pits-scientists-against-each-other/ (last visited June 20, 2023).

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408.

Frederick Seitz, then chairman of the George C. Marshall Institute, wrote a supporting cover letter, attached as Exhibit 27, signed as "Past President National Academy of Sciences USA, President Emeritus Rockefeller University."[291] The National Academy held a press conference to disclaim the mailing and distance itself from its former president.[292] Between 1998 and 2008, the George C. Marshall Institute received a total of $715,000 in funding from ExxonMobil alone.[293]

409.

The petition also included a 12 page "review article" with information about global warming. The article, attached as Exhibit 28, is titled "Environmental Effects of Increased Atmospheric Carbon Dioxide" by Arthur B. Robinson, Noah E. Robinson, Sallie Baliunas, and Willie Soon.[294]

410.

Within the article are the following conclusions meant to mislead the public,

> "There are no experimental data to support the hypothesis that in - creases in human hydrocarbon use or in atmospheric carbon dioxide and other greenhouse gases are

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[291] Gary J. Weisel, Skeptics, Naysayers, Anomalies, and Controversies in Eds. Brian C. Black et al., Climate Change: An Encyclopedia of Science and History, ABC-CLIO (2013) at 1241.
[292] Id.
[293] Ed Pilkington, Palin fought safeguards for polar bears with studies by climate change sceptics, THE GUARDIAN (Sep. 30, 2018), https://www.theguardian.com/world/2008/sep/30/uselections2008.sarahpalin1#:~:text=The%20Republican%20Sarah%20Palin%20and,species%2C%20the%20Guardian%20can%20disclose (last visited June 20, 2023).
[294] W. Soon, S. L. Baliunas, A. B. Robinson & Z. W. Robinson (Oct. 26, 1999). Environmental Effects of Increased Atmospheric Carbon Dioxide, CLIMATE RESEARCH, https://www.researchgate.net/publication/260851815_Environmental_Effects_of_Increased_Atmospheric_Carbon_Dioxide (last visited June 20, 2023).

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causing or can be expected to cause unfavorable changes in global temperatures, weather, or landscape. There is no reason to limit human production of CO_2, CH_4, and other minor greenhouse gases as has been proposed."

411.

"We also need not worry about environmental calamities even if the current natural warming trend continues. The Earth has been much warmer during the past 3,000 years without catastrophic effects. Warmer weather extends growing seasons and generally improves the habitability of colder regions."

412.

"Human use of coal, oil, and natural gas has not harmfully warmed the Earth, and the extrapolation of current trends shows that it will not do so in the foreseeable future. The CO_2 produced does, however, accelerate the growth rates of plants and also permits plants to grow in drier regions. Animal life, which depends upon plants, also flourishes, and the diversity of plant and animal life is increased."

413.

"Human activities are producing part of the rise in CO_2 in the atmosphere. Mankind is moving the carbon in coal, oil, and natural gas from below ground to the atmosphere, where it is available for conversion into living things. We are living in an increasingly lush environment of plants and animals as a result of this CO_2 increase. Our children will therefore enjoy an Earth with far more plant and animal life than that with which we now are blessed." [Except the 69 Multnomah County residents that lost their lives as a result of the 2021 PNW extreme heat event].

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414.

This paper and the misrepresentations within it are still published and disseminated today by the Oregon Institute of Science and Medicine as a part of the Petition Project both within Oregon and to all 50 states.

3. Fossil Fuel Defendants Attempt To Sanitize Carbon Front Groups From Their Image

415.

Despite the success that Fossil Fuel Defendants accomplished through their front groups, publicly they attempted to distance themselves from the deception, and that facade was also deceptive.

416.

John Browne, Chairman of British Petroleum, in a speech at Stanford University on May 19, 1997, announced that "the time to consider the policy dimensions of climate change is not when the link between greenhouse gases and climate change is conclusively proven, but when the possibility cannot be discounted and is taken seriously by the society of which we are part. We in BP have reached that point." BP itself withdrew from the GCC, but stayed as a member of API, which is a member of GCC. Shell also formally withdrew, but its trade groups did not.

417.

In February 1999, Atlantic Richfield Company, then a division of BP, CEO Michael Bowlin acknowledged in a speech he delivered at an energy industry conference, "We've embarked on the

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beginning of the Last Days of the Age of Oil."[295] Bowlin discussed the need to convert our carbon-based energy economy into a hydrogen-based energy economy. However, BP maintained membership and private participation with the GCC through its trade association, API.

418.

The companies who publicly left GCC then formed the Pew Center for Environmental Change ("C2ES") and appointed a "Business Environmental Leadership Council" ("BELC") in 1998 with the following statement: "We accept the views of most scientists that enough is known about the science and environmental impacts of climate change for us to take actions to address its consequences."[296]

419.

But they did not. Publicly, the companies left GCC and formed the BELC to address the growing public outrage for blatantly funding climate denial and hid behind their trade associations to continue to profit. This two-faced position would dominate for decades, all to the detriment of Multnomah County, Oregon residents, and consumers.

420.

While the GCC members formed the new Pew Center to appease the public, the companies met privately and formed the "Global Climate Science Communications Team" (GCSCT), setting

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[295] Id.

[296] Center for Climate and Energy Solutions, Business Environmental Leadership Council, CENTER FOR CLIMATE AND ENERGY SOLUTIONS, www.c2es.org/our-work/belc/ (last visited June 20, 2023).

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out their marketing battle plan to undermine the science they knew was accurate regarding climate change.

421.

In 2000, the GCC announced that it was restructuring as an association of trade associations and would henceforth only include trade associations in its membership. The companies, which had abandoned the GCC, as one journalist noted, like "rats leaving a sinking ship," and adopted scientific consensus on climate change through the Pew Center were still represented by their trade associations in the GCC, which funded climate denial of that scientific consensus.

422.

In 1998, API distributed a roadmap memo after the "Victory" memo, (Exhibit 24), outlining the fossil fuel industry's plan to use scientists as spokespersons for the industry's views.

423.

The GCSCT Action Memo outlined five distinct hierarchal levels:

a) **Global Climate Coalition:** a group of trade associations representing the Defendants and many others.

b) **Organizers of the GCSCT:** GCC members API (Shell, Chevron, BP, ConocoPhillips, Motiva, and Anadarko), Exxon, with CEI (Koch), CFACT, Lynn Bouchey, Myron Ebell, SEPP, and others.

c) **Funders:** National Mining Association (Peabody) API (Shell, Chevron, BP, ConocoPhillips, Motiva, Anadarko and others), Business Round Table (all Defendants), Independent Petroleum Association of America and Edison Electric Institute (EEI).

d) **Allocators:** ALEC (Koch), CEI (Koch), CFACT (Koch), Frontiers of Freedom, and The Marshall Institute.

e) **Promoters:** Heartland Institute, CFACT (Koch), ALEC (Koch), Frontiers of Freedom, the (George) Marshall Institute, SEPP, CO_2, CEI

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> (Koch), Myron Ebell, Marc Morano, Lord Christopher Monckton, Sherwood Idso, ICE, Fred Singer, Willie Soon, among many others.

424.

The GCSCT Action Memo stresses how the Defendants individually and collectively have utilized propaganda to combat the perception and reality that pollution from their fossil fuel products is destructive to our planet and those who live on it.

425.

Defendants have funded and continue to fund dozens of think tanks, front groups, and dark money foundations as the GCC marketers, pushing climate change denial. These include the Competitive Enterprise Institute, the Heartland Institute, Frontiers for Freedom, Committee for a Constructive Tomorrow, and the Heritage Foundation.

426.

From 1998 to 2014, Exxon alone spent almost **$31 million** funding numerous organizations to undermine the scientific consensus that Defendants' fossil fuel products were causing climate change.[297] Several Defendants have been linked to other groups that undermine the scientific basis linking Defendants' fossil fuel products to climate change, including the Frontiers of Freedom Institute and the George C. Marshall Institute.

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[297] Union of Concerned Scientists, ExxonMobil Foundation & Corporate Giving to Climate Change Denier & Obstructionist Organizations, UNION OF CONCERNED SCIENTISTS, https://www.ucsusa.org/sites/default/files/attach/2015/07/ExxonMobil-Climate-Denial-Funding-1998-2014.pdf (last visited June 20, 2023).

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4. Fossil Fuel Defendants Use Advertorials to Sow Public Doubt Through Deception

427.

Researchers who scoured through advertorials and published internal documents of ExxonMobil concluded that "in essence, these public statements reflect only the 'doubt' side of ExxonMobil's mixed internal dialogue."[298] Geoffrey Supran and Naomi Oreskes' "Assessing ExxonMobil's climate change communications (1977–2014)", attached as Exhibit 29, concluded that Exxon's peer-reviewed literature overwhelmingly acknowledges anthropogenic global warming as real, and human caused.

428.

Exxon's non-peer reviewed documents, including industry targeted speeches, reports, and company pamphlets, contain more references designed to misinform. The predominant stance taken in ExxonMobil's propaganda, however, according to the researchers is 'Doubt'. According to the researchers, of the 72% of climate change advertorials by Exxon that took a position, 81% of those take the position of 'Doubt', with the remainder split between 'Acknowledge' (11.5%) and 'Acknowledge and Doubt' (7.5%).

429.

Roughly 80% of Exxon's external communications designed to hit big audiences—its consumers—emphasized uncertainty, while more than 80% of internal and scientific

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[298] Geoffrey Supran and Naomi Oreskes, Assessing ExxonMobil's climate change communications (1977–2014), Environ. Res. Lett., (2017), https://iopscience.iop.org/article/10.1088/1748-9326/aa815f (last visited June 20, 2023).

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communications designed to be seen by no one other than internal communications or a very small number of academic audiences agree with the real scientific consensus that fossil fuels caused climate change and that it was very dangerous.

430.

The Researchers concluded:

> Available documents show a discrepancy between what ExxonMobil's scientists and executives discussed about climate change privately and in academic circles and what it presented to the general public. The company's peer-reviewed, non-peer-reviewed, and internal communications consistently tracked evolving climate science: broadly acknowledging that AGW is real, human-caused, serious, and solvable, while identifying reasonable uncertainties that most climate scientists readily acknowledged at that time. In contrast, ExxonMobil's advertorials in the NYT overwhelmingly emphasized only the uncertainties, promoting a narrative inconsistent with the views of most climate scientists, including ExxonMobil's own. This is characteristic of what Freudenberg et al term the **Scientific Certainty Argumentation Method (SCAM)**—a tactic for undermining public understanding of scientific knowledge.[299] Likewise, the company's peer-reviewed, non-peer-reviewed, and internal documents acknowledge the risks of stranded assets, whereas their advertorials do not. In light of these findings, we judge that ExxonMobil's AGW communications were misleading; we are not in a position to judge whether they violated any laws.[300]

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[299] William R. Freudenburg, Robert Gramling and Debra J. Davidson, Scientific Certainty Argumentation Methods (SCAMs): Science and the Politics of Doubt, SOCIOLOGICAL INQUIRY (2008), https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1475-682X.2008.00219.x (last visited Nov. 15, 2022); Robert N. Proctor and Londa Schiebinger, Agnotology—The Making and Unmaking of Ignorance, STANFORD UNIVERSITY PRESS (2008).

[300] Supran & Oreskes, *supra* note 298.

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5. The False "Scientists" Sowed Doubt as Defendants Intended.

431.

The creation of this false sense of disagreement in the scientific community is a direct contradiction of the consensus that the industry's own scientists, experts, and managers had previously acknowledged. The GCSCT Action Memo's entire purpose, however, was to create disagreement where there should be none.

432.

The National Coal Association 1991 ICE campaign noted that opinion polls revealed 60% of Americans believed global warming was a serious environmental problem and that "our industry cannot sit on the sidelines in this debate."[301] The GCSCT 1998 Action Memo mentions how public opinion can be swayed with fake science:

> Charlton Research's survey of 1,100 "informed Americans" suggests that while Americans currently perceive climate change to be a great threat, public opinion is open to change on climate science. When informed that "some scientists believe there is not enough evidence to suggest that [what is called global climate change] is a long-term change due to human behavior and activities," 58 percent of those surveyed said they were more likely to oppose the Kyoto treaty. Moreover, half the respondents harbored doubts about climate science."[302]

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[301] Naomi Oreskes, My Facts Are Better Than Your Facts: Spreading Good News about Global Warming, in Peter Howlett et al., How Well Do Facts Travel? The Dissemination of Reliable Knowledge, CAMBRIDGE UNIVERSITY PRESS (2011), at 136–66, https://doc.lagout.org/Others/Cambridge.University.Press-How.Well.Do.Facts.Travel.2010.RETAiL.EBook.pdf (last visited Nov. 15, 2022).

[302] Joe Walker, Global Climate Science Communications Action Plan, GLOBAL CLIMATE SCIENCE COMMUNICATIONS TEAM (GCSCT) (Apr. 3, 1998), at 2, https://insideclimatenews.org/wp-content/uploads/2015/12/Global-Climate-Science-Communications-Plan-1998.pdf (last visited June 20, 2023).

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433.

Defendants' propaganda has been successful. A 2007 Yale University-Gallup poll found that while 71% of Americans personally believed global warming was happening, only 48% believed that there was a consensus among the scientific community, and 40% believed there was a lot of disagreement among scientists over whether global warming was occurring.[303]

434.

The purpose of undermining public opinion was mercantile: to continue to sell enormous amounts fossil fuel for astronomical profits products, irrespective of the extreme weather changes those products cause by their use, and the GCC and its members were—and are—successful in fulfilling that objective.

435.

IPCC published its Fourth Assessment Report in 2007, in which it concluded that "there is very high confidence that the net effect of human activities since 1750 has been one of warming."[304] The IPCC defined "very high confidence" as at least a 9 out of 10 chance.[305] Despite these findings, and the fact that the Fossil Fuel Defendants understood that causal relationship

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[303] American Opinions on Global Warming: A Yale/Gallup/Clearvision Poll, YALE PROGRAM ON CLIMATE CHANGE COMMUNICATION (July 31, 2007), https://climatecommunication.yale.edu/publications/american-opinions-on-global-warming/ (last visited June 20, 2023).

[304] Intergovernmental Panel on Climate Change (IPCC), Summary for Policymakers in Climate A report of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, CAMBRIDGE UNIVERSITY PRESS (2007), at 3, https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-spm-1.pdf (last visited June 18, 2023).

[305] Id.

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decades earlier, the Defendants continued to market their products by funding climate change denialism and undermining scientific consensus to keep consumer demand high.

436.

Exxon acknowledged its own previous success in sowing uncertainty—when there should have been none—and slowing mitigation through funding of climate denial groups. In its 2007 Corporate Citizenship Report, Exxon declared: "In 2008, we will discontinue contributions to several public policy research groups whose position on climate change could divert attention from the important discussion on how the world will secure the energy required for economic growth in an environmentally responsible manner."[306] Despite this pronouncement, Exxon continued to support several such groups after the report's publication.

6. Western States Petroleum Association—A Front Group with An Oregonian Audience

437.

The GCSCT Action Plan mentions developing and utilizing grass root organizations three times (pages 4, 5 and 7) in a PowerPoint presentation leaked in November of 2014 from the Western States Petroleum Association ("WSPA"),[307] the top lobbyist for the oil industry in the

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[306] ExxonMobil, 2007 Corporate Citizenship Report, EXXONMOBIL (Dec. 31, 2007), https://grist.org/wp-content/uploads/2009/07/community_ccr_2007.pdf (last visited June 20, 2023).

[307] Western States Petroleum Association (WSPA) is a non-profit trade association that represents companies that account for the bulk of petroleum exploration, production, refining, transportation and marketing in the six western states of Arizona, California, Hawaii, Nevada, Oregon, and Washington. Founded in 1907, WSPA is the oldest petroleum trade association in the United States of America. WSPA's headquarters are located in Sacramento, California. Additional WSPA

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western United States (including Oregon) and the oldest petroleum trade association in the country. The WPSA "activates" and funds front groups that are designed to change public opinion on climate change.[308]

438.

The WPSA front groups, with names like the "Oregonians For Sound Fuel Policy" and "Fed Up At The Pump," appeared to be grassroots groups representing consumer interests, but were really part of WSPA's multimillion dollar public relations campaign to further the oil industry's propaganda machine.[309]

439.

The slide below identifies groups that were "activated" by the WSPA. Many of the names are clearly "greenwashed" to hide the group's and WPSA's real purpose of working against climate policy. The actions of some of these groups were conducted in, or directed to, Multnomah County.

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locations include offices in Torrance; Santa Barbara; Bakersfield; Scottsdale, Arizona; and Olympia, Washington.
Western States Petroleum Association, About, WESTERN STATES PETROLEUM ASSOCIATION, https://www.wspa.org/about/ (last visited June 20, 2023).

[308] Bloomberg, Leaked: The Oil Lobby's Conspiracy to Kill Off California's Climate Law. BLOOMBERG (Nov. 25, 2014), https://www.bloomberg.com/news/articles/2014-11-25/leaked-the-oil-lobbys-conspiracy-to-kill-off-californias-climate-law?leadSource=uverify%20wall (last visited June 20, 2023).

[309] Matt Connolly, California's Friendly Neighborhood Citizens Groups Are Really Just Big Oil in Disguise, MIC (Nov. 26, 2014) https://www.mic.com/articles/105196/california-s-friendly-neighborhood-citizens-groups-are-really-just-big-oil-in-disguise (last visited June 20, 2023).

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440.

This leaked presentation from WSPA revealed a stealth campaign to change public opinion and keep the consumers lulled into purchasing their products.

441.

Most of the publications questioning climate change came not from scientific journals, but from industry-funded think tanks masquerading as scientific. A study by Professors Peter Jacques and Mark Freeman, political scientists at University of Central Florida, found that 92.2% of the

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skepticism literature was published by GCC-funded think tanks or authors affiliated with those think tanks.[310]

442.

Even though Exxon was aware as early as 1979 that fossil fuels affected climate change and that its fossil fuels posed an existential threat to the future, Exxon continued funding front groups, providing over $2 million in funding from 1998 to 2005.[311]

443.

The GCSCT also funded Willie Soon, another lead climate skeptic.[312] Soon co-authored the article which accompanied the Oregon Petition, *supra* ¶ 410. Most infamously, Soon wrote one of the few denialist articles to be published in a peer-reviewed scientific journal.[313] But that article quickly turned into a scandal where the editorial staff quit. Despite this, Soon earned a "Courage in Defense of Science Award" from The Heartland Institute.[314]

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[310] James Hoggan & Richard Littlemore, Climate Cover-Up: The Crusade to Deny Global Warming, on 81 (2009).

[311] Seth Shulman et al. Smoke, Mirrors & Hot Air: How ExxonMobil Uses Big Tobacco's Tactics to Manufacture Uncertainty on Climate Science, UNION OF CONCERNED SCIENTISTS, (Jan. 2007), https://www.ucsusa.org/sites/default/files/2019-09/exxon_report.pdf (last visited June 20, 2023).

[312] Note-many of the articles authored by Lord Monckton cited by the Heartland Institute are co-authored with Willie Soon.

[313] Justin Gillis and John Schwartz, Deeper Ties to Corporate Cash for Doubtful Climate Researcher, N.Y. TIMES (Feb. 21, 2015), https://www.nytimes.com/2015/02/22/us/ties-to-corporate-cash-for-climate-change-researcher-Wei-Hock-Soon.html (last visited June 20, 2023).

[314] Heartland holds climate conferences and publishes literature that has the "veneer of scientific credibility." John Abrahams, Fossil fuel funded report denies the expert global warming consensus, The Guardian (Feb. 22, 2016), https://www.theguardian.com/environment/climate-consensus-97-per-cent/2016/feb/22/fossil-fuel-funded-report-denies-the-expert-global-warming-consensus (last visited June 20, 2023); For its International Conference on Climate Change, the Heartland Institute offers to pay $1,000 to any scientist willing to help generate international media

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444.

From 2005 to 2015, Soon received $1.2 million from the fossil fuel industry (including Exxon Mobil, the API, and others)[315]

445.

Soon's peer reviewed article, published in *Climate Research* in 2003, concluded that "the 20th century is probably not the warmest nor a uniquely extreme climatic period of the last millennium." The paper was immediately debunked in a publication by 13 climate scientists, who pointed out that Soon's data measured changes in <u>moisture</u>, not changes in temperature, and confused <u>regional</u> changes in temperature with global changes.

446.

Following the 2003 publication, nearly half of *Climate Research*'s editorial board resigned in protest, citing the failure of the journal's peer review process to catch these glaring errors. Furthermore, the journal's parent company stated that *Climate Research* "should have been more careful and insisted on solid evidence and cautious formulations before publication."[316]

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attention for the proposition that rapid warming is not supported by sound science. James Hoggan & Richard Littlemore, Climate Cover-Up: The Crusade to Deny Global Warming, on 81 (2009).

[315] Gillis *et al.*, *supra* note 313.

[316] Richard Monastersky, Storm Brews Over Global Warming. THE CHRONICLE OF HIGHER EDUCATION (Sep. 2003), https://www.chronicle.com/article/storm-brews-over-global-warming/ (last visited Nov. 14, 2022).

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447.

It was also subsequently discovered that Soon's research budget for the article was funded by the API, which Soon did not disclose in his paper.[317]

448.

Soon has also advanced the claim that polar bears do better in a warmer climate. In 1998, Soon argued that "For polar bears…you do want to watch out for ice. Too much ice is really bad for polar bears…I would suggest that the current [ice] condition today is nowhere optimal for the polar bear, which means it can grow a little bit warmer." [318] In reality, global warming melts sea ice, which threatens the polar bears' survival by reducing their food supplies and forcing them to swim longer distances.

449.

The Heartland Institute promotes Willie Soon on its current website, claiming Soon's bio and account of his work "debunks lies of the generously funded environmental left's attacks on an honest climate scientist."[319]

450.

Soon, who is a part-time employee at the Smithsonian Institution, had failed to disclose his oil industry funding in 11 papers since 2008, which violated the disclosure rules of at least **8** of the

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[317] Suzanne Goldenberg, Work of prominent climate change denier was funded by energy industry, THE GUARDIAN, (Feb. 21, 2015) https://www.theguardian.com/environment/2015/feb/21/climate-change-denier-willie-soon-funded-energy-industry (last visited Nov. 14, 2022).

[318] Skeptical Science, How will global warming affect polar bears?, SKEPTICAL SCIENCE, http://bit.ly/1UhCSHn (last visited Nov. 14, 2022).

[319] As of May 21, 2019.

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journals. Correspondence between Soon and his corporate funders, obtained by the *NY Times*, shows that Soon described his scientific papers as 'deliverables,' a project management term denoting services delivered on a specific timeline in exchange for funding.[320]

451.

Articles by Soon, and others appear on Heartland Institute's "Policybot" promoting climate change denial.

452.

Heartland holds climate conferences and publishes literature that has the "veneer of scientific credibility."[321] For its International Conference on Climate Change, the Heartland Institute offers to pay $1,000 to any scientist willing to help generate international media attention for the proposition that rapid warming is not supported by sound science.[322]

453.

Heartland also sponsored a "petition-style attack" on the consensus viewpoint that fossil fuels cause global warming.[323] Heartland published a 'report' on its website titled, "500 Scientists Whose Research Contradicts Man-Made Global Warming Scares."[324] The "report" listed all five

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[320] Gillis *et al.*, *supra* note 313.
[321] John Abrahams, Fossil fuel funded report denies the expert global warming consensus, The Guardian (Feb. 22, 2016), https://www.theguardian.com/environment/climate-consensus-97-per-cent/2016/feb/22/fossil-fuel-funded-report-denies-the-expert-global-warming-consensus (last visited Nov. 14, 2022).
[322] Hoggan & Littlemore, *supra* note 310 at 86.
[323] Id. at 94.
[324] Id.

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hundred scientists as “coauthors”, implying that “each of the five hundred had a hand in [the] report or, at the very least, signed off on its conclusions.”[325]

454.

Immediately after the report’s release, the scientists listed on the report began protesting. “I am horrified to find my name on such a list. I have spent the last 20 years arguing the opposite,” wrote David Sugden, a professor of geography at the University of Edinburgh.[326] “I don’t believe any of my work can be used to support any of the statements listed in the article,” said Robert Whittaker, a professor of biogeography at the University of Oxford.[327] And Gregory Cutter, a professor of ocean and atmospheric sciences at Old Dominion University wrote, “I have NO doubts … the recent changes in global climate ARE man-induced. I insist that you immediately remove my name from this list ….”[328]

455.

To support its denialism methods, Heartland received nearly a million dollars from Exxon and $13.5 million in dark money contributions from Donors Trust, a known front group for oil money.

456.

In a December 2019 expose of Heartland’s dark money funding from Donors Trust to undermine scientific consensus on climate change, Heartland’s chief strategist, James Taylor, told

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[325] Id.
[326] Id.
[327] Id.
[328] Id.

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undercover reporters that Donors Trust is now directing between two thirds and three quarters of its budget to Heartland to support its climate-skeptical positions and claims that this is his personal doing.[329]

457.

On March 19, 2020, Heartland announced it was launching a new website, Climate at a Glance" to "prepare you for climate crisis claims" and hired a 19-year-old German woman named Naomi Seibt to serve as the face of a new campaign for what Heartland calls "climate alarmism."[330]

7. In Pursuit of Profits: The Enterprise Targets School Children

458.

The GCSCT recognized that the tide might turn against fossil fuels unless they could reach the next generation, and it needed to deceive schoolteachers and students about climate science.

459.

So, under the guise of "present[ing] a credible, balanced picture of climate science," they opted to push out materials for teachers and their students that directly countered the scientific evidence. At this point, Children will be the most affected by climate change, having to endure more years of weather extremes and dire effects caused by the Defendants' deception through these

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[329] Katarina Huth, The Heartland Lobby, CORRECTIVE (Feb. 11, 2020), https://correctiv.org/en/top-stories-en/2020/02/11/the-heartland-lobby/ (last visited June 20, 2023).
[330] Nicholas Kusnetz, Heartland Launches Website of Contrarian Climate Science Amid Struggles with Funding and Controversy, INSIDE CLIMATE NEWS (Mar. 13, 2020), https://insideclimatenews.org/news/13032020/heartland-instutute-climate-change-skeptic/ (last visited June 20, 2023).

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front groups.

460.

Page 7 of the GCSCT Action Plan targeted children, tomorrow's consumers:

- Organize under the GCSDC a "Science Education Task Group" that will serve as the point of outreach, to the National Science Teachers Association (NSTA) and other influential science education organizations. Work with NSTA to develop school materials that present a credible, balanced picture of climate science for use in classrooms nationwide.

- Distribute educational materials directly to schools and through grassroots organizations of climate science partners (companies, organizations that participate in this effort).

461.

This insidious directive has been implemented in lockstep. On March 27, 2017, the Heartland Institute mailed a book titled "Why Scientists Disagree about Global Warming: The NIPCC Report on Scientific Consensus", in addition to a DVD and letter to over 200,000 teachers, attached as Exhibit 30.

462.

The material would be sent to an additional 25,000 teachers every two weeks, until every public-school science teacher in the nation has a copy, Heartland president and CEO Joseph Bast said in an interview to PBS in 2017.[331] Heartland claims on its website, that it reached over 300,000 K-12 science teachers.

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[331] Katie Worth, Climate Change Skeptic Group Seeks to Influence 200,000 Teachers, PBS (Mar. 28, 2017), https://www.pbs.org/wgbh/frontline/article/climate-change-skeptic-group-seeks-to-influence-200000-teachers/ (last visited June 20, 2023).

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463.

The campaign elicited immediate derision from the National Center for Science Education (NCSE), a nonprofit in Oakland, California that monitors climate change education in classrooms.[332] “It’s not science, but it’s dressed up to look like science,” said NCSE executive director Ann Reid. “It’s clearly intended to confuse teachers.”[333]

8. NW Natural – Front Groups and Greenwashing for Oregon

464.

NW Natural has emitted in Oregon at least 72,145,570 metric tons of CO_2 equivalent since records began being kept in the last few decades. They have been averaging well over 57,000 metric tons of CO2 equivalent in the past decade, as their sales have steadily increased. NW Natural has deceived the public by claiming that its product is safe, clean, and environmentally friendly, despite the fact that methane is 80 times more potent than carbon dioxide at trapping GHG and is responsible for a substantial percentage of the human-made greenhouse gases in the atmosphere.

In its current Environmental Stewardship policy, NW Natural states:

> NW Natural’s core value of environmental stewardship is a driving force behind everything we do. We believe NW Natural has an important role to play in helping our region move to a lower-carbon, renewable energy future in a more resilient and affordable way.[334]

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[332] Id.
[333] Id.
[334] Alex Baumhardt, A, *Oregon DEQ says NW Natural is misleading people on state climate program* Oregon Capital Chronicle, The Oregonian, August 22, 2024, https://www.nwnatural.com/-

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Further, NW Natural has paid for advertisements misleading the public about their commitment to a "carbon neutral future." Yet, NW Natural has not implemented any operational changes that would reduce greenhouse gas emissions in Oregon, and it deceptively distorts to the public any initiatives aimed at lowering emissions as an infringement on the consumer's "freedom of choice."

465.

Upon information and belief, NW Natural also engages in "astro turfing" which is the practice of deceptively presenting a corporate driven public relations campaign under the guise of an organic community effort. Notably, NW Natural engaged in astroturfing by funding a front group called Eugene Residents for Energy Choice, but the committee is registered in Portland and is nothing more than a front group for NW Natural to fight local climate policy to address the harm caused in the community by the changing climate to line its own pockets.

466.

In an effort to maintain market share and control how its harmful products are perceived by the public, NW Natural sent emails and print mailers to schools offering free "gas-related" activity books for children.[335] The purpose of these books is not to warn of the dangers of using NW Naturals' products and services, but instead to promote the continued use and consumption of

/media/nwnatural/pdfs/communityandsustainabilityreport_2022environmentalstewardship.pdf?rev=1e4749fdcb4a4d4bbe8f987a9be2a789&hash=F47C2C88CF16454A71B67CC7BBCD7722

[335] Testimony of Greer Ryan, Before the Public Utility Commission of Oregon, April 22, 2022, at pp. 11-14, https://edocs.puc.state.or.us/efdocs/HTB/ug435htb16597.pdf

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fossil fuel gas by influencing public opinion, which in this campaign targets the next generation through children.

467.

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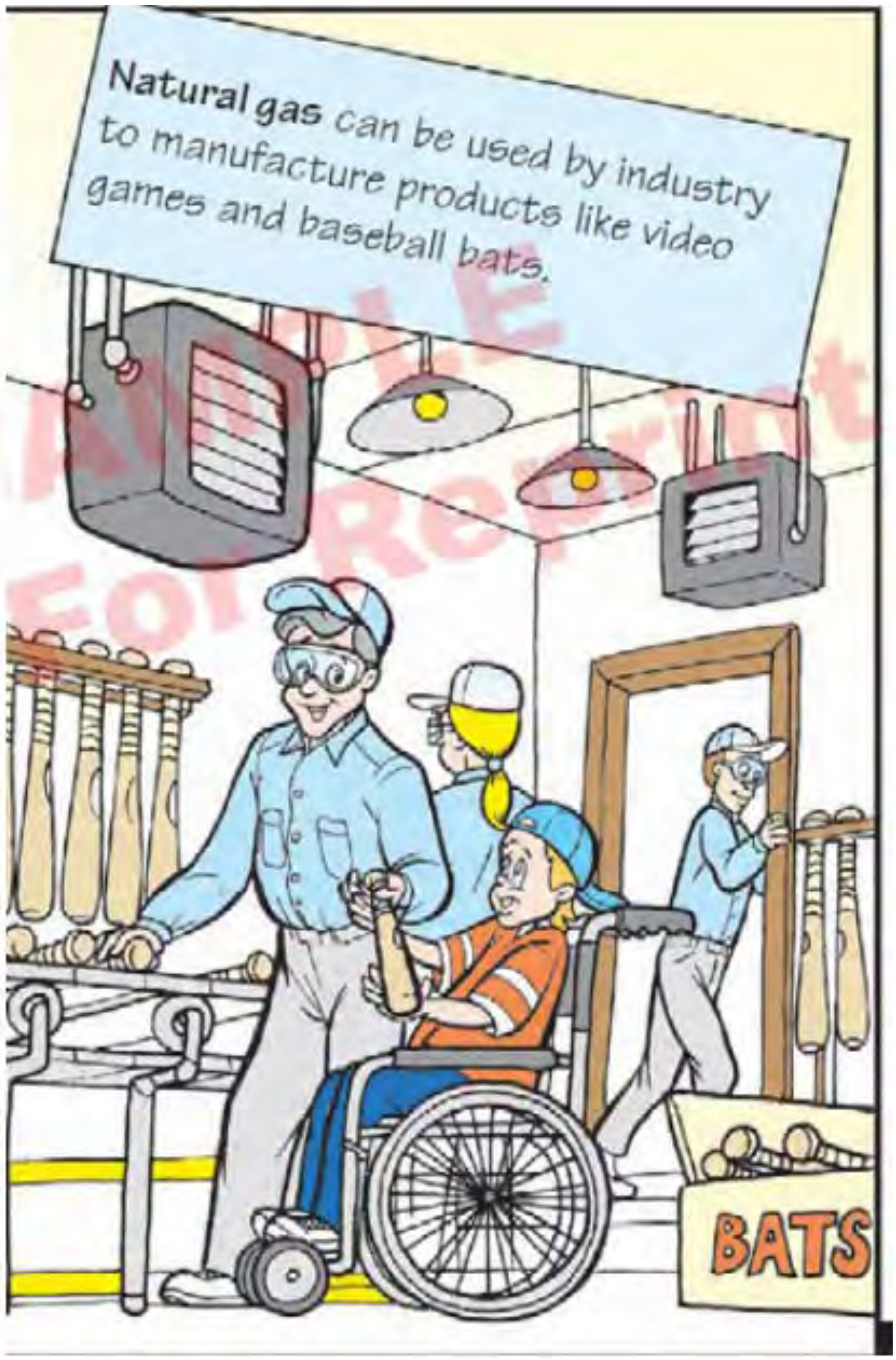
468.



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469.

Another example of NW Natural's propaganda directed towards children in Multnomah County.[336]

[336] Id.

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470.

Further entrenching its bid to remain viable, NW Natural planned for an event held by a front group it funds called, Bonneville Environmental Foundation, to convey propaganda to teachers titled, "Clean Energy Teacher Training: Exploring Renewable Gas."[337] Pursuant to the campaign, each teacher who attended the Portland based training session would receive a $200 stipend, and if the teacher lived more than 50 miles away, they would be reimbursed for mileage.[338] After a public outcry, the training was cancelled. NW Natural's central message is that its gas products are safe, clean, and environmentally friendly.

471.

In 2024, NW Natural engaged in a campaign of disinformation related to a key Oregon climate policy, the Climate Protection Program. NW Natural distributed a newsletter that contended that any costs incurred by NW Natural under this new climate policy will result in a 14% rate hike for each and every one of the 2,000,000 customers it serves while not reducing GHG emissions. This newsletter and its characterization of the policy was so egregious that the DEQ issued a rebuke and accused NW Natural of misleading Oregonians.[339] NW Natural has misled the public about the adverse climate impacts of extracting, storing, delivering and burning their

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[337] Effinger, A, Gas Fight Continues as Students Plan Protest of Teacher Training Sponsored by NW Natural, WILLAMETTE WEEK, https://www.wweek.com/news/schools/2023/01/20/gas-fight-continues-as-students-plan-protest-of-teacher-training-sponsored-by-nw-natural/ (last visited on September 20, 2024).

[338] *Id.*

[339] Baumhardt, *supra* note 334.

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products.

472.

In 2023, Oregon's Public Utility Commission, after reviewing NW Natural's self-style "Clean Energy/Decarbonization" plan to meet the state's clean energy targets, deemed their plan as unrealistic, insufficient and misleading. NW Natural is a member of the American Gas Association, which, like the API, is a chief source of funding and spreading misinformation about the impact of the natural gas pollution on global warming.

473.

NW Natural has admitted Oregon needs to prepare for "more extreme weather events," but the company has neither invested accordingly nor accepted responsibility for their contributing role in causing these extreme weather events. Instead, NW Natural encourages us to "feel good about natural gas as your energy source" because it's "efficient," *without* disclosing the foreseeable catastrophic consequences of adding more methane to an already polluted atmosphere that is fast approaching its tipping point.

474.

In summary, NW Natural has routinely misrepresented to the public the climate impacts of extracting, transporting, storing and burning their product while over-estimating the costs of transitioning to renewables or reducing their pollution in an effort to frighten customers and discourage policy makers from using their authority to protect the public.

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9. McKinsey and Big Oil – Fueling Fossil Fuel Disinformation

475.

In McKinsey's code of conduct it claims, "We are committed to protecting the planet." McKinsey also contends "[a]s a firm, we take seriously our responsibility for the environmental sustainability of our operations and our offices take steps to reduce our environmental footprint. We also serve private, public, and social sector clients across the world on steps they are taking to address climate change."

476.

These public proclamations by McKinsey are contrary to how it conducts its business behind closed doors. While McKinsey is shrouded in secrecy about its consultancy, it represented many Fossil Fuel Defendants since 1950 to present.

477.

Mobil Oil was McKinsey's first large client in the 1950s. McKinsey represented Royal Dutch Shell in the mid-1950s. McKinsey represented Texaco. McKinsey consulted and worked with these companies as their internal understanding was that rising CO_2 levels can heat the earth and cause extreme weather events.

478.

McKinsey has also consulted for ExxonMobil, BP, Royal Dutch Shell, Gazprom, and Qatar Petroleum. McKinsey's work is based on the promotion and furtherance of its clients' fossil fuel products and has fueled the disinformation and deceptive promotion of fossil fuels' dangers and environmental impacts including, upon information and belief, in Oregon.

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10. Oregon and the Heartland Institute

479.

The Defendants' deception campaign was vigorously executed in Oregon and targeted to mislead the Plaintiff and its residents.

480.

Gordon Fulks is a prolific anthropogenic climate change denier and is a policy advisor to the Heartland Institute, which as described above, provides a medium through which Defendants have propagated false and misleading denials and downplays of the causal relationship between carbon pollution and extreme climate change. At the behest of benefactors that included Fossil Fuel Defendants, Fulks has published editorials in the Oregonian that deny the existence of any scientific consensus that carbon pollution causes warming of the planet.[340] He writes, "The many objections from real scientists will be countered with fictitious claims of 'consensus.' (Should that, too, be questioned — based on studies that show widely divergent scientific opinions — the political formula calls for stonewalling.) Never mind that science proceeds from openly discussed logic and evidence. The scientifically illiterate will not understand and can be easily fooled with unsupportable claims that each succeeding year is the 'warmest ever.'"

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[340] Fulks, G. J., Kitzhaber is allowing climate malpractice: Guest opinion, The Oregonian, *https://www.oregonlive.com/opinion/2015/01/kitzhaber_is_allowing_climate.html* (last visited June 20, 2023).

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481.

In another piece in the Oregonian, Fulks dismissed scientific support for anthropogenic climate change as a "storm of alarmism" based on faulty science. "The problems with classical greenhouse gas theory escape those who view science as politics (consensus) or as religion (belief)," he wrote.[341]

482.

Thus, in these and other ways, Defendants' deception was directly targeted at the County and its inhabitants. These lies created enough doubt as to whether extreme weather events from anthropogenic climate change could harm those *in the County*, and thereby left the community and its leadership unprepared for extreme heat events that Defendants' products caused and the harm that Defendants' deceptions exacerbated.

483.

Had the Defendants exercised ordinary care rather than a plan to deceive the Plaintiff and the public while simultaneously causing extreme harm to the Plaintiff and to the planet, they would have taken several steps that they refused to take. These measures include, not exhaustively,

a) Public and full-throated endorsement of the scientific validity of the existence of anthropogenic climate change and the catastrophic harm it can cause. The Defendants unequivocal, forward-facing acceptance of that information would have altered the debate from *whether t*o combat global warming to *how* to combat it; and avoided much of the public confusion that has ensued over the last several decades.

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[341] Fulks, G. J., "The Changing Climate of Climate Change," The Oregonian, January 19, 2013. Archive.ph *URL*: *https://archive.ph/wip/70ONn* (last visited June 20, 2023).

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b) Forthrightly communicating with Defendants' shareholders, consumers, banks, insurers, the public, regulators, and the Plaintiff that the problem to be mitigated is the accumulation of excessive amounts of GHGs in the atmosphere from the use of Defendants' products, rather than "alarmist" concerns about it.

c) Refraining from affirmative efforts, whether directly, through coalitions, or through front groups, to distort public debate, and to cause many consumers and business and political leaders to think the relevant science was far less certain that it was.

d) Sharing their internal scientific research with the public, and with other scientists and business leaders, to increase public understanding of the scientific underpinnings of climate change and its relation to Defendants' fossil fuel products.

e) Supporting and encouraging policies to avoid dangerous climate change and demonstrating responsible corporate leadership in addressing the challenges of transitioning to a low carbon economy.

f) Prioritizing alternative sources of energy through sustained investment and research on renewable energy sources to replace dependence on Defendants' hazardous fossil fuel products.

g) Adopting their shareholders' concerns about Defendants' need to protect their businesses from the inevitable consequences of profiting from their fossil fuel products. Over the period of 1990–2015, Defendants' shareholders proposed hundreds of resolutions to change Defendants' policies and business practices regarding climate change. These included increasing renewable energy investment, cutting emissions, and performing carbon risk assessments, among others.

484.

Instead, the Defendants negligently and intentionally created a public nuisance by their failures to warn, refusals to warn, and misrepresentations that caused enormous harm to and in the County, and in other regions, about which each Defendant treated as a public relations problem to be spun rather than an existential human threat to be solved. In so doing, they caused catastrophic harm to Plaintiff that will continue and grow worse. As the frequency and intensity of extreme heat

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events and wildfires in Multnomah County will increase, so too will the harms inflicted upon the County.

IV. DAMAGES

485.

As a sovereign entity, the County is charged with protecting the health, security, and welfare of its residents. It operates as a steward that safeguards the fabric of the community, its ecosystems and way of life, including those for future generations. In its exercise of its police powers, the County is empowered to take actions to prevent the pollution of the County's property and resources, to prevent and abate nuisances, and to prevent and abate hazards to public health, safety, welfare, and the environment.

486.

The Country provides services that are essential to the health, safety, and welfare of its residents, including, not exhaustively: emergency planning, early warning and disaster management; health care, police and fire protection; flood controls; maintenance of bridges, and protection of public outdoor space.

487.

Populations, property, and transportation infrastructure within the County have been and will continue to be damaged by Defendants' misconduct. The County has taken steps to prepare, mitigate, repair, and adapt to the hazards facing its residents, public property, and infrastructure, and will and must continue to do so, as ACC continues to increase the frequency and severity of extreme heat events, wildfires, drought, storms, and other hazards threatening the public's physical and mental health.

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488.

Because of Defendants' failures to warn, refusals to warn, knowing concealment, deception and misrepresentation of the dangers of fossil fuels and the climate impacts of carbon pollution on the environment, ACC has and will continue to impact the County and its ability, without the infusion of substantial resources, to deliver services including health care, social services, climate resiliency and sustainability programs, and disaster relief, especially for its most vulnerable residents.

489.

Defendants engaged in an enterprise of misrepresentation and deception about the effect its products would have on the climate, and that they could cause extreme weather events such as the 2021 extreme heat event. Further, Defendants' individual and collective emissions, including those in Oregon, were a cause of the 2021 extreme heat event. This suit does not seek to challenge the legal rights of Defendants to create emissions that occur outside of the state of Oregon. The law, however, does not and should not permit Defendants to conceal and misrepresent the dangers of their products' emissions, which led to an increase in the demand and consumption of those products and lack of preparedness for extreme heat drastically exacerbating past and continuing damages from the 2021 extreme heat event.

A. Damage: Substantial Cost Incurred to Respond to Extreme Heat Events

490.

The County incurred the following costs (and others) in responding to the 2021 heat dome and 2022 heatwave:

a) The County established numerous emergency shelters to provide relief to thousands of heat-stressed residents, including the supply of portable

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air conditioning units, fans and fresh water, as well as staffing to provide social services and medical care.

b) The County responded to hundreds of heat-related illness or urgent care visits, in addition to a drastic increase in heat related hospitalizations over previous years.

c) The County Coroner determined that the 2021 heat dome was responsible for 69 heat related deaths in the County, which the coroner ruled were caused by hyperthermia. In 2022, five residents perished from extreme heat.[342]

B. Damage: Added Costs to Protect Residents and Property from Wildfires And Smoke

491.

In September of 2020, the County experienced a spike in medical visits for respiratory issues caused by poor air quality because of ACC-related wildfire smoke. Asthma-related health related visits in Multnomah County increased by nearly one-third in the four weeks during and after wildfires in 2020.

492.

In 2022, the County responded to thousands of urgent care clinic visits as a result of poor air quality arising from waves of wildfire smoke.

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[342] The United States EPA has quantified the value of a human *life* at $10.05 million for the social cost of a life taken prematurely because of GHG driven climate change. According to that metric, **the societal cost of the combined loss of the 69 lives in 2021 and 5 lives in 2022 because of extreme heat is $743,700,000.** See EPA Draft of Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances (September 2022). *https://www.epa.gov/system/files/documents/2022-11/epa_scghg_report_draft_0.pdf* (last visited June 20, 2023).

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493.

The number of wildfire smoke related healthcare visits and hospitalizations has continued to increase along with the frequency and severity of wildfires since 2020.

494.

The County expects increased costs from increased wildfire risk due to Defendants' misrepresentations and deception about the dangers of their products emissions that have led to increased demand and consumption and in turn climate change. The County's response, prevention, mitigation and/or recovery costs are increasing and will continue to increase.

C. Damage: Substantial Costs Incurred For Public Health Emergency Response and Preparedness

495.

The County has invested substantial sums to prepare for severe public health emergencies from extreme heat and wildfires, including protocols for bolstering the County's Emergency Response Plan and for training and testing health care professionals.

496.

The County has invested substantial sums in developing and strengthening emergency plans that increase preparedness within the county and the region, ensure that critical operations will continue during an emergency, and provide for staff training, workshops and disaster plan management and coordination.

497.

The County has invested substantial sums to coordinate disaster preparedness activities within the county, including training, exercise and equipment procurement, and collaboration with cities, special districts, and non-governmental organizations. During ACC related disasters, the

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Emergency Management program activates an emergency command center to facilitate the appropriate response using the staff and resources available.

498.

The County has incurred substantial costs in leasing, staffing, and operating an emergency supply depot designed specifically to store disaster relief materials and vehicles for use in climate related disasters such as heat domes, this was not needed before 2021.

499.

The County has invested substantial sums to fund programs to identify and eliminate environmental hazards that contribute to racial and ethnic disparities.

500.

The County has incurred substantial costs in recruiting and retaining a Climate Resilience Coordinator, whose job is to coordinate policy interventions with other city, county and state agencies relating to climate change risks. The job description includes updating wildfire mitigation zones, weatherization of low-income dwellings, development of best practices for public buildings to mitigate extreme heat and smoke conditions, develop strategies to reduce heat islands and develop partnerships with under-resourced East County cities.

501.

The County has incurred substantial costs in funding initiatives in the East County to support community climate resiliency efforts which investigate needed upgrades in services and physical infrastructure to safely and timely respond to ACC-related disasters. Significant funds have been spent to monitor and assess the services and infrastructure that underserved and marginalized communities need to enhance the community's tolerance for natural disasters.

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502.

The County has incurred substantial costs in funding the purchase and installation of 1,000 portable air conditioners and 10,000 emergency cooling kits, intended for at risk households. The County has created and funded a Cooling Support Program for the purpose of providing air conditioners and other life sustaining materials to low-income residents.

503.

The County has incurred substantial costs in providing emergency shelters, assistance and street outreach for vulnerable homeless youth, veterans, and families during extreme weather events.

504.

The County has incurred substantial costs to fund, recruit, hire and train an Emergency Analyst to support the County's shelter and disaster resource center functions. The Emergency Analyst works within the Department of County Human Services and works with County Health Department and focuses on the implementation of the County's post 2021 heat dome employee incentive program to develop a robust pool of staff and volunteers who will be available to staff and service emergency shelters during and after ACC-related disasters.

505.

The County has incurred substantial costs to fund outreach efforts to reduce the burden on limited emergency response capacity during an extreme emergency by collaborating with local businesses, non-governmental organizations, faith-based groups and volunteer groups, as well as community members, to encourage resilience and create a coordinated disaster response.

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D. Damage: Substantial Costs Incurred in Monitoring, Educating and Mitigating ACC Impacts

506.

The County has incurred substantial costs in creating, staffing, supplying, and operating the Multnomah County Office of Sustainability, which was established in 2010 in response to the escalating climate emergency for the purpose of studying, planning, implementing and coordinating the County's growing need for modernized social, environmental, and economic policies and programs. The mission of the Office of Sustainability is to grow and nourish a county that is equitable, livable, healthy, resilient, and low carbon.

507.

The County has incurred substantial costs in staffing and equipping a program that provides low-income households with energy efficient heat pumps to replace wood burning stoves. Heat pumps provide cooling during heat events and reduce greenhouse gas emissions as well as particulate emissions from the burning of wood. The program continues the Wood Stove Replacement Program which, in the interest of improving air quality and public health, exchanges wood stoves for new energy efficient furnaces or heat pumps.

508.

The county has incurred substantial costs and will continue to do so to assess the need for expansion of County services in low-income East County neighborhoods and build satellite county facilities with culturally specific social services that meet the growing needs of East side communities as ACC-driven extreme weather events escalate.

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509.

The County has incurred substantial costs and will continue to do so to design, staff, equip and operate Environmental Health Community Programs, the purpose of which is to identify and mitigate ACC-driven environmental health hazards that contribute to racial and ethnic inequities. The program allocates staffing and material resources to lower income communities who are disproportionately impacted by ACC. Expenditures include monitoring and assessing ACC health and environmental impacts.

510.

The County has incurred substantial costs in assessing damage to County-owned property and infrastructure for the purpose of "climatizing" air filtration, air conditioning and other systems and components with repairs, replacements, and upgrades to protect the health and safety employees and visitors. The County has incurred substantial costs in modernizing, weatherizing, repairing and upgrading Heating Ventilation Air Conditioning systems to maintain compliance with indoor air quality systems and Oregon Occupational Safety and Health Administration standards.

511.

The County has incurred substantial costs in creating, staffing, equipping, and operating a Climate Justice Program, the goal of which is to collaborate with frontline communities and resiliency experts to develop a new climate action community justice framework that continues and builds upon the results of the 2015 Climate Action Plan.

E. Damage: Substantial Costs Incurred In Preparing for and Responding to Extreme Heat and Wildfire Events

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512.

In addition to the costs to repair and maintain climate change-damaged County owned property, bridges, public buildings, and in addition to the costs of providing healthcare, shelters, custodial care and autopsies for the climate casualties, the County has incurred additional substantial costs because of the extreme heat events, wildfires and drought described herein, which include:

a) Costs of increased electrical power and potable water consumption;

b) Costs from the loss of productivity from county employees and contractors who were unable to work outside because of hazardous temperatures and /or air quality;

c) Costs of training first responders;

d) Costs associated with employing and dispatching public safety officers, 911 operators, and first responders;

e) Costs for providing mental-health services, treatment, counseling, and rehabilitation services;

f) Loss of tax revenue;

g) Loss of tourism revenue;

h) Losses from diminished property values;

i) Losses from damaged or destroyed natural resources, including trees, wildlife, and marine life, crops, and vegetation;

j) Losses from increased heat-related mental illness, increased violence, increased property crimes and increased utilization of county health services and the criminal justice system;

k) Costs of increased property, casualty and disaster risk insurance costs;

l) Costs of implementing nature-based climate solutions, e.g., reforestation and drought tolerant, native plant landscaping;

m) Loss of enjoyment and use of a habitable climate;

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n) Costs of treating people with ACC-related ground level ozone impairment and harmful exposure to allergens, salmonella and other infectious pathogens;

o) The increased costs of maintaining the County's infrastructure, such as its bridges over the Willamette River the lifelines between the west and east sides of the city and County;

p) The costs of population displacement and migration of climate refugees from southern states or nations.

513.

The actual damages incurred by the County, because of Defendant's misconduct which substantially contributed to and caused the extreme heat, wildfire and other disasters described herein exceed $50,000,000.

F. The County will Incur Substantial Costs to Prepare for, Prevent, Mitigate, and Abate the Climate Change Nuisance

514.

The costs of studying, consulting with experts, preparing for, mitigating, adapting to, and abating the ongoing nuisance caused by Defendants will be enormous. The programs and adaptation measures that County has undertaken, as described herein, are only the beginning of an adequate response to dealing with increased risks from ACC. These costs are occurring now and being borne by taxpayers to protect the safety, health, and lives of residents, and the County's property and infrastructure. The costs will continue to grow for decades to come as several Defendants continue to deny the worsening climate calamity so as to not drastically reduce the demand for consumption of fossil fuels. This lawsuit does not seek to regulate GHG emissions.

515.

The costs will include, not exhaustively:

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a) The costs to monitor and assess climate change impacts and devise remedial actions;

b) The costs to prepare for, adapt to and abate the health impacts on the County for the increased frequency and duration of extreme heat events, wildfires and wildfire-generated smoke, droughts, storms and other disasters caused by Defendants' misconduct;

c) The costs to protect, upgrade, weatherize and fortify transportation systems and structures, levees, roads, utility networks, sewage and potable water systems, school buildings, railways, and bridges;

d) The costs of creating wildfire defensive spaces and home hardening to reduce the risk of wildfire destruction;

e) The costs to expand health emergency and clinical care services and shelters;

f) The costs to design, purchase, install and operate air conditioning and air filtration systems and weatherize at-risk buildings and residences;

g) The costs for the county to draw down atmospheric carbon by planting more trees and biomass, expanding open spaces, protecting slopes and riverbanks from erosion, preserving forests, expanding the tree canopy in dense urban areas to mitigate heat islands, and converting to carbon neutral energy systems.

516.

All Defendants acted individually and in concert with other Defendants and propagandists for the purpose of deceiving Plaintiff and its citizens as to how the manufacture, distribution, sale, and use of its fossil fuel products would affect the atmosphere and change the County's weather from mild and predictable to extreme, erratic, destructive, and deadly.

517.

As a result of each Defendant's misconduct alleged herein, Plaintiff has suffered extreme and destructive heat events, degraded air quality from wildfire, increased medical costs for fire and heat-related services, increased burden on the County infrastructure, drought, loss of

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agricultural production, loss of snowpack and water resources, causing economic damages exceeding $50,000,000.

518.

As a result of each Defendant's misconduct alleged herein, Plaintiff will incur future economic damages from reoccurring extreme and destructive heat events, degraded air quality from wildfire, increased medical costs for fire and heat-related services, increased burden on the County infrastructure, drought, loss of agricultural production, loss of snowpack and water resources, in the amount of no less than $1.5 Billion.

V. FIRST CLAIM FOR RELIEF: INTENTIONAL AND NEGLIGENT CREATION OF PUBLIC NUISANCE

519.

Plaintiff realleges and reaffirms the allegations set forth in paragraphs 1-518 as if fully restated in this claim.

520.

Defendants' actions were intentional, reckless, deceitful, or negligent as detailed throughout this Second Amended Complaint.

521.

Plaintiffs and its citizens have possessory interests in the lands of Multnomah County. Plaintiff and its citizens have a right to enjoy those lands and the air above same.

522.

Defendants' intentional and negligent acts in concealing and misrepresenting the dangers of fossil fuels and climate impacts from the use and sales of fossil fuel-based consumer products in Multnomah County and elsewhere have caused the losses, death, and destruction of County

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property, lands, and resources resulting from the extreme weather event known as the 2021 extreme heat event, wildfires, and their aftermath. Defendants created a public nuisance that is unreasonable, harmful, and disruptive to health, safety, the County's fiscal health, and general welfare of Multnomah County.

523.

Defendants knew or should have known that their unreasonable, deliberate, reckless, and deceitful promotion of fossil fuels and the harms they cause would lead to a lack of preparedness for extreme heat events causing a public nuisance that is harmful to health, obstructs free use of the County lands and property and will require enormous financial resources to abate.

524.

Defendants knew or should have known that their unreasonable, deliberate, reckless, and deceitful promotion of fossil fuels and the harms they cause would lead to an increase in demand and consumption of fossil fuels causing a public nuisance that is harmful to health, obstructs free use of the County lands and property and will require enormous financial resources to abate.

525.

Defendants' concealments of knowledge that their fossil fuel products could cause extreme heat events like those that have struck the County, have created an unreasonable interference with a public right common to the public, including public health, the right to enjoyment of life and property, and excessive expenditure of taxpayer resources. Extreme heat in a moderate climate, when coupled with inadequate climate adaptation measures, causes unreasonable interference with each of these rights common to the public.

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526.

The harms and future risks imposed upon Plaintiff and its inhabitants from climate shift and extreme heat events in the County that Defendants caused far outweigh any social utility that Defendants create through their fossil fuel business activities when coupled with the Defendants' deception of the damage that is wrought therefrom.

527.

Multnomah County has suffered harm and will continue to suffer harm that is different from the type of harm suffered by the general public, including damage to County resources, and expenditures of treasury funds to protect the health and welfare of its citizens and ecosystem.

528.

Pled in the alternative, and as alleged throughout this Complaint[343] Fossil Fuel Defendants' in-state emissions in Oregon are, in and of themselves, a cause of extreme weather events, including the 2021 extreme heat event, and an unreasonable interference with a public right common to the public, including public health, the right to enjoyment of life and property, and excessive expenditure of taxpayer resources. Extreme heat in a moderate climate causes unreasonable interference with each of these rights common to the public.

529.

Each Defendant's conduct was a cause of the harm to Multnomah County.

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[343] *See e.g.*, *supra* ¶¶ 39, 53, 66, 80, 89, 100, 109, 116, 127, 134, 149, 159, 164, 167, 170, 171 and 486.

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530.

Defendants' conduct was malicious, wanton, and willful.

531.

Multnomah County seeks abatement of the extreme weather events through a provision of resources necessary to adequately prepare the County and its citizens for a new normal—heat domes, blocking events, periods of high heat and/or wildfire so severe that they kill and sicken inhabitants, destroy property, and weaken—sometimes cripple—critical infrastructure.

532.

Adequate abatement will require, not exhaustively, renovating buildings to withstand extreme heat, fitting cooling units into buildings, providing cooling units in the community, providing additional cooling shelters for heat emergencies, installing air filtration systems, planting of greenspaces to reduce temperature in heat islands, reroofing buildings with materials that better manage heat, repave roads and fortify bridges.

VI. SECOND CLAIM FOR RELIEF: NEGLIGENCE

533.

Plaintiff realleges and reaffirms each and every allegation set forth in all the preceding paragraphs as if fully restated in this claim.

534.

Defendants knew or should have known that their unreasonable, deliberate, reckless, and deceitful promotion of fossil fuels and the harms they cause would lead to an increase in demand and consumption of their products causing extreme weather events like the 2021 heat event, and to a lack of preparedness by the County for extreme weather events like the 2021 event, which

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caused and exacerbated the County's damages.

535.

Defendants were negligent in the following respects:

a) They continued to extract, process and sell fossil fuel products in Oregon which they knew or should have known would cause injury to Plaintiff and others;

b) They failed to warn Plaintiff and others of the foreseeable consequences of using their fossil fuel products leading to an increase in demand, consumption and dependence on fossil fuel products;

c) They concealed from the public and regulators their knowledge and research concerning the effects of the extraction, refining and use of their products;

d) They developed, designed, tested, inspected, distributed, labeled and marketed their fossil fuel products and advertised their business practices in a manner designed to conceal, downplay and obfuscate the long-term effects of the widespread use of their products;

e) They misled Plaintiff, its citizens and others regarding the harm caused by fossil fuel products so as to not discourage excessive purchase, use, and consumption of the products.

536.

Plaintiff's injuries were the foreseeable results of Defendants' negligence.

537.

Pled in the alternative, and as alleged throughout this Complaint[344] Fossil Fuel Defendants knew or should have known, that their in-state emissions in Oregon, in and of themselves, would

[344] *See e.g.*, *supra* ¶¶ 39, 53, 66, 80, 89, 100, 109, 116, 127, 134, 149, 159, 164, 167, 170, and 171.

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foreseeably cause extreme weather events, including the 2021 extreme heat event, causing harm to the Plaintiff.

VII. THIRD CLAIM FOR RELIEF: FRAUD AND DECEIT

538.

Plaintiff realleges and reaffirms each and every allegation set forth in all the preceding paragraphs as if fully restated in this claim.

539.

Fossil Fuel Defendants, jointly with the Trade Group Defendants and Other Defendants (McKinsey), engaged in fraud, deceit, or intentional misrepresentation.

540.

From 1969 to present, Defendants, individually and through both legitimate and illegitimate means, engaged in a nationwide—including in Oregon—marketing campaign and civil conspiracy with the purpose and intent to make material representations that were false. Defendants made these representations knowing they were false.

541.

Defendants intended that Multnomah County, its citizens and persons across the country rely on their misrepresentations and excessively purchase, use, and consume fossil fuel products.

542.

Multnomah County, and its citizens did justifiably rely on Defendants decades-long assertions that burning fossil fuel products would not cause climate change that would harm the County or its residents and would not increase the probability and severity of extreme weather events in the County.

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543.

Multnomah County and its residents' reliance on Defendants' misrepresentations, fraudulent statements, and deceptive statements led to Multnomah County being unprepared for the 2021 extreme heat event, suffering the loss of property, infrastructure, financial resources, lives, and health.

544.

Multnomah County is entitled to its past damages and future damages due to the fraud and deceits committed by Defendants. Defendants knew that their acts, omissions, fraud and deceit would encourage consumption of Fossil Fuel Defendants' products and preclude Multnomah County and its citizens from adequately preparing for the regional climate shift that has occurred due to Fossil Fuel Defendants' GHG emissions. The regional climate shift includes but is not limited to, extreme heat events with greater frequency and intensity, extended drought conditions that lead to greater intensity and longer wildfires resulting in smoke penetration pollution in Multnomah County. These extreme weather events have heat smothered the County and caused millions of dollars in damages. Fossil Fuel Defendants fraudulently concealed their knowledge that the continued and increased use of their products would cause climate shifts resulting in extreme heat waves and heat domes of greater than 40° F over the mean temperature.

VIII. FOURTH CLAIM FOR RELIEF: TRESPASS

545.

Plaintiff realleges and reaffirms each and every allegation set forth in all the preceding paragraphs as if fully restated in this claim.

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546.

Plaintiff is the owner, in lawful possession, of real property and has sovereign responsibilities for Multnomah County.

547.

Fossil Fuel Defendants have engaged in intentional conduct in Oregon, including their in-state emissions, that has caused and contributed to climate change, thus causing airborne particulates from extreme wildfires to enter Plaintiffs' property.

548.

Fossil Duel Defendants have engaged in intentional conduct in Oregon that has caused and contributed to climate change, resulting in a radical shift in climate patterns that has caused waters, from extreme rain events and excessive snowpack melting, to enter Plaintiff's property.

549.

Multnomah County has not granted permission to Defendants to damage its property nor enter nor intrude upon it with fire, smoke, water, or intense heat created by Defendants' misconduct.

550.

Fossil Fuel Defendants knew that the use of their products, including the in-state emissions therefrom, would both cause climate change—extreme weather events, more intense fires causing smoke intrusion—and cause these invasions of Plaintiff's property and that they lacked permission for these invasions but intruded anyway.

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551.

These invasions are now occurring and will continue to occur causing harm to the County. Fossil Fuel Defendants' trespasses are a cause of injury and losses to the County.

552.

The County's real property has been and continues to be damaged by these intrusions.

IX. RELIEF REQUESTED

WHEREFORE, Plaintiff prays for a judgment and an order against each Defendant as follows:

a) That the acts alleged herein be adjudged and decreed to be unlawful and that the Court enter a judgment declaring them to be so;

b) Finding Defendants, and each of them, liable for causing, creating, assisting in the creation of, contributing to, and/or maintaining a public nuisance;

c) Compensatory award for past damages in the amount of $50,000,000 according to proof, of the costs of actions Multnomah County has already taken, expenditures made, and losses incurred to protect the public health, safety, and property of the County and its residents from extreme heat weather events and wildfire smoke;

d) The entry of an order that will abate the nuisance by the establishment of an abatement fund remedy to be paid for by the Defendants in the amount of at least $50 Billion for the costs of studying and planning on a countywide scale for the renovations, replacements, retrofits and revised programs that are reasonably necessary to reduce the ongoing harms caused by the Defendants, the implementation of which will reasonably prepare the County and its residents for foreseeable negative impacts arising from the increased frequency and severity of extreme heat, wildfire, drought and consequences of Defendants' misconduct. The planning, approval and implementation will take considerable time, staffing and resources, during which time the nuisance is expected to continue to worsen, even if carbon emissions worldwide ceased altogether, as the current hazardous levels of GHG in the atmosphere will remain aloft for decades where said pollution will continue to cause extreme events, absent massive but untested and unproven technological carbon capture programs. The abatement funds will be necessary to essentially "weatherize" the County to prepare for

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and safeguard against the continued infliction of harms from extreme weather events, for which Defendants are liable;

e) Compensatory award for future damages in the amount of no less than $1.5 Billion, according to proof, for the damages Defendants will cause to Plaintiff before an abatement plan to reduce or prevent future harms can be implemented;

f) Awarding attorneys' fees as permitted by law;

g) Awarding costs and expenses as permitted by law;

h) Awarding pre-judgment and post-judgment interest as permitted by law; and

i) Awarding such additional relief as may be just and proper.

Dated this 4th day of October 2024.

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to be sent by the following indicated method or methods, on the date set forth below:

X	by **sending via the court's electronic filing system, to the extent it exists and counsel is registered**
X	by **email**
	by **mail, to each of the attorneys listed as counsel for Plaintiff above**
X	by **service of process to the added parties (unlisted above) as governed by the applicable ORCP**

DATED: October 4, 2024

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EXHIBIT 1

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[redacted]

Final Report

February 1968

SOURCES, ABUNDANCE, AND FATE OF GASEOUS ATMOSPHERIC POLLUTANTS

Prepared for:

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SRI Project PR-6755

B4007

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18 μ. As such CO_2 prevents the loss of considerable heat energy from the earth and radiates it back to the lower atmosphere, the so-called "greenhouse" effect. Thus the major changes which are speculated about as possibly resulting from a change in atmospheric CO_2 are related to a change in the earth's temperature.

The latest data available for estimating CO_2 temperature effects are those of Moller (1963). From Möller's data a CO_2 increase of 25% would result in an increase in temperature at the earth's surface of between 1.1 and 7°F, depending on the assumption made regarding the likely humidity changes accompanying this temperature change. If the amount of water vapor in the atmosphere remained unchanged, the smaller increase would occur, but if the relative humidity were to remain constant then the larger calculated increase would prevail. If, instead of a 25% increase, the CO_2 content were to double, the expected change would be about three times this figure. For atmospheric calculations, Möller's model is still a relatively simple one and has not included all of the possible major interactions occurring in the atmosphere. For this reason it is likely that Möller's calculations overestimate the effects on temperature of an increase in CO_2. More comprehensive models are under development and should be available shortly.

If the earth's temperature increases significantly, a number of events might be expected to occur, including the melting of the Antarctic ice cap, a rise in sea levels, warming of the oceans, and an increase in photosynthesis. The first two items are of course related since the increase in sea level would be mainly due to the added water from the ice cap. Estimates of the possible rate at which the Antarctic ice cap might melt have been made. If the poleward heat flux were increased 10%, the ice cap could disappear in about 4000 years. A shorter time, about 400 years, is estimated if it is considered that half the energy associated with a 2% increase in radiation were used to melt the polar ice cap. A 2% increase might result from a 25% increase in CO_2 by the year 2000.

With regard to sea level changes, if 1000 years were required to melt the Antarctic ice cap, the resulting 400 foot rise in sea level would occur at a rate of 4 feet per 10 years. This is 100 times greater than presently observed changes.

Changes in ocean temperature would change the distribution of fish and cause a retreat in the polar sea ice. This has happened in recent time on a very limited scale.

Changes in CO_2 might also bring about increased photosynthesis in areas where CO_2 might be a limiting factor in present growth patterns. Where temperature has been a limiting factor to growth and development, an increase in biological activity might be expected.

Although there are other possible sources for the additional CO_2 now being observed in the atmosphere, none seems to fit the presently observed situation as well as the fossil fuel emanation theory.

C. Summary of Carbon Dioxide in the Atmosphere

In summary, Revelle makes the point that man is now engaged in a vast geophysical experiment with his environment, the earth. Significant temperature changes are almost certain to occur by the year 2000 and these could bring about climatic changes.

Since Revelle's report, McCormick and Ludwig (1966) have studied the possible world-wide change of atmospheric fine particles. An increase in fine particulate material will have the effect of increasing the reflectivity of the earth's atmosphere and reducing the amount of radiation received from the sun. Thus this effect would be the opposite of that caused by an increase in CO_2. The argument has been made that the large-scale cooling trend observed in the northern hemisphere since about 1955 is due to the disturbance of the radiation balance by fine particles and that this effect has already reversed any warming trend due to CO_2.

It is clear that we are unsure as to what our long-lived pollutants are doing to our environment; however, there seems to be no doubt that the potential damage to our environment could be severe. Whether one chooses the CO_2 warming theory as described in detail by Revelle and others or the newer cooling prospect indicated by McCormick and Ludwig, the prospect for the future must be of serious concern.

It seems ironic that in our view of air pollution technology we take such a serious concern with small-scale events such as the photochemical reactions of trace concentrations of hydrocarbons, the effect on vegetation of a fraction of a part per million of SO_2, when the abundant pollutants which we generally ignore because they have little local effect, CO_2 and submicron particles, may be the cause of serious world-wide environmental changes.

the ambient atmosphere should be carefully checked, but probably the most important feature as far as atmospheric chemistry is concerned is to determine the source of the nitrate in the atmosphere. The source, on the basis of our analysis of the atmospheric nitrogen cycle, seems to be by the oxidation of NH_3. The oxidation mechanism for atmospheric NH_3 is unknown. This is a very difficult problem which has been evaded or ignored for several years. If NH_3 cannot be shown to be the source of the nitrate, then it will be necessary to find a sufficient natural source of NO or NO_2 to provide the nitrate.

In the area of atmospheric organic gases the almost complete absence of information on all the possible components except CH_4 should be remedied. Proven analytical techniques are available for such studies. While there may be some doubt in the cases of SO_2, H_2S, and other compounds that available techniques are sufficiently sensitive for use in the ambient atmosphere, this is not the case for the low molecular weight organics. Here, gas chromatography is presently capable of detecting the trace levels of many atmospheric organics present in the fractional part-per-billion range. Although the ambient concentrations are known, methane is in the same category as CO in that there is a major need to determine the sink or scavenging mechanism. At present this can only be guessed at.

Past and present studies of CO_2 are detailed and seem to explain adequately the present state of CO_2 in the atmosphere. What is lacking, however, is an application of these atmospheric CO_2 data to air pollution technology and work toward systems in which CO_2 emissions would be brought under control.

Another point which has been made in our discussion is that N_2O, CO, CH_4, and CO_2 have essentially the same atmospheric residence times because, we believe, vegetation plays a major role in the scavenging cycle for each of the materials. This postulate should obviously be carefully checked by

EXHIBIT 2

EXXON RESEARCH AND ENGINEERING COMPANY

P.O. BOX 8, LINDEN, N. J. 07036

GOVERNMENT RESEARCH LABORATORIES
W. M. COOPER, JR.
Director

December 7, 1978

Dr. Edward E. David, Jr.
General Administration
FP #101/Room G-119

Dear Ed:

A set of highly visible programs has been developed to help clarify the mechanisms associated with storage of carbon dioxide, and thus help predict the likelihood of a greenhouse effect. The programs will make use of Exxon facilities such as tankers and drilling ships to measure the rate of CO_2 uptake by the various layers of the ocean. Sophisticated techniques involving measurements of changes in isotopic ratios of carbon and the distribution of radon in the ocean will be used in conjunction with state-of-the-art techniques to measure CO_2 concentration in the atmosphere and in the oceans.

In addition to the ocean related work, a program is proposed to determine the source of the annual atmospheric CO_2 increment that has been increasing since the Industrial Revolution (1860). Researchers have attributed the CO_2 increment to varying combinations of fossil fuel burning and forest clearing. The program would measure the concentration of C-13 (stable) and C-14 (radioactive) in wines from sources that have well documented histories of temperature, weather, and location as a function of the time the wines were produced. By taking into account the relative absence of C-14 in wines, we will be able to estimate the contribution of fossil fuels (in which C-14 has decayed over the thousands of years of storage), and thus determine the relative concentration of fossil fuel derived CO_2 that was present in the atmosphere at the time the grapes were grown. Similarly, by analyzing the wine for the relative depletion of C-13 (this isotope is less reactive in photosynthesis than the predominant C-12), we will be able to estimate the contribution of forest clearing to the growth of CO_2 in the atmosphere. The wine measurement program would provide a unique and novel method to unravel the historical source of the incremental growth of CO_2 in the atmosphere.

We propose to implement our programs by May 1, 1979 in order to begin to assess the real meaning of the greenhouse effect to Exxon. We would start by equipping a tanker on the Persian Gulf to Aruba and Houston run with continuous instrumentation to measure CO_2 in the atmosphere and

in the ocean. A number of batch ocean samples will be taken and stored for measurement of C-14. This measurement will be used to estimate the penetration of CO_2 into the ocean. The equipment will be manned by two ER&E technicians. We expect to conduct measurements for at least a year, and this will involve 5 round trips. Preliminary discussions with Esso International tanker personnel on the feasibility of using Exxon tankers have been favorable.

The drilling ship program which is designed to measure the mass transfer coefficient for CO_2 between the atmosphere and the ocean as a function of weather conditions would probably be started in Exxon drilling operations off the coast of Australia. The program would involve a month or two of Rn-222 on-board measurement using conventional equipment for α-counting. The program would get underway towards the end of the Summer of 1979. The wine measurement program would procure some 100 bottles of wine that have well documented histories, probably from a single chateau in France. These wines would be analyzed for C-13 using the highly sophisticated facilities at EPRCo., and for C-14 using the unique equipment at the University of Miami (School of Marine and Atmospheric Science). The program would start in May 1979.

We expect to conduct these programs in two phases over the period 1979-1984 (inclusive). Phase I would start May 1, 1979 and be conducted entirely with Exxon funding over the first year. Phase II would start as soon as Government (DOE) funding can be obtained. We visualize the drilling ship operations and the wine measurements programs to be entirely funded by Exxon and the tanker measurements program funded by the DOE. Our screening-type estimates in 1979 $ indicate the Phase I programs will cost 0.5 M$ and the total programs (Phase I and Phase II) 8 M$. Personnel costs account for over 70% of the cost, so methods of automating the tanker sampling program will be sought during Phase I.

In view of the highly complex nature of the programs, and the need to integrate the Exxon results into the global weather modeling programs, we intend to work closely with a university and the Government. We are currently considering a cooperative program with Columbia University's Lamont-Doherty Geological Observatory because two of the oustanding oceanographers and experts on the CO_2 problem, W. S. Broecker and T. Takahashi are associated with that institution.

The rationale for Exxon's involvement and commitment of funds and personnel is based on our need to assess the possible impact of the greenhouse effect on Exxon business. Exxon must develop a credible scientific team that can critically evaluate the information generated on the subject and be able to carry bad news, if any, to the corporation. This team must be recognized for its excellence in the scientific community, the government, and internally by Exxon management. We see no better method to acquire the necessary reputation than by attacking one of the major uncertainties in the global CO_2 balance, i.e., flux to the oceans and providing the necessary data. In addition, the international significance of the proposed programs will enhance the Exxon image in the public domain and provide great public relations value. As a consequence of the above, these programs are prime candidates for early implementation under the National Impact Program charter.

We have attached to this letter two appendices which assess the state-of-the-art on the greenhouse effect and provide details of the proposed programs. We are looking to you and the management council for guidance.

Very truly yours,

Henry Shaw

Henry Shaw

HS/jep

Attachments

cc: J. F. Black
W. M. Cooper, Jr.
R. T. Craig
F. J. Feely
W. Glass
E. J. Gornowski, Jr.
P. J. Lucchesi
R. E. Lyon, Jr.
J. K. Patterson
B. T. Richards, Jr.
L. E. Swabb, Jr.
R. L. Weeks
H. N. Weinberg
N. R. Werthamer

EXHIBIT 3

EXXON RESEARCH AND ENGINEERING COMPANY
P.O. BOX 51, LINDEN, N.J. 07036

PRODUCTS RESEARCH DIVISION
J.F. BLACK
Scientific Advisor

June 6, 1978

The Greenhouse Effect

Ref. No: 78PR 461

Mr. F. G. Turpin, Vice President
Exxon Research and Engineering Co.
Petroleum Staff
P. O. Box 101
Florham Park, NJ 07932

Dear Frank:

The review of the Greenhouse Effect which I presented to the Exxon Corporation Management Committee last July used only vugraphs, without a prepared text. Last month, I had the opportunity to present an updated version of this talk to PERCC. The attached text was dictated shortly afterward to satisfy requests for a written version of the talk from people who had not heard the presentation last July. Also attached is a summary.

Sincerely,

Jim

J. F. BLACK

JFB/mbh
Attachments: Summary
Text
Vugraphs

CC: Messrs. N. Alpert
W. M. Cooper, Jr.
E. E. David
E. J. Gornowski
R. L. Hirsch
F. A. L. Holloway
P. J. Lucchesi
L. E. Swabb, Jr.

THE GREENHOUSE EFFECT

J. F. Black, Products Research Division
Exxon Research and Engineering Co.

SUMMARY

The earth's atmosphere presently contains about 330 ppm of CO_2. This gas does not absorb an appreciable amount of the incoming solar energy but it can absorb and return part of the infrared radiation which the earth radiates toward space. CO_2, therefore, contributes to warming the lower atmosphere by what has been called the "Greenhouse Effect."

The CO_2 content of the atmosphere has been monitored since 1957 at two locations, the Mauna Loa Observatory, Hawaii and the South Pole. These and other shorter studies show that CO_2 is increasing. If the increase is attributed to the combustion of fossil fuels, it can be calculated that the CO_2 content of the atmosphere has already been raised by about 10 to 15% and that slightly more than half of the CO_2 released by fossil fuel combustion is remaining in the atmosphere. Assuming that the percentage of the CO_2 remaining in the atmosphere will stay at 53% as fossil fuel consumption increases, one recent study predicts that in 2075 A.D., CO_2 concentration will peak at a level about twice what could be considered normal. This prediction assumes that fossil fuel consumption will grow at a rate of 2% per year until 2025 A.D. after which it will follow a symetrical decrease. This growth curve is close to that predicted by Exxon's Corporate Planning Department.

Mathematical models for predicting the climatic effect of a CO_2 increase have not progressed to the point at which all the feedback interactions which can be important to the outcome can be included. What is considered the best presently available climate model for treating the Greenhouse Effect predicts that a doubling of the CO_2 concentration in the atmosphere would produce a mean temperature increase of about 2°C to 3°C over most of the earth. The model also predicts that the temperature increase near the poles may be two to three times this value.

The CO_2 increase measured to date is not capable of producing an effect large enough to be distinguished from normal climate variations. As an example of normal variations, studies of meteorological and historical records in England indicate that the mean temperature has varied over a range of about ±0.7°C in the past 1000 years. A study of past climates suggests that if the earth does become warmer, more rainfall should result. But an increase as large as 2°C would probably also affect the distribution of the rainfall. A possible result might be a shift of both the desert and the fertile areas of the globe toward higher latitudes. Some countries would benefit but others could have their agricultural output reduced or destroyed. The picture is too unclear to predict which countries might be affected favorably or unfavorably.

It seems likely that any general temperature increase would be accentuated in the polar regions, possibly as much as two- or three-fold as mentioned above. Any large temperature increase at high latitudes would be associated with a reduction in snow cover and a melting of the floating ice-pack. Present thinking suggests that there would be little or no melting of the polar ice-caps in response to warmer temperatures on a time scale over which the Greenhouse Effect is predicted to apply.

A number of assumptions and uncertainties are involved in the predictions of the Greenhouse Effect. The first is the assumption that the observed CO_2 increase can be attributed entirely to fossil fuel combustion. At present, meteorologists have no direct evidence that the incremental CO_2 in the atmosphere comes from fossil carbon. The increase could be at least partly due to changes in the natural balance. There is considerable uncertainty regarding what controls the exchange of atmospheric CO_2 with the oceans and with carbonaceous materials on the continents.

Models which predict the climatic effects of a CO_2 increase are in a primitive stage of development. The atmosphere is a very complicated system, particularly on a global scale. In existing models, important interactions are neglected, either because they are not completely understood or because their proper mathematical treatment is too cumbersome. Substantial efforts are being expended to improve existing models. But there is no guarantee that better knowledge will lessen rather than augment the severity of the predictions.

The Greenhouse Effect has been the subject of a number of international scientific conferences during the past two years. These meetings have identified the information needed to definitely establish the source and ultimate significance of the CO_2 increase in the atmosphere. Present thinking holds that man has a time window of five to ten years before the need for hard decisions regarding changes in energy strategies might become critical. The DOE is presently seeking Congressional support for a research program which will produce the necessary information in the required time. This program is described.

THE GREENHOUSE EFFECT

By

J. F. BLACK

Transcript of a Talk
Delivered Before the PERCC Meeting
May 18, 1978

The Greenhouse Effect refers to a warming of the earth's atmosphere due to an increase in the concentration of carbon dioxide. As a background for the discussion today, the first vugraph outlines the basis for the Greenhouse Effect.

The earth receives energy in the form of both visible and ultraviolet radiation from the sun. Some of this radiation is reflected back into space, some is absorbed by the atmosphere but most is absorbed at the earth's surface. The earth in turns reemits energy in the form of infrared radiation toward space. Carbon dioxide and other atmospheric constituents absorb part of the infrared radiation. This absorbed energy warms the atmosphere. Therefore, higher carbon dioxide concentrations result in a more rapid absorption of the outgoing infrared radiation and warmer temperatures near the earth's surface. In my talk today I am planning to discuss:

I. The Source and Projected Magnitude of the CO_2 Increase in the Atmosphere

II. The Global Temperature Increase Which Can Be Expected From Higher CO_2 Concentrations

III. The Potential Problems Arising From a Global Temperature Increase

IV. Research Needed to Establish the Validity and Significance of Projected Increases of CO_2 in the Atmosphere.

My information is derived from following recent literature in this area and from talks with some of the leading research people in the field.

I. The Source and Projected Magnitude of the CO_2 Increase in the Atmosphere

Since 1958, CO_2 has been monitored at a number of remote sites which are free from local inputs (Vugraph 2). These are Point Barrow, Alaska; some Swedish aircraft flights; Mauna Loa, Hawaii; American Samoa and the South Pole. The carbon dioxide concentration has been found to be increasing rather uniformly at all locations with the South Pole measurements rather lagging those in the Northern Hemisphere.

Atmospheric scientists generally attribute this growth in CO_2 to the combustion of fossil fuel. A principal reason for this is that fossil fuel combustion is the only readily identifiable source which is (1) growing at the same rate, (2) large enough to account for the observed increases, and (3) capable of affecting the Northern Hemisphere first. If this assumption regarding the origin of carbon dioxide is true, it can be calculated that a little over 50% of the CO_2 entering the atmosphere is remaining there and the rest is being absorbed in surface sinks on the continents or in the ocean. Extrapolating backwards in time to follow the history of fossil fuel combustion, it can be estimated that since 1850 the concentration of this gas in the atmosphere has increased by about 13%. This increase amounts to about 75 billion metric tons of carbon dioxide.

It is also possible to extrapolate into the future. One of the most commonly quoted extrapolations is that of the Oak Ridge National Laboratory which was published in 1976[1]. This study produced two scenarios for the growth of fossil fuel consumption (Vugraph 3). Prior to 1973, fossil fuel use had been growing exponentially at about 4.3% per year. The scenario for most rapid growth assumed that this growth rate would continue, modified by a depletion factor which reduced the exponent in proportion to the amount of fossil fuel which remained unburned. Their second and more conservative assumption presumed that fossil fuel utilization would grow with a 2% growth rate out to 2025 A.D. followed by a symetrical decrease. This latter scenario is close to that developed independently by the Coordination and Planning Department of the Exxon Corporation.

Vugraph 4 presents the predicted atmospheric carbon dioxide levels which would result from each of these scenarios. The vertical axis in this vugraph presents the atmospheric carbon dioxide concentration relative to that which was calculated to have existed in 1850, prior to the combustion of appreciable amounts of fossil fuel. It can be seen that the scenario based upon very rapid growth predicts that by 2075 the atmospheric carbon dioxide concentration will be about 4 to 5 times that which existed prior to the industrial revolution. Moreover, at that time, the carbon dioxide concentration will still be increasing. The more conservative assumption, shown in the lower curve, predicts that carbon dioxide concentrations will level out about a century from now at a value which is about twice that in existence in 1850 and then would decline at a very slow rate.

Although carbon dioxide increase is predominantly attributed to fossil fuel combustion, most scientists agree that more research is needed to definitely establish this relationship. The possibility that the increasing carbon dioxide in the atmosphere is due to a change in the natural balance has not yet been eliminated. In fact, a look at the magnitude of the natural interchanges, as shown in Vugraph 5, shows that this possibility should be taken seriously.

The data in Vugraph 5 are taken from a Scientific Workshop on Atmospheric CO_2 sponsored by the World Meteorological Organization in December 1976. The vugraph shows the fluxes of CO_2 into and out of the atmosphere in units of billions of metric tons of carbon per year. It can be seen that fossil fuels are estimated to contribute five billion tons of carbon per year to the atmosphere and that about half of this is reabsorbed by the oceans or by the biosphere. The conclusion that fossil fuel combustion represents the sole source of incremental carbon dioxide involves assuming not only that the contributions from the biosphere and from the oceans are not changing but also that these two sources are continuing to absorb exactly the same amount as they are emitting. The World Meteorological Organization recognized the need to validate these assumptions, particularly in view of the fact that the rate of carbon dioxide increase represents less than 2% of the rate at which the atmosphere is exchanging carbon dioxide with the biosphere and the oceans.

The biologists have been claiming that deforestation and associated biogenic effects on the continents represent an important input of carbon dioxide to the atmosphere. Vugraph 6 summarizes the results from recent papers by a number of biologists on the contribution of the biosphere to the growth of CO_2 in the atmosphere relative to the contribution of fossil fuel combustion. Their estimates for this ratio are presented in the first column. In April of 1977, Adams[2] estimated that the ratio of the weight of carbon from net wood burned to the weight of carbon from fossil fuel burned in this century has been at least 0.1 and may have approached 1.0. The following month, Bolin[3] claimed that the increase in carbon dioxide due to the expansion of forestry and agriculture was at least half that due to fossil fuel combustion. In August of 1977, the National Academy of Sciences issued a report[4] which attributed the Greenhouse Effect to fossil fuel combustion and which received a considerable amount of sensational publicity. This has produced a rash of papers by the biologists to support their position. In January of this year, Woodwell[5] and a number of other authors from academic and oceanographic centers published a paper claiming that the terrestrial biomass appears to be a net source of carbon dioxide for the atmosphere which is possibly greater than that due to fossil fuel combustion. The following week, Stuiver[6] published results based upon C^{13}/C^{12} ratios which reported that the net release of carbon dioxide from the biosphere in the century prior to 1950 was twice as great as that from fossil fuel combustion. Even if it is assumed that the biospheric release stopped in 1950, the contribution of the biosphere up to the present time would still be 1.2 that from fossil fuel. The last four articles which I have quoted were all published in Science. In the present month, Wilson[7] published an article in Nature which supports the claim that deforestation has produced at least half as much carbon dioxide in the atmosphere as can be attributed to fossil fuel.

Now, you will remember that earlier in this talk it was pointed out that if the increase in carbon dioxide in the atmosphere is due to fossil fuel combustion, about 50% of the CO_2 being released remains in the atmosphere and the rest is absorbed in either the oceans or the continents. If there have been substantial releases of carbon dioxide in addition to that which can be attributed to fossil fuels, the natural sinks for carbon dioxide must be larger and more efficient than previously estimated. This would reduce the levels to which carbon dioxide has been projected to increase. This possibility is vehemently denied by the oceanographers,who claim that the oceans cannot possibly absorb much more carbon dioxide. However, it is my impression that the science of oceanography has not as yet reached a state of development which can justify such a positive claim.

The current status of scientific opinion regarding the carbon cycle is summarized in Vugraph 7. First, current scientific opinion overwhelmingly favors attributing atmospheric carbon dioxide increase to fossil fuel combustion. However, most scientists feel that more research is needed to support an unqualified conclusion. Finally, some scientists, particularly the biologists, claim that part or all of the CO_2 increase arises from the destruction of forests and other land biota.

II. The Global Temperature Increase Which Can Be Expected From Higher CO_2 Concentrations

Predictions on the significances of increases in atmospheric CO_2 must be based upon climate modeling. Modeling climatic effects is currently handicapped by an inability to handle all the complicated interactions which are important to predicting the climate. Some of these are shown in Vugraph 8.

One interaction which has not has yet been included with any degree of sophistication in climate models is the effect of cloudiness. Clouds can reflect incoming visible and ultraviolet radiation back into space with greater efficiency than would occur at the ground. On the other hand, at their bottom surface they absorb outgoing radiation and the cloud tops also emit infrared radiation, depending upon the temperature (that is altitude) at which the top is located. The effect of a cloud will therefore depend upon its size, its shape, and the altitude at which it is located.

Another uncertainty which has not, as yet, been handled in any great detail is the atmosphere - ocean circulation - sea surface temperature interaction. How should the heat capacity of the oceans be handled in view of the turbulence at the surface and to what depths are the oceans involved in interacting with the atmosphere? These are important questions because the entire heat content of the atmosphere is equal to the heat content of just the first three meters of the oceans. A third uncertainty in modeling is the interaction between the seasons and long-term climate trends. In present models, the changes which are predicted for increasing carbon dioxide concentrations are calculated with respect to a constant climate, that is a perpetual spring or summer season. It is quite possible that this assumption is inadequate. For example, the best accepted explanation for the on-set of the ice ages is that orbital and other changes result in the earth entering a period in which summers are cooler and winters are warmer than normal. Thus, this produces more precipitation and faster glacier growth during the winter and less melting during the summer.

Finally, a serious question has been raised as to whether climate is really predictable. This possibility was raised by Lorenz[8] in 1970. He drew an analogy to mathematical modeling. Many mathematical models of complicated phenomena are based upon a large number of non-linear equations with a variety of complex feedback interactions. If the mathematician is fortunate, when a model of this type is run on the computer, it will converge and give him a definite answer. Such a model is called transitive. On the other hand, when a complicated model is tested, it is not at all unusual to find that the solution will not converge but will oscillate back and forth without producing a stable answer. Such a model is called intransitive. There is also an intermediate condition. Occasionally, a model is found to converge initially upon a definite answer but after a short period to jump off this solution and settle down upon another one. After a second indefinite period, it will jump up and converge again upon a third solution and so on producing a number of apparent solutions in a random manner. Such a model is called almost transitive (or almost intransitive). Lorenz pointed out that the climate is a system which is the result of a large number of non-linear energy inputs between which there are many complicated feedback interactions. He therefore suggested that the climate may be a natural example of an almost transitive system which does not have a stable solution. It will settle down into an apparently stable condition but then after a random period will jump over to another apparent stability, etc.

It is not certain, however, that such a pessimistic outlook is justified and it has not stopped the development of many models of the Greenhouse Effect and other climate phenomena. The simplest of these are the one-dimensional models in which the input at the earth's surface is averaged over the globe and detailed calculations are carried out to predict vertical variations. Such models do not require much computer time and can include detailed treatment of vertical phenomena such as radiative transfer. They suffer, however, from the fact that the influence of latitudinal variations is completely ignored.

The next more complicated models are so-called zonally averaged models in which various latitude regions are treated separately in a two-dimensional manner. These take more computer time but are still short enough to permit considerable sophistication in the calculations. They still suffer, however, from an incomplete treatment of latitudinal interactions. In spite of this, many modelers feel that they are the most valuable type of model upon which to work.

The most complicated models are the so-called general circulation models which are three-dimensional in character. These take very long times to compute and the ratio of real to machine time can be as low as 10 to 1. A great deal of the computer time is spent in moving large masses of air around the globe and recalculating the snyoptic profiles every 10 to 15 minutes. Their advantage is that latitudinal effects are completely included but the sophistication with which vertical effects can be treated is limited due to the time and expense associated with running the model.

One of the best general circulation models of the Greenhouse Effect, and the one which is most frequently quoted, is that developed by Manabe and Wetherald[9]. Their predictions for the climatic effect of a doubling of CO_2 are presented in Vugraph 9. This vugraph predicts that a doubling of the atmospheric CO_2 concentration would produce a temperature rise at lower altitudes and a temperature decrease above twenty kilometers. At the surface the temperature rise would be about 2 to 3°C from the equator up to about 60° latitude, with a much greater increase predicted for the poles. The larger increase at the poles results from two effects. First, vertical mixing at the poles is reduced due to a natural decrease in the height of the inversion layer in these regions. Second, the model contains a temperature - ice and snow cover - reflectivity interaction by which increases in atmospheric temperature melt the snow and ice cover and reduce the amount of heat reflected back into space.

Simplifications incorporated in this model include fixed cloudiness, a "swamp" ocean which has zero heat capacity, and idealized treatment of the topography. The model also contains a simplified treatment of the infrared radiation transfer in the atmosphere. In a separate calculation, Manabe[10] calculated that the use of a more sophisticated treatment, developed by Rodgers and Walshaw[11], would reduce the indicated temperature increases at the surface by about 0.5°C. In the light of this and other models, it is generally accepted by climatologists that a doubling of the carbon dioxide concentration in the atmosphere would produce from 1.5°C-3.0°C warming at the earth's surface in the lower and mid-latitudes with about 2 to 3 times greater effect at the poles.

The next natural question is the significance of such a temperature rise compared to the magnitude of the natural temperature changes which have been observed to occur in the past. A comparison with respect to historical temperature changes since 1850, according to Kellogg[12], is presented in Vugraph 10. In this figure, the observed mean Northern Hemisphere temperature is plotted as the solid line. It can be seen that this has varied less than ±1°C over the last century. The extrapolations past 1977 result from the application of Manabe and Wetherald's model[9] with the assumption that the carbon dioxide levels will double by 2050 A.D. The lower dashed line in the figure represents an estimate of what the recent temperature trends would have been if the CO_2 increase had not occurred.

The significance of a temperature increase of the magnitude predicted by Manabe and Wetherald with respect to the long term record of climate is presented in Vugraph 11 which was prepared by Mitchell[13]. This figure shows that the expected temperature increase would be large even compared to the temperatures at the time of the last interglacial. As this temperature increase decayed, however, it would represent an amelioration of an expected natural cooling trend.

III. The Potential Problems Arising from a Global Temperature Increase

The implications arising from Manabe and Wetherald's predictions for the temperature effects resulting from a doubling of carbon dioxide concentrations in the atmosphere are outlined in Vugraph 12. It appears fairly certain that if the high increases they predict in the polar regions do occur, the permanent snow cover and floating sea ice will be reduced or possibly eliminated. This will have a negligible effect on sea level, however, since the snow cover does not represent an appreciable amount of water and the floating ice is already in equilibrium with the sea.

There will probably be no effect on the polar ice sheets. These are three in number. The Greenland ice sheet in the Northern Hemisphere represents an amount of water equivalent to a five meter rise in sea level. If the floating sea ice is removed, the Greenland ice cap would be surrounded by water. This might produce increased precipitation and actually result in the growth of this ice sheet.

The world's largest ice sheet is the East Antarctic sheet which contains water equivalent to a rise of 70 meters in the world's oceans. It is estimated that the temperature effects produced by doubling the atmospheric CO_2 concentration would not affect this very large glacier and that it too might increase in size.

The area on which most uncertainty exists is with respect to the West Antarctic ice sheet. The water in this glacier is equivalent to about a seven meter rise in the world's oceans. The West Antarctic ice sheet extends out over the ocean floor. Warmer oceans might result in an intrusion of the ocean waters underneath this ice sheet and a decrease in its size might occur. If this happens, an oceanic rise of some fraction of the maximum amount (7 meters) might take place.

With a warmer climate around the world, it seems fairly certain that precipitation would increase. On a global basis, this should result in a lengthening of the growing season. Growing seasons are estimated to increase about ten days for each 1°C rise in temperature.

The changing precipitation patterns, however, would benefit some areas and would harm others. It is not possible, on the basis of present information, to predict just where these effects would occur. As a first estimate, one might say that the climatic zones in the world would move northward. The effect of this on the agriculture of the U.S. and Russia is indicated in Vugraph 13.

The broadening of the equatorial regions might result in a northward migration of the desert areas in the United States. Our present corn and wheat belts would also move northward and migrate into Canada. It can be seen that Russia, which is indicated by the crossed hatched area, lies considerably farther north than does the United States. The very dark areas indicate the agricultural regions of Russia. If climatic zones migrate northward, the Russians have plenty of room to adopt to the change. Even those nations which are favored, however, would be damaged for a while since their agricultural and industrial patterns have been established on the bais of the present climate.

IV. Research Needed to Establish the Validity and Significance of Projected Increases of CO_2 in the Atmosphere

The Greenhouse Effect has been attracting a large amount of scientific attention. Some of the more important recent meetings on this subject are presented in Vugraph 14. The World Meteorological Organization held a scientific workshop on atmospheric CO_2 in Washington, DC, in December 1976. ERDA held a workshop on the Environmental Effect of CO_2 from Fossil Fuel Combustion at Miami in March of 1977. This meeting was organized by their Advisory Committee for research on the Greenhouse Effect, the Chairman of which is Dr. Alvin Weinberg. DOE's present research effort on the Greenhouse Effect is a direct result of this workshop and I will be saying more about their program later. SCOPE (Standing Committee on the Planetary Environment), a West European organization, held a workshop on the world carbon budget in March of 1977 in Hamburg, Germany. The most recent major meeting was that organized in Luxenburg, Austria, this past February by IIASA (International Institute for Applied Systems Analysis) for the World Meteorological Organization, the U.N. Committee on the Environment and SCOPE.

The conclusions from this last meeting summarize the present world scientific opinion with respect to the Greenhouse Effect. The IIASA meeting was organized into three working groups. Some of the more significant recommendations of these working groups are presented in Vugraph 15.

The working group on the carbon cycle concluded that scientific confidence in models of that cycle is considerably less than it was ten years ago. What is necessary to instill greater confidence is to provide a better understanding of the flux from the biosphere as reported by the biologists. The working group also recommended that more information be obtained on the interchange of CO_2 into the ocean and how it is transported to greater depths.

The second working group, on the climatic impact of a doubling of CO_2, reached conclusions close to those which have been summarized in the present talk. They felt that a doubling of atmospheric carbon dioxide would produce a 2-3 degree centigrade increase in temperature depending upon the influence of clouds.

The third working group was concerned with the impact of the Greenhouse Effect on energy strategies. They recommended that man can afford a 5-10 yr. time window to establish the validity and significance of the Greenhouse Effect. They said that it is premature to limit the use of fossil fuels at present but that their use should not be encouraged. This group went on to recommend more research and greater effort on the development of energy sources which would not result in CO_2 release.

The DOE has initiated a major research program on the Greenhouse Effect under the leadership of David Slade. Detailed recommendations for this effort have been prepared by an Advisory Committee. These recommendations would have the DOE research program concentrate principally upon obtaining better information regarding the carbon cycle while research on climatic effects, including climate modeling, would be left up NOAA. Six programs for research on the carbon cycle are being recommended for immediate funding. These are presented in order of priority in Vugraph 16.

This immediate program would cost \$1.56 MM in the first year and would soon grow to about \$10 MM per year. The program to receive highest priority, is obtaining a better estimate of fossil fuel CO_2 output. This would involve a worldwide study of how fossil fuel combustion might be expected to increase and what would limit this increase in both the under-developed and developed countries. The second project relates to the use of carbon isotopes to obtain a better estimate of the input of carbon dioxide from the biosphere. It is hoped that C^{13}/C^{12} ratios as well as C^{14}/C^{12} ratios can be used for this purpose.

The third project is to obtain a direct assessment of the biosphere input by observing the growth or depletion of vegetated areas around the world from the Landstat satellites. High resolution radar and aerial photography will probably be required in some instances to identify vegetation types. The global vegetation map provided by these methods would be used to identify sample areas for 1) further analysis using photographs of higher resolution and 2) ground validation of vegetation and soil type to define the relationship between image characteristics and desired ground information. Two hundred to a thousand such areas would be identified and would be resurveyed at 2 to 5 year intervals in a program which would be expected to be able to detect a 2% change in the vegetation. This is an expensive program and would require about \$3 MM per year when it is running in full force.

The fourth project is to expand and improve the carbon dioxide monitoring network. This would involve adding 10 to 15 additional monitoring stations at suitably remote areas and expanding the instrumentation at all stations so that it could determine carbon isotope ratios.

The fifth project is to obtain better information on the transfer of carbon dioxide from surface waters into the deeper ocean. This would involve not only studies of CO_2 but also of tracers such as tritium, helium-3 and radiocarbon. This would require research with oceanographic ships and, when completely under way, would cost about $5 MM/year. The last of the high priority programs for immediate funding is to obtain better information on the buffering of CO_2 absorption in the ocean.

After the initial programs are under way, the Advisory Committee is recommending that an additional effort involving seven more programs be established. These are listed, in order of priority, in Vugraph 17. The entire program would cost $1.26 MM in the planning phase and would rise to $5 MM/year when under way.

The first item in this program, and the seventh in the overall priority list, is to determine whether shallow water carbonates are dissolving because of CO_2 levels. The second item would be to obtain a better estimate of the response of the biota as a sink for additional carbon dioxide. The third in this program is to develop better models for the carbon cycle. Although modeling is an extremely important undertaking, it is placed ninth on the overall list because information from the earlier programs is needed for better model development.

Item number ten recommends a study and a better definition of the rate of carbon dioxide exchange across the interface between the air and the ocean. The next project would be to study the flux of organic carbon into and within the sea. Item number twelve is to develop improved carbon dioxide measurement techniques, while the final item on this list is to study the dissolution of deep sea calcium carbonate as a final sink for atmospheric carbon dioxide.

V. Summary

A summary of my talk is presented in Vugraph 18. In the first place, there is general scientific agreement that the most likely manner in which mankind is influencing the global climate is through carbon dioxide release from the burning of fossil fuels. A doubling of carbon dioxide is estimated to be capable of increasing the average global temperature by from 1° to 3°C, with a 10°C rise predicted at the poles. More research is needed, however, to establish the validity and significance of predictions with respect to the Greenhouse Effect. It is currently estimated that mankind has a 5-10 yr. time window to obtain the necessary information. A major research effort in this area is being considered by the U.S. Department of Energy.

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THE GREENHOUSE EFFECT

J. F. BLACK

TALK BEFORE

PERCC MEETING

MAY 18, 1978

BASIS FOR THE GREENHOUSE EFFECT

I. EARTH RECEIVES VISIBLE & UV RADIATION FROM SUN

A. Some Reflected Into Space
B. Some Absorbed By Atmosphere
C. Most Absorbed At Earth's Surface

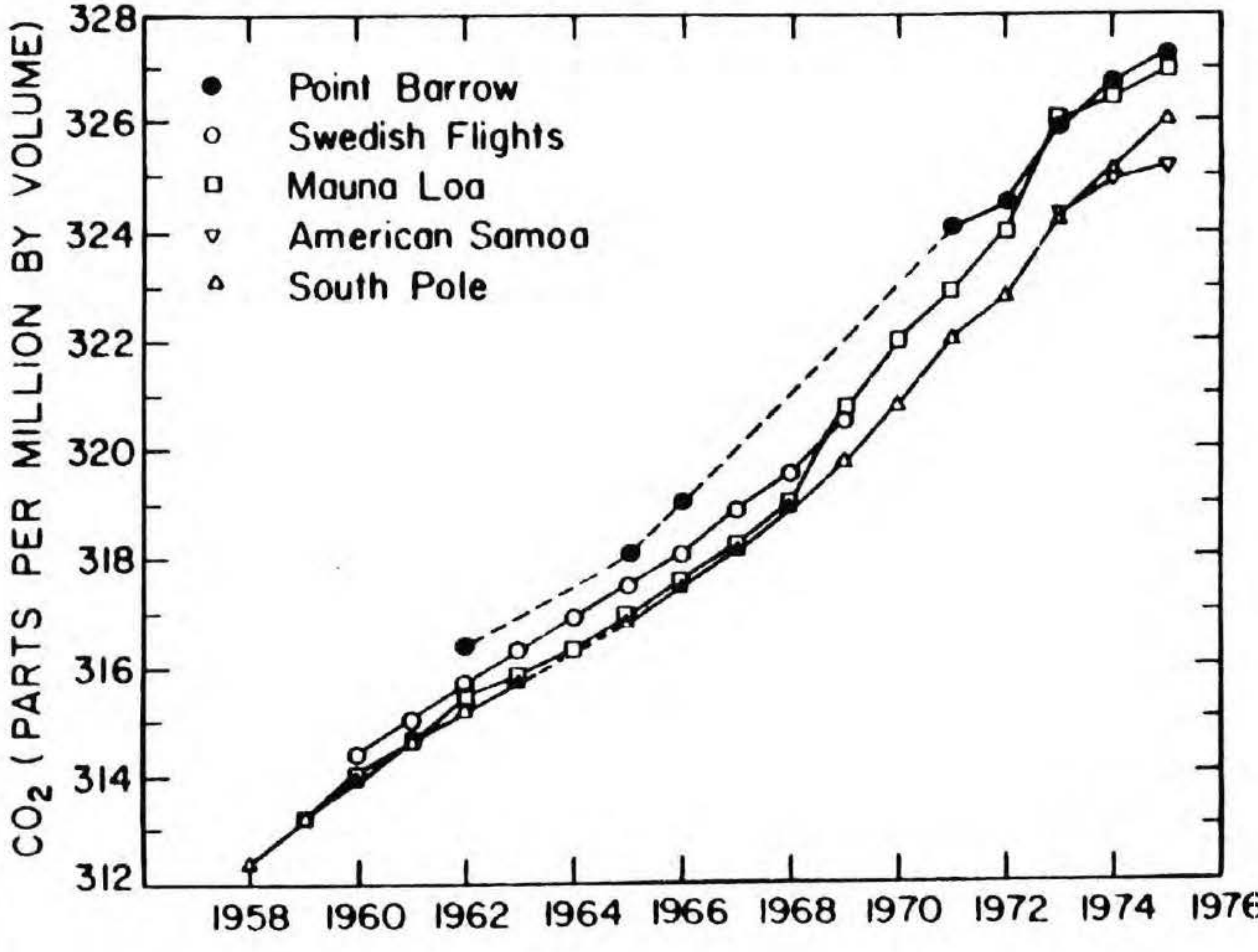
II. EARTH EMITS INFRARED RADIATION TOWARD SPACE

A. Carbon Dioxide And Other Atmospheric Constituents Absorb Part Of The Infrared Radiation
B. Absorbed Energy Warms The Atmosphere

III. THEREFORE HIGHER CO_2 CONCENTRATIONS WARM THE LOWER ATMOSPHERE

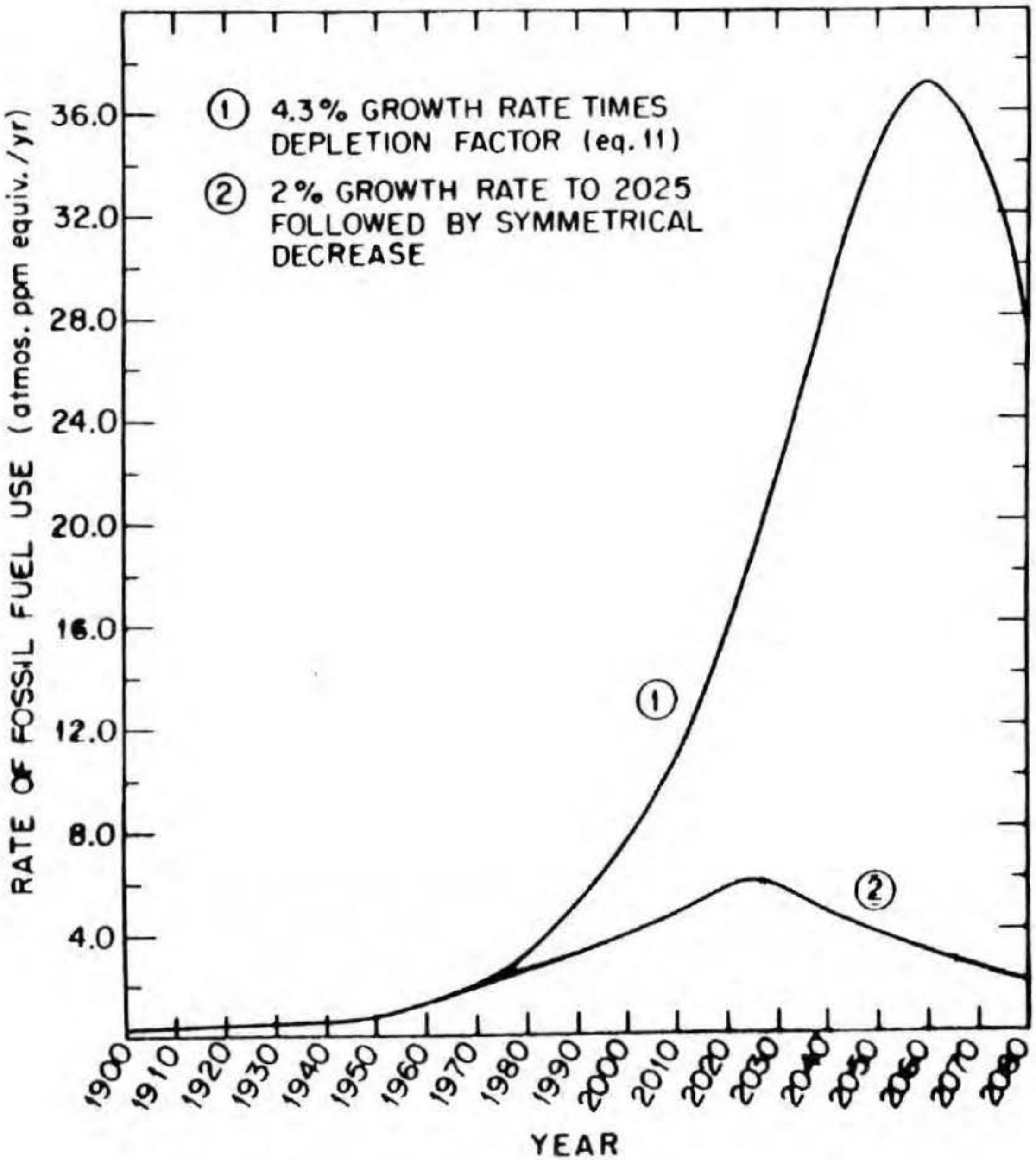
VUGRAPH 2

CO_2 MEASURED AT REMOTE SITES



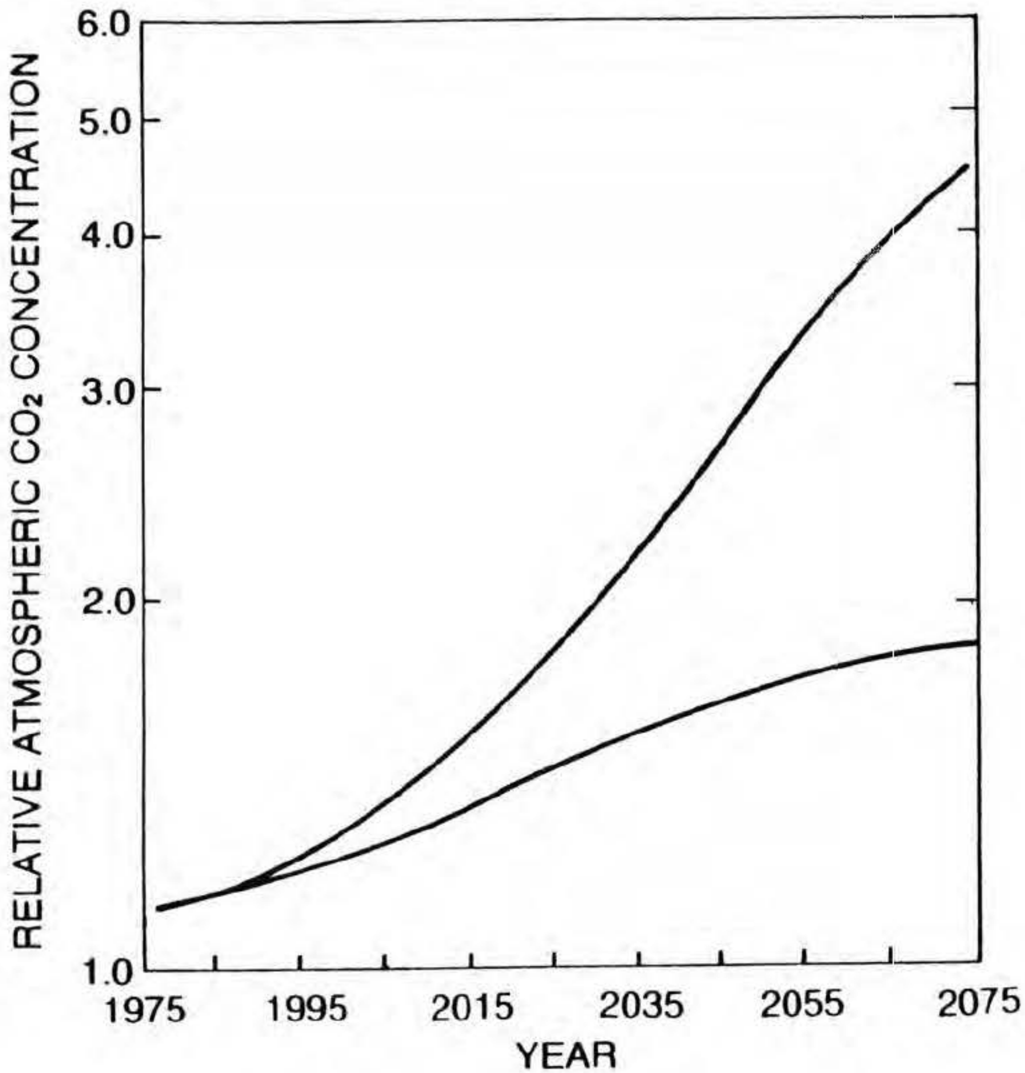
VUGRAPH 3

POSSIBLE LIMITING SCENARIOS FOR THE USE OF FOSSIL FUELS

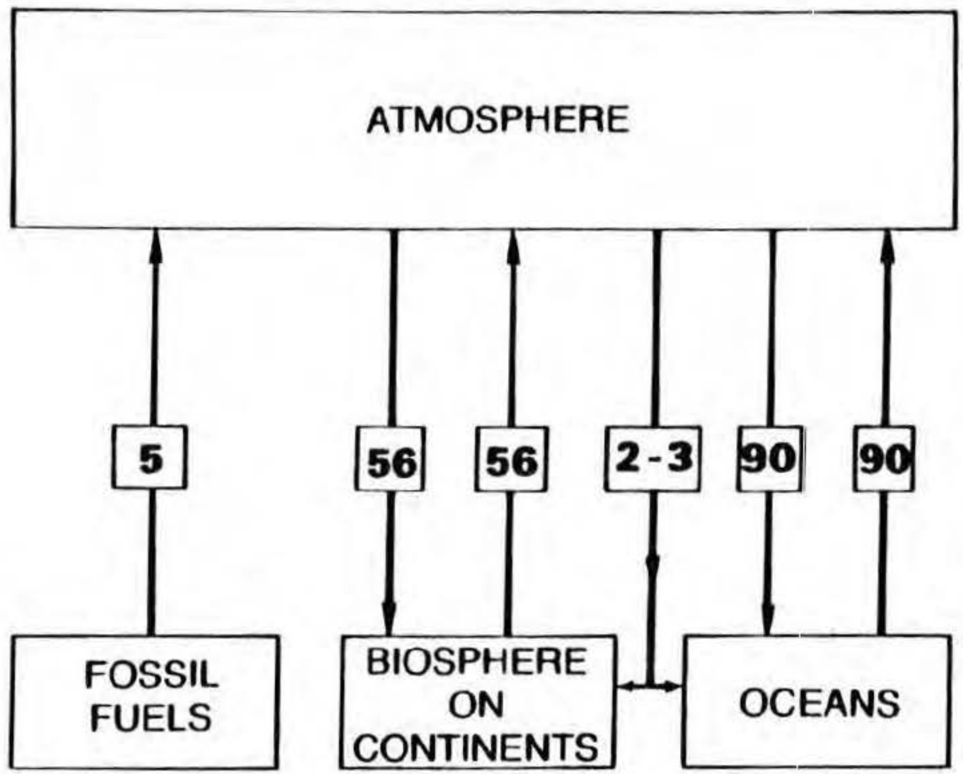


VUGRAPH 4

PROJECTED ATMOSPHERIC CO_2 CONCENTRATIONS RELATIVE TO 1860



CO_2 EXCHANGE
(Billions Of Tons Of Carbon Per Year)



VUGRAPH 6

RATIO OF CO_2 DERIVED FROM BIOSPHERE VS FOSSIL FUEL

RATIO	1st AUTHOR	JOURNAL	DATE
0.1-1.0	ADAMS	SCIENCE	4/1/77
0.5	BOLIN	SCIENCE	5/6/77
0.8-1.6 (1)	WOODWELL	SCIENCE	1/13/78
2.0 (2)	STUVIER	SCIENCE	1/19/78
0.5	WILSON	NATURE	5/4/78

(1) PRESENT RATE (2) 1850-1950

CURRENT STATUS OF SCIENTIFIC OPINION

I. Current Opinion Overwhelmingly Favors Attributing Atmospheric CO_2 Increase To Fossil Fuel Combustion

II. Most Scientists Feel More Research Is Needed To Support An Unqualified Conclusion

III. Some Scientists Claim That Part Or All Of The CO_2 Increase Arises From The Destruction Of Forests And Other Land Biota.

UNCERTAINTIES WHICH LIMIT CLIMATE MODELING

I. CLOUDINESS

A. Effect Of A Cloud Depends On Size, Shape and Position.

II. ATMOSPHERE — OCEAN INTERACTIONS

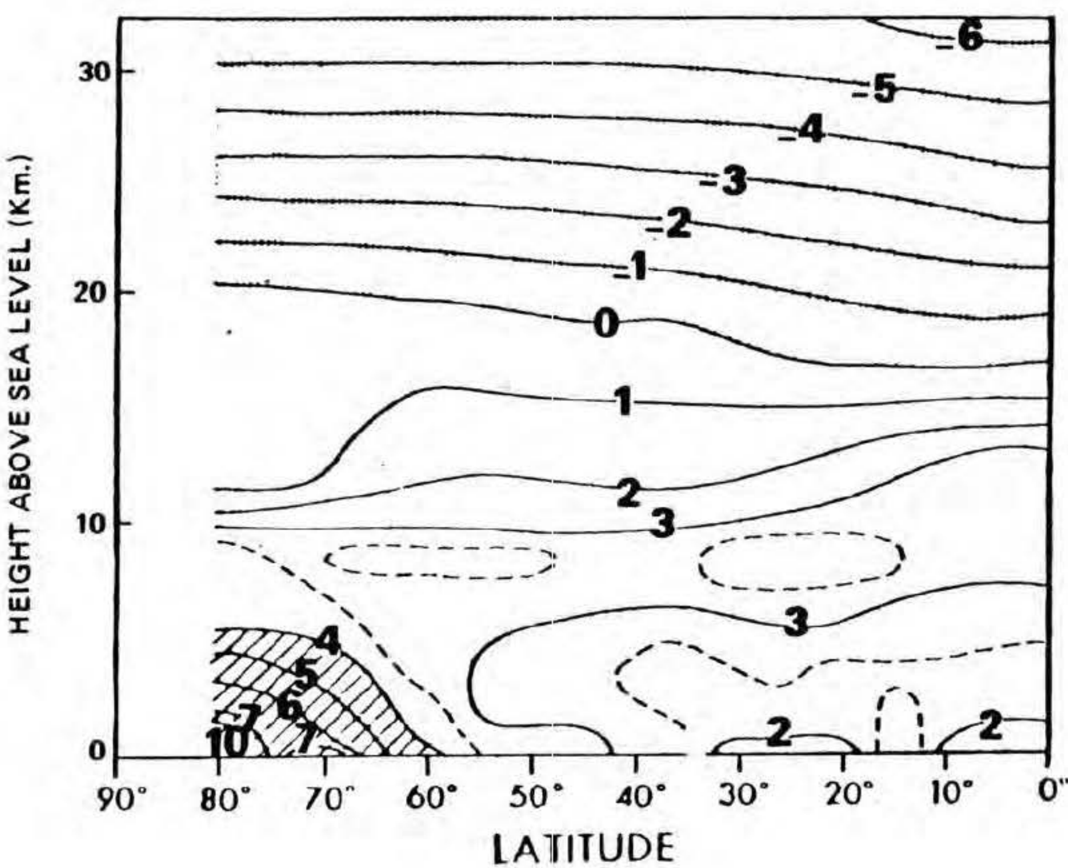
A. How Should Heat Capacity Be Handled
B. To What Depth Is The Ocean Involved

III. THE INTERACTION BETWEEN SEASONS AND LONG TERM TRENDS

IV. IS CLIMATE REALLY PREDICTABLE

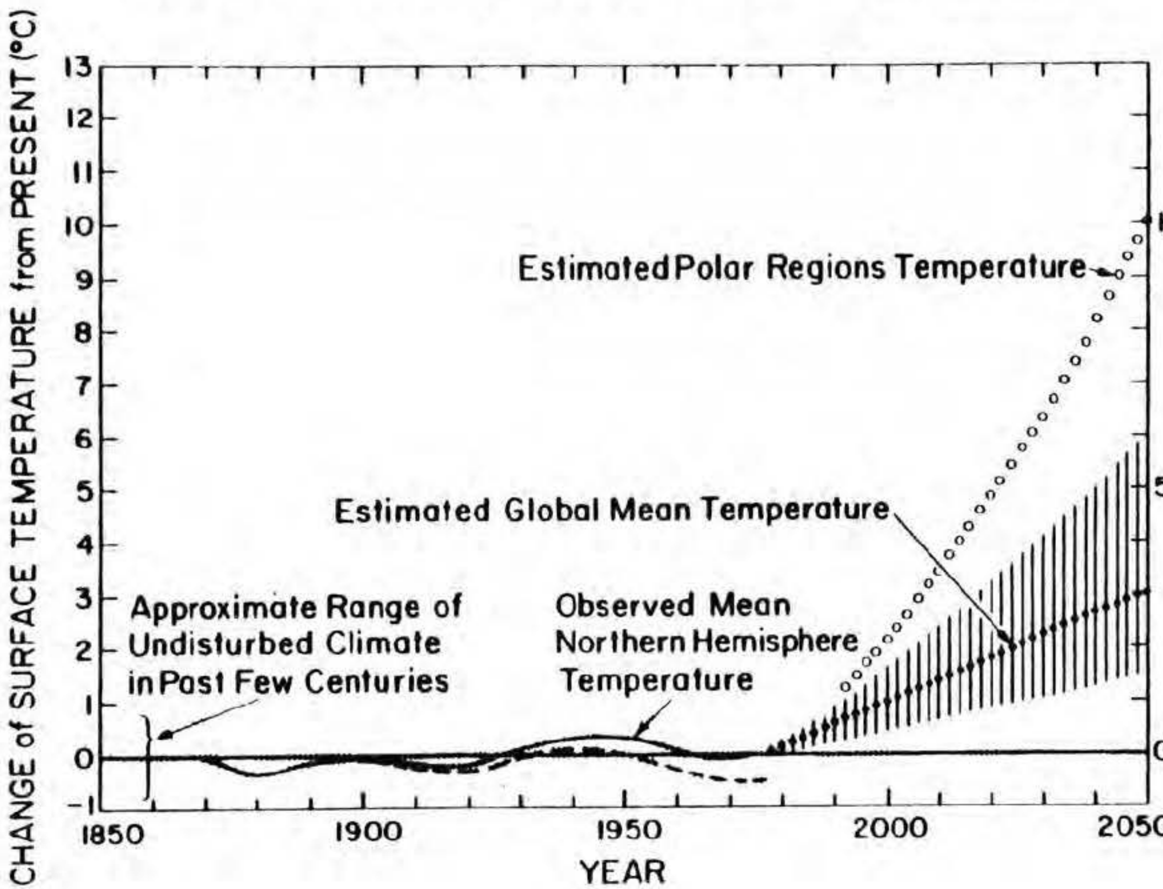
A. Could Be An "Almost Transitive " System Which Fluctuates Between Stable States.

TEMPERATURE EFFECT OF DOUBLING CO_2

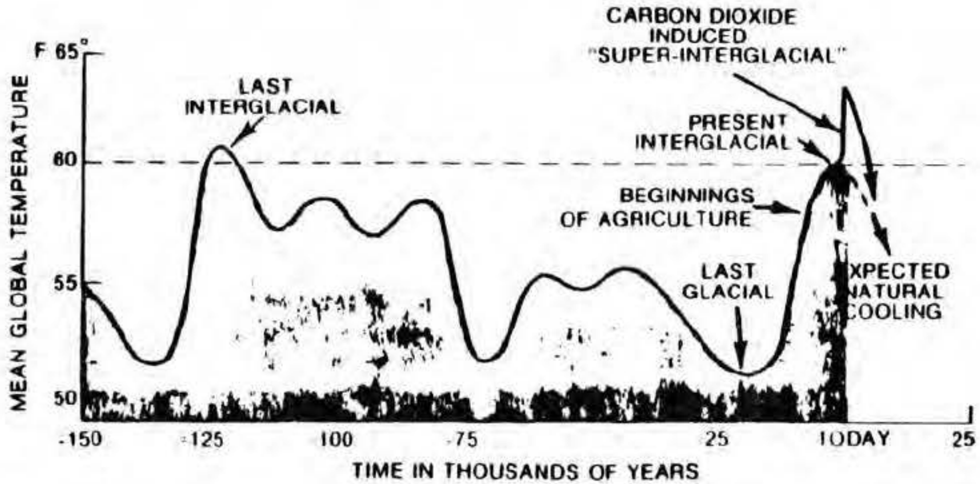


VUGRAPH 10

HOW PREDICTED ΔT COMPARES WITH RECENT TEMPERATURES



EFFECT OF CO_2 ON AN INTERGLACIAL SCALE



IMPLICATION OF PREDICTED GREENHOUSE EFFECT

I. **PERMANENT SNOW COVER AND FLOATING SEA ICE WILL BE REDUCED**

   A. Negligible Effect On Sea Level

II. **PROBABLY NO EFFECT ON POLAR ICE SHEETS**

   A. West Antarctic Ice Sheet Most Critical

III. **LENGTH OF GROWING SEASON WOULD INCREASE**

   A. 1°C Temperature Rise Adds 10 Days

IV. **CHANGES IN PRECIPITATION PATTERNS WILL BENEFIT SOME AREAS AND HARM OTHERS.**

   A. Models Can Not Predict These Effects
   B. Can Study Evidence From Climatic Optimum 4000-8000 Years Ago.


MOST OF THE USSR'S VAST
AGRICULTURAL LAND BASE
LIES LATITUDINALLY NORTH
OF THE UNITED STATES
Fairbanks
Leningrad
Kiev
Moscow
Arctic Circle
60
40
40
Minneapolis
Philadelphia
San Francisco
Washington
Denver
Springfield
SOVIET AGRICULTURAL LANDS

VUGRAPH 13

VUGRAPH 14

RECENT MEETINGS ON GREENHOUSE EFFECT

I. WORLD METEOROLOGICAL ORGANIZATION

SCIENTIFIC WORKSHOP ON ATMOSPHERIC CO_2
NOV. 28 - DEC. 3, 1976, WASHINGTON, D. C.

II. ERDA - WORKSHOP

ENVIRONMENTAL EFFECT OF CO_2 FROM FOSSIL FUEL COMBUSTION
MARCH 7-11, 1977, MIAMI BEACH, FLA.

III. SCOPE

WORKSHOP ON WORLD CARBON BUDGET
MARCH 21-26, 1977, HAMBURG, GERMANY

IV. IIASA

CARBON DIOXIDE, CLIMATE AND SOCIETY
FEB. 21-24, 1978, LAXENBURG, AUSTRIA

VUGRAPH 15

WORKING GROUP REPORTS - IIASA WORKSHOP

I. THE CARBON CYCLE

A. CONFIDENCE IN MODELS CONSIDERABLY LESS THAN 10 YEARS AGO

B. BIOSPHERE FLUX MUST BE ESTABLISHED

II. WHAT WILL BE CLIMATE IMPACT OF 2 X CO_2

A. 2-3°C INCREASE DEPENDING ON HOW CLOUDS ACT

III. CO_2 QUESTION VS. ENERGY STRATEGIES

A. MAN CAN AFFORD 5-10 YR. TIME WINDOW TO ESTABLISH WHAT MUST BE DONE.

B. IT IS PREMATURE TO LIMIT USE OF FOSSIL FUELS BUT THEY SHOULD NOT BE ENCOURAGED.

ERDA PROPOSALS FOR IMMEDIATE FUNDING

($1.56 $\overline{MM}$ TO START - SOON UP TO $9.8 $\overline{MM}$/YR.)

1. BETTER ESTIMATE OF FOSSIL FUEL CO_2 OUTPUT
2. USE CARBON ISOTOPES TO GET INPUT FROM BIOSPHERE
3. DIRECT ASSESSMENT OF BIOSPHERE INPUT ($3 $\overline{MM}$)
4. EXPAND AND IMPROVE MONITORING NETWORK
5. TRANSFER OF CO_2 INTO DEEPER OCEAN ($5 $\overline{MM}$)
6. BUFFERING OF CO_2 ABSORPTION IN OCEAN

PROJECTS STARTING AFTER INITIAL PROGRAMS ARE UNDER WAY

($1.26 $\overline{MM}$ TO START - RISES TO $5.0 $\overline{MM}$/YR)

7. ARE SHALLOW WATER CARBONATES DISSOLVING
8. RESPONSE OF BIOTA TO CO_2 INCREASE
9. BETTER MODELS OF CARBON CYCLE
10. CO_2 EXCHANGE ACROSS AIR-SEA INTERFACE
11. FLUX OF ORGANIC CARBON INTO & WITHIN SEA
12. IMPROVE CO_2 MEASUREMENT TECHNIQUES
13. DISSOLUTION OF DEEP SEA $CaCO_3$ AS FINAL SINK

VUGRAPH 18

SUMMARY

I. CO_2 RELEASE MOST LIKELY SOURCE OF INADVERTENT CLIMATE MODIFICATION.

II. PREVAILING OPINION ATTRIBUTES CO_2 INCREASE TO FOSSIL FUEL COMBUSTION.

III. DOUBLING CO_2 COULD INCREASE AVERAGE GLOBAL TEMPERATURE 1°C TO 3°C BY 2050 A.D. (10°C PREDICTED AT POLES).

IV. MORE RESEARCH IS NEEDED ON MOST ASPECTS OF GREENHOUSE EFFECT

V. 5-10 YR. TIME WINDOW TO GET NECESSARY INFORMATION

VI. MAJOR RESEARCH EFFORT BEING CONSIDERED BY DOE

EXHIBIT 4

Control Files

PROPRIETARY INFORMATION
For Authorized Company Use Only

EXXON RESEARCH AND ENGINEERING COMPANY

P.O. BOX 101, FLORHAM PARK, NEW JERSEY 07932

EXXON ENGINEERING PETROLEUM DEPARTMENT
Planning Engineering Division

Cable: ENGREXXON, N.Y.

R. L. MASTRACCHIO
Manager
L. E. Hill
Senior Eng. Assoc.

October 16, 1979

Controlling Atmospheric CO_2

79PE 554

Dr. R. L. Hirsch:

The attached memorandum presents the results of a study on the potential impact of fossil fuel combustion on the CO_2 concentration in the atmosphere. This study was made by Steve Knisely, a summer employee in Planning Engineering Division.

The study considers the changes in future energy sources which would be necessary to control the atmospheric CO_2 concentration at different levels. The principle assumption for the CO_2 balance is that 50% of the CO_2 generated by fossil fuels remains in the atmosphere. This corresponds to the recent data on the increasing CO_2 concentration in the atmosphere compared to the quantity of fossil fuel combusted.

Present climatic models predict that the present trend of fossil fuel use will lead to dramatic climatic changes within the next 75 years. However, it is not obvious whether these changes would be all bad or all good. The major conclusion from this report is that, should it be deemed necessary to maintain atmospheric CO_2 levels to prevent significant climatic changes, dramatic changes in patterns of energy use would be required. World fossil fuel resources other than oil and gas could never be used to an appreciable extent.

No practical means of recovering and disposing of CO_2 emissions has yet been developed and the above conclusion assumes that recovery will not be feasible.

It must be realized that there is great uncertainty in the existing climatic models because of a poor understanding of the atmospheric/terrestrial/oceanic CO_2 balance. Much more study and research in this area is required before major changes in energy type usage could be recommended.

W. L. Ferrall

W. L. FERRALL

WLF:ceg
Attachment

c: J. F. Black
J. W. Herrmann
L. E. Hill
E. D. Hooper
F. J. Kaiser
R. L. Mastracchio
W. H. Mueller
H. Shaw
G. O. Wilhelm

CONTROLLING THE CO_2 CONCENTRATION IN THE ATMOSPHERE

The CO_2 concentration in the atmosphere has increased since the beginning of the world industrialization. It is now 15% greater than it was in 1850 and the rate of CO_2 release from anthropogenic sources appears to be doubling every 15 years. The most widely held theory is that:

- The increase is due to fossil fuel combustion
- Increasing CO_2 concentration will cause a warming of the earth's surface
- The present trend of fossil fuel consumption will cause dramatic environmental effects before the year 2050.

However, the quantitative effect is very speculative because the data base supporting it is weak. The CO_2 balance between the atmosphere, the biosphere and the oceans is very ill-defined. Also, the overall effect of increasing atmospheric CO_2 concentration on the world environment is not well understood. Finally, the relative effect of other impacts on the earth's climate, such as solar activity, volcanic action, etc. may be as great as that of CO_2.

Nevertheless, recognizing the uncertainty, there is a possibility that an atmospheric CO_2 buildup will cause adverse environmental effects in enough areas of the world to consider limiting the future use of fossil fuels as major energy sources. This report illustrates the possible future limits on fossil fuel use by examining different energy scenarios with varying rates of CO_2 emissions. Comparison of the different energy scenarios show the magnitude of the switch from fossil fuels to non-fossil fuels that might be necessary in the future. Non-fossil fuels include fission/fusion, geothermal, biomass, hydroelectric and solar power. The possible environmental changes associated with each scenario are also discussed.

CONCLUSIONS

As stated previously, predictions of the precise consequences of uncontrolled fossil fuel use cannot be made due to all of the uncertainties associated with the future energy demand and the global CO_2 balance. On the basis that CO_2 emissions must be controlled, this study examined the possible future fuel consumptions to achieve various degrees of control. Following are some observations and the principle conclusions from the study:

- The present trends of fossil fuel combustion with a coal emphasis will lead to dramatic world climate changes within the next 75 years, according to many present climatic models.

- The CO_2 buildup in the atmosphere is a worldwide problem. U.S. efforts to restrict CO_2 emission would delay for a short time but not solve the problem.

- Warming trends which would move the temperate climate northward may be beneficial for some nations (i.e., the USSR, see Figure 1) and detrimental for others. Therefore, global cooperation may be difficult to achieve.

- Removal of CO_2 from flue gases does not appear practical due to economics and lack of reasonable disposal methods.

- If it becomes necessary to limit future CO_2 emissions without practical removal/disposal methods, coal and possibly other fossil fuel resources could not be utilized to an appreciable extent.

- Even with dramatic changes in current energy resource use, it appears unlikely that an increase of 50% over the pre-industrial CO_2 level can be avoided in the next century. This would be likely to cause a slight increase in global temperatures but not a significant change in climate, ocean water level or other serious environmental efforts.

The potential problem is great and urgent. Too little is known at this time to recommend a major U.S. or worldwide change in energy type usage but it is very clear that immediate research is necessary to better model the atmosphere/terrestrial/oceanic CO_2 balance. Only with a better understanding of the balance will we know if a problem truly exists.

Existing Data and Present Models

Since the beginning of industrialization, the atmospheric carbon dioxide concentration has increased from approximately 290 ppm in 1860 to 336 ppm today. Atmospheric CO_2 concentrations have been recorded on a monthly basis by C. D. Keeling since 1958 at Mauna Loa Observatory in Hawaii (see Figure 2). Seasonal variations are clearly shown with the CO_2 concentrations lowest during the North American and Eurasian summers, due to increased photosynthetic activities. Over the last ten years, the atmospheric concentration has been increasing at an average rate of about 1.2 ppm/year.

The present consumption of fossil fuels releases more than 5 billion tons of carbon as CO_2 into the atmosphere each year. Data to date indicate that of the amount released approximately one-half is absorbed by the oceans. The other half remains in the atmosphere. There is some question as to whether the terrestrial biosphere is a sink, absorbing atmospheric CO_2, or a source of CO_2 emissions, due to man's land clearing activities. Current opinion attributes the atmospheric CO_2 increase to fossil fuels and considers the biosphere input to be negligible.

Figure 3 shows the carbon cycle with the ocean and the biosphere as sinks for approximately 50% of the fossil fuel emissions. Most models show the ocean to be a major sink while the biosphere appears to be a much smaller sink if it absorbs any CO_2 at all. It is clear from Figure 3 that the net atmospheric increase in CO_2 is quite small compared to the quantities of CO_2 exchanged between the atmosphere and the earth. This makes it very difficult to analyze the fossil fuel impact on the overall carbon cycle.

The fossil fuel resource is very large compared to the quantity of carbon in the atmosphere. Therefore, if one half of the CO_2 released by combustion of fossil fuels remains in the atmosphere, only about 20% of the recoverable fossil fuel could be used before doubling the atmospheric CO_2 content.

The concern over the increasing CO_2 levels arises because of the radiative properties of the gas in the atmosphere. CO_2 does not affect the incoming short-wave (solar) radiation to the earth but it does absorb long-wave energy reradiated from the earth. The absorption of long-wave energy by CO_2 leads to a warming of the atmosphere. This warming phenomenom is known as the "greenhouse effect."

A vast amount of speculation has been made on how increased CO_2 levels will affect atmospheric temperatures. Many models today predict that doubling the 1860 atmospheric CO_2 concentration will cause a 1^o to 5^oC global temperature increase (see Figure 4). Extrapolation of present fossil fuel trends would predict this doubling of the CO_2 concentration to occur about 2050. A temperature difference of 5^oC is equal to the difference between a glacial and an interglacial period. The temperature increases will also tend to vary with location being much higher in the polar region (see Figure 5). These temperature predictions may turn out too high or low by several fold as a result of many feedback mechanisms that may arise due to increased temperatures and have not been properly accounted for in present models.

These mechanisms include:

- A decrease in average snow and ice coverage. This is a positive feedback mechanism since it would result in a decrease of the earth's albedo (reflectivity) which would produce an added warming effect.

- Cloud Cover. This is considered the most important feedback mechanism not accounted for in present models. A change of a few percent in cloud cover could cause larger temperature changes than those caused by CO_2. Increased atmospheric temperature could cause increased evaporation from the oceans and increased cloud cover.

- Ocean and Biosphere Responses. As the CO_2 level is increased and the ambient temperature rises, the ocean may lose some of its capacity to absorb CO_2 resulting in a positive feedback. However, increased CO_2 levels could increase photosynthetic activities which would then be a negative feedback mechanism.

As evidenced by the balance shown in Figure 3, the atmospheric carbon exchange with the terrestrial biosphere and the oceans is so large that small changes due to these feedback mechanisms could drastically offset or add to the impact of fossil fuel combustion on the earth's temperature.

Appendix A gives one, but not unanimous, viewpoint of how the environment might change if the feedback mechanisms are ignored. The contribution that will ultimately be made by these feedback mechanisms is unknown at present.

Energy Scenarios for Various CO_2 Limits

Using the CO_2 atmospheric concentration data recorded to date, the correlation of these data with fossil fuel consumption and the proposed "greenhouse effect" models, this study reviews various world energy consumption scenarios to limit CO_2 atmospheric buildup. The concentration of CO_2 in the atmosphere is controlled in these studies by regulating the quantity of each type of fossil fuel used and by using non-fossil energy sources when required. The quantity of CO_2 emitted by various fuels is shown in Table 1. These factors were calculated based on the combustion energy/carbon content ratio of the fuel and the thermal efficiency of the overall conversion process where applicable. They show the high CO_2/energy ratio for coal and shale and the very high ratios for synthetic fuels from these base fossil fuels which are proposed as fuels of the future.

The total world energy demand used in these scenarios is based upon the predictions in the Exxon Fall 1977 World Energy Outlook for the high oil price case for the years 1976 to 1990. It is assumed that no changes in the sources of supply of energy could be made during this period of time. Case A, which has no restrictions on CO_2 emissions, follows the high oil price predictions until 2000.

Petroleum production and consumption is the same in each scenario. The high oil price case predictions are followed until 2000. After 2000 petroleum production continues to increase until a reserve to production ratio (R/P) equals ten to one. Production peaks at this point and then continues at a ten to one R/P ratio until supplies run out.

The consumption of coal, natural gas and non-fossil fuels (fission/fusion, geothermal, biomass, hydroelectric and solar power) vary with each scenario. Shale oil makes small contributions past the year 2000. It is not predicted to be a major future energy source due to environmental damage associated with the mining of shale oil, and also due to rather large amounts of CO_2 emitted per unit energy generated (see Table 1). If more shale oil were used, it would have the same effect on CO_2 emissions as the use of more coal. The fossil fuel resources assumed to be recoverable are tabulated in Appendix B.

A. No Limit on CO_2 Emissions

In this scenario no limitations are placed upon future fossil fuel use. The use of coal is emphasized for the rest of this century and continues on into the next century. The development and use of non-fossil fuels continue to grow but without added emphasis. Natural gas production continues at a slowly increasing rate until an R/P ratio of 7/1 is reached around 2030. Production after 2030 continues at a 7/1 ratio until reserves run out. Figure 6 shows the future energy demand for this scenario.

Figure 7 shows that the CO_2 buildup from this energy strategy is quite rapid. The yearly atmospheric CO_2 increase rises from 1.3 ppm in 1976 to 4.5 ppm in 2040. Noticeable temperature changes would occur around 2010 as the concentration reaches 400 ppm. Significant climatic changes occur around 2035 when the concentration approaches 500 ppm. A doubling of the pre-industrial concentration occurs around 2050. The doubling would bring about dramatic changes in the world's environment (see Appendix A). Continued use of coal as a major energy source past the year 2050 would further increase the atmospheric CO_2 level resulting in increased global temperatures and environmental upsets.

B. CO_2 Increase Limited to 510 ppm

This energy scenario is limited to a 75% increase over the pre-industrial concentration of 290 ppm. No limitations are placed on petroleum production. Natural gas production is encouraged beginning in 1990 to minimize coal combustion until non-fossil fuels are developed. Production of natural gas would increase until 2010 when an R/P ratio of 7/1 would be reached. Production would then continue at a R/P of 7/1 until supplies ran out. The development and use of nonfossil fuels are emphasized beginning the 1990's. Non-fossil fuels start to be substituted for coal in 1990's. Figure 8 shows the future energy demand by fuel for this scenario.

Figure 9 shows the atmospheric CO_2 concentration trends for this scenario. The lower graph shows the maximum yearly atmospheric CO_2 increase allowable for the 510 ppm limit. The yearly CO_2 increase peaks in 2005 when it amounts to 2.3 ppm and then steadily decreases reaching 0.2 ppm in 2100. A 0.2 ppm increment is equivalent to the direct combustion of 5.1 billion B.O.E. of coal. This would be approximately 2 to 3% of the total world energy demanded in 2100. (For more detail on the construction of Figure 9, see Appendix C.)

A comparison of the Exxon year 2000 predictions and this scenario's year 2000 requirements shows the magnitude of possible future energy source changes. The Exxon predictions call for nonfossil fuels to account for 18 billion B.O.E. in 2000. This scenario requires that 20 billion B.O.E. be supplied by non-fossil fuels by

2000. This difference of 2 billion B.O.E. is equivalent to the power supplied by 214-1000 MW nuclear power plants operating at 60% of capacity. If it were supplied by methane produced from biomass, it would be equivalent to 80,000 square miles of biomass at a yield of 50 ton/acre, heat value of 6500 Btu/dry pound and a 35% conversion efficiency to methane. Therefore even a 20% increase in non-fossil fuel use is a gigantic undertaking.

The magnitude of the change to non-fossil fuels as major energy sources is more apparent when scenarios A and B are compared in the year 2025. Scenario B requires an 85 billion B.O.E. input from non-fossil fuels in 2025. This is almost double the 45 billion B.O.E. input predicted in scenario A. This 35 billion B.O.E. difference is approximately equal to the total energy consumption for the entire world in 1970.

The environmental changes associated with this scenario wouldn't be as severe as if the CO_2 concentration were allowed to double as in scenario A. Noticeable temperature changes would occur around 2010 when the CO_2 concentration reaches 400 ppm. Significant climate changes would occur as the atmospheric concentration nears 500 ppm around 2080. Even though changes in the environment due to increased atmospheric CO concentrations are uncertain, an increase to 500 ppm would probably bring about undesirable climatic changes to many parts of the earth although other areas may be benefitted by the changes. (See Appendix A, part 1).

C. CO_2 Increase Limited to 440 ppm

This scenario limits future atmospheric CO_2 increases to a 50% increase over the pre-industrial concentration of 290 ppm. As in the previous case, no limitations are placed on petroleum production and increased natural gas production is encouraged. Much emphasis is placed on the development and use of non-fossil fuels. Non-fossil fuels are substituted for coal beginning in the 1990's. By 2010 they will have to account for 50% of the energy supplied worldwide. This would be an extremely difficult and costly effort if possible. In this scenario coal or shale will never become a major energy source. Figure 10 shows the future world energy demand by fuel for this scenario.

The atmospheric CO_2 concentration trends for this scenario are shown in Figure 11. To satisfy the limits of this scenario the yearly CO_2 emissions would have to peak in 1995 at 2.0 ppm,

and then rapidly decrease reaching a value of 0.04 ppm in 2100. A 0.04 ppm maximum allowable increase means that unless removal/disposal methods for CO_2 emissions are available only one billion B.O.E. of coal may be directly combusted in 2100 (or 1.4 billion Barrels of Oil). This would be less than 1% of the total energy demanded by the world in 2100.

To adhere to the 440 ppm limit, non-fossil fuels will have to account for 28 billion B.O.E. in 2000 as compared to 20 billion B.O.E. in scenario B and 18 billion B.O.E. in scenario A. This difference between scenarios A and C of 10 billion B.O.E. is equivalent to over 1000, 1000 MW nuclear power plants operating at 60% of capacity. Ten billion B.O.E. is also approximately equivalent to 400,000 square miles of biomass at 35% conversion efficiency to methane. This is equivalent to almost one-half the total U.S. forest land.

By 2025 the 110 billion B.O.E. input from non-fossil fuels called for in this scenario is more than twice as much as the 45 billion B.O.E. input predicted in scenario A. This difference of 65 billion is approximately equal to the amount of energy the entire world will consume in 1980. In terms of power plants, 65 billion B.O.E. is equivalent to almost 7000, 1000 MW nuclear power plants operating at 60% of capacity.

An atmospheric CO_2 concentration of 440 ppm is assumed to be a relatively safe level for the environment. A slight global warming trend should be noticeable but not so extreme as to cause major changes. Slight changes in precipitation might also be noticeable as the atmospheric CO_2 concentration nears 400 ppm.

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R. L. MASTRACCHIO
Manager
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October 16, 1979

Controlling Atmospheric CO_2

79PE 554

Dr. R. L. Hirsch:

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The study considers the changes in future energy sources which would be necessary to control the atmospheric CO_2 concentration at different levels. The principle assumption for the CO_2 balance is that 50% of the CO_2 generated by fossil fuels remains in the atmosphere. This corresponds to the recent data on the increasing CO_2 concentration in the atmosphere compared to the quantity of fossil fuel combusted.

Present climatic models predict that the present trend of fossil fuel use will lead to dramatic climatic changes within the next 75 years. However, it is not obvious whether these changes would be all bad or all good. The major conclusion from this report is that, should it be deemed necessary to maintain atmospheric CO_2 levels to prevent significant climatic changes, dramatic changes in patterns of energy use would be required. World fossil fuel resources other than oil and gas could never be used to an appreciable extent.

No practical means of recovering and disposing of CO_2 emissions has yet been developed and the above conclusion assumes that recovery will not be feasible.

It must be realized that there is great uncertainty in the existing climatic models because of a poor understanding of the atmospheric/terrestrial/oceanic CO_2 balance. Much more study and research in this area is required before major changes in energy type usage could be recommended.

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- The increase is due to fossil fuel combustion
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- The present trend of fossil fuel consumption will cause dramatic environmental effects before the year 2050.

However, the quantitative effect is very speculative because the data base supporting it is weak. The CO_2 balance between the atmosphere, the biosphere and the oceans is very ill-defined. Also, the overall effect of increasing atmospheric CO_2 concentration on the world environment is not well understood. Finally, the relative effect of other impacts on the earth's climate, such as solar activity, volcanic action, etc. may be as great as that of CO_2.

Nevertheless, recognizing the uncertainty, there is a possibility that an atmospheric CO_2 buildup will cause adverse environmental effects in enough areas of the world to consider limiting the future use of fossil fuels as major energy sources. This report illustrates the possible future limits on fossil fuel use by examining different energy scenarios with varying rates of CO_2 emissions. Comparison of the different energy scenarios show the magnitude of the switch from fossil fuels to non-fossil fuels that might be necessary in the future. Non-fossil fuels include fission/fusion, geothermal, biomass, hydroelectric and solar power. The possible environmental changes associated with each scenario are also discussed.

CONCLUSIONS

As stated previously, predictions of the precise consequences of uncontrolled fossil fuel use cannot be made due to all of the uncertainties associated with the future energy demand and the global CO_2 balance. On the basis that CO_2 emissions must be controlled, this study examined the possible future fuel consumptions to achieve various degrees of control. Following are some observations and the principle conclusions from the study:

- The present trends of fossil fuel combustion with a coal emphasis will lead to dramatic world climate changes within the next 75 years, according to many present climatic models.

- The CO_2 buildup in the atmosphere is a worldwide problem. U.S. efforts to restrict CO_2 emission would delay for a short time but not solve the problem.

- Warming trends which would move the temperate climate northward may be beneficial for some nations (i.e., the USSR, see Figure 1) and detrimental for others. Therefore, global cooperation may be difficult to achieve.

- Removal of CO_2 from flue gases does not appear practical due to economics and lack of reasonable disposal methods.

- If it becomes necessary to limit future CO_2 emissions without practical removal/disposal methods, coal and possibly other fossil fuel resources could not be utilized to an appreciable extent.

- Even with dramatic changes in current energy resource use, it appears unlikely that an increase of 50% over the pre-industrial CO_2 level can be avoided in the next century. This would be likely to cause a slight increase in global temperatures but not a significant change in climate, ocean water level or other serious environmental efforts.

The potential problem is great and urgent. Too little is known at this time to recommend a major U.S. or worldwide change in energy type usage but it is very clear that immediate research is necessary to better model the atmosphere/terrestrial/oceanic CO_2 balance. Only with a better understanding of the balance will we know if a problem truly exists.

Existing Data and Present Models

Since the beginning of industrialization, the atmospheric carbon dioxide concentration has increased from approximately 290 ppm in 1860 to 336 ppm today. Atmospheric CO_2 concentrations have been recorded on a monthly basis by C. D. Keeling since 1958 at Mauna Loa Observatory in Hawaii (see Figure 2). Seasonal variations are clearly shown with the CO_2 concentrations lowest during the North American and Eurasian summers, due to increased photosynthetic activities. Over the last ten years, the atmospheric concentration has been increasing at an average rate of about 1.2 ppm/year.

The present consumption of fossil fuels releases more than 5 billion tons of carbon as CO_2 into the atmosphere each year. Data to date indicate that of the amount released approximately one-half is absorbed by the oceans. The other half remains in the atmosphere. There is some question as to whether the terrestrial biosphere is a sink, absorbing atmospheric CO_2, or a source of CO_2 emissions, due to man's land clearing activities. Current opinion attributes the atmospheric CO_2 increase to fossil fuels and considers the biosphere input to be negligible.

Figure 3 shows the carbon cycle with the ocean and the biosphere as sinks for approximately 50% of the fossil fuel emissions. Most models show the ocean to be a major sink while the biosphere appears to be a much smaller sink if it absorbs any CO_2 at all. It is clear from Figure 3 that the net atmospheric increase in CO_2 is quite small compared to the quantities of CO_2 exchanged between the atmosphere and the earth. This makes it very difficult to analyze the fossil fuel impact on the overall carbon cycle.

The fossil fuel resource is very large compared to the quantity of carbon in the atmosphere. Therefore, if one half of the CO_2 released by combustion of fossil fuels remains in the atmosphere, only about 20% of the recoverable fossil fuel could be used before doubling the atmospheric CO_2 content.

The concern over the increasing CO_2 levels arises because of the radiative properties of the gas in the atmosphere. CO_2 does not affect the incoming short-wave (solar) radiation to the earth but it does absorb long-wave energy reradiated from the earth. The absorption of long-wave energy by CO_2 leads to a warming of the atmosphere. This warming phenomenom is known as the "greenhouse effect."

A vast amount of speculation has been made on how increased CO_2 levels will affect atmospheric temperatures. Many models today predict that doubling the 1860 atmospheric CO_2 concentration will cause a 1^o to 5^oC global temperature increase (see Figure 4). Extrapolation of present fossil fuel trends would predict this doubling of the CO_2 concentration to occur about 2050. A temperature difference of 5^oC is equal to the difference between a glacial and an interglacial period. The temperature increases will also tend to vary with location being much higher in the polar region (see Figure 5). These temperature predictions may turn out too high or low by several fold as a result of many feedback mechanisms that may arise due to increased temperatures and have not been properly accounted for in present models.

These mechanisms include:

- A decrease in average snow and ice coverage. This is a positive feedback mechanism since it would result in a decrease of the earth's albedo (reflectivity) which would produce an added warming effect.

- Cloud Cover. This is considered the most important feedback mechanism not accounted for in present models. A change of a few percent in cloud cover could cause larger temperature changes than those caused by CO_2. Increased atmospheric temperature could cause increased evaporation from the oceans and increased cloud cover.

- Ocean and Biosphere Responses. As the CO_2 level is increased and the ambient temperature rises, the ocean may lose some of its capacity to absorb CO_2 resulting in a positive feedback. However, increased CO_2 levels could increase photosynthetic activities which would then be a negative feedback mechanism.

As evidenced by the balance shown in Figure 3, the atmospheric carbon exchange with the terrestrial biosphere and the oceans is so large that small changes due to these feedback mechanisms could drastically offset or add to the impact of fossil fuel combustion on the earth's temperature.

Appendix A gives one, but not unanimous, viewpoint of how the environment might change if the feedback mechanisms are ignored. The contribution that will ultimately be made by these feedback mechanisms is unknown at present.

Energy Scenarios for Various CO_2 Limits

Using the CO_2 atmospheric concentration data recorded to date, the correlation of these data with fossil fuel consumption and the proposed "greenhouse effect" models, this study reviews various world energy consumption scenarios to limit CO_2 atmospheric buildup. The concentration of CO_2 in the atmosphere is controlled in these studies by regulating the quantity of each type of fossil fuel used and by using non-fossil energy sources when required. The quantity of CO_2 emitted by various fuels is shown in Table 1. These factors were calculated based on the combustion energy/carbon content ratio of the fuel and the thermal efficiency of the overall conversion process where applicable. They show the high CO_2/energy ratio for coal and shale and the very high ratios for synthetic fuels from these base fossil fuels which are proposed as fuels of the future.

The total world energy demand used in these scenarios is based upon the predictions in the Exxon Fall 1977 World Energy Outlook for the high oil price case for the years 1976 to 1990. It is assumed that no changes in the sources of supply of energy could be made during this period of time. Case A, which has no restrictions on CO_2 emissions, follows the high oil price predictions until 2000.

Petroleum production and consumption is the same in each scenario. The high oil price case predictions are followed until 2000. After 2000 petroleum production continues to increase until a reserve to production ratio (R/P) equals ten to one. Production peaks at this point and then continues at a ten to one R/P ratio until supplies run out.

The consumption of coal, natural gas and non-fossil fuels (fission/fusion, geothermal, biomass, hydroelectric and solar power) vary with each scenario. Shale oil makes small contributions past the year 2000. It is not predicted to be a major future energy source due to environmental damage associated with the mining of shale oil, and also due to rather large amounts of CO_2 emitted per unit energy generated (see Table 1). If more shale oil were used, it would have the same effect on CO_2 emissions as the use of more coal. The fossil fuel resources assumed to be recoverable are tabulated in Appendix B.

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A. No Limit on CO_2 Emissions

In this scenario no limitations are placed upon future fossil fuel use. The use of coal is emphasized for the rest of this century and continues on into the next century. The development and use of non-fossil fuels continue to grow but without added emphasis. Natural gas production continues at a slowly increasing rate until an R/P ratio of 7/1 is reached around 2030. Production after 2030 continues at a 7/1 ratio until reserves run out. Figure 6 shows the future energy demand for this scenario.

Figure 7 shows that the CO_2 buildup from this energy strategy is quite rapid. The yearly atmospheric CO_2 increase rises from 1.3 ppm in 1976 to 4.5 ppm in 2040. Noticeable temperature changes would occur around 2010 as the concentration reaches 400 ppm. Significant climatic changes occur around 2035 when the concentration approaches 500 ppm. A doubling of the pre-industrial concentration occurs around 2050. The doubling would bring about dramatic changes in the world's environment (see Appendix A). Continued use of coal as a major energy source past the year 2050 would further increase the atmospheric CO_2 level resulting in increased global temperatures and environmental upsets.

B. CO_2 Increase Limited to 510 ppm

This energy scenario is limited to a 75% increase over the pre-industrial concentration of 290 ppm. No limitations are placed on petroleum production. Natural gas production is encouraged beginning in 1990 to minimize coal combustion until non-fossil fuels are developed. Production of natural gas would increase until 2010 when an R/P ratio of 7/1 would be reached. Production would then continue at a R/P of 7/1 until supplies ran out. The development and use of nonfossil fuels are emphasized beginning the 1990's. Non-fossil fuels start to be substituted for coal in 1990's. Figure 8 shows the future energy demand by fuel for this scenario.

Figure 9 shows the atmospheric CO_2 concentration trends for this scenario. The lower graph shows the maximum yearly atmospheric CO_2 increase allowable for the 510 ppm limit. The yearly CO_2 increase peaks in 2005 when it amounts to 2.3 ppm and then steadily decreases reaching 0.2 ppm in 2100. A 0.2 ppm increment is equivalent to the direct combustion of 5.1 billion B.O.E. of coal. This would be approximately 2 to 3% of the total world energy demanded in 2100. (For more detail on the construction of Figure 9, see Appendix C.)

A comparison of the Exxon year 2000 predictions and this scenario's year 2000 requirements shows the magnitude of possible future energy source changes. The Exxon predictions call for nonfossil fuels to account for 18 billion B.O.E. in 2000. This scenario requires that 20 billion B.O.E. be supplied by non-fossil fuels by

2000. This difference of 2 billion B.O.E. is equivalent to the power supplied by 214-1000 MW nuclear power plants operating at 60% of capacity. If it were supplied by methane produced from biomass, it would be equivalent to 80,000 square miles of biomass at a yield of 50 ton/acre, heat value of 6500 Btu/dry pound and a 35% conversion efficiency to methane. Therefore even a 20% increase in non-fossil fuel use is a gigantic undertaking.

The magnitude of the change to non-fossil fuels as major energy sources is more apparent when scenarios A and B are compared in the year 2025. Scenario B requires an 85 billion B.O.E. input from non-fossil fuels in 2025. This is almost double the 45 billion B.O.E. input predicted in scenario A. This 35 billion B.O.E. difference is approximately equal to the total energy consumption for the entire world in 1970.

The environmental changes associated with this scenario wouldn't be as severe as if the CO_2 concentration were allowed to double as in scenario A. Noticeable temperature changes would occur around 2010 when the CO_2 concentration reaches 400 ppm. Significant climate changes would occur as the atmospheric concentration nears 500 ppm around 2080. Even though changes in the environment due to increased atmospheric CO concentrations are uncertain, an increase to 500 ppm would probably bring about undesirable climatic changes to many parts of the earth although other areas may be benefitted by the changes. (See Appendix A, part 1).

C. CO_2 Increase Limited to 440 ppm

This scenario limits future atmospheric CO_2 increases to a 50% increase over the pre-industrial concentration of 290 ppm. As in the previous case, no limitations are placed on petroleum production and increased natural gas production is encouraged. Much emphasis is placed on the development and use of non-fossil fuels. Non-fossil fuels are substituted for coal beginning in the 1990's. By 2010 they will have to account for 50% of the energy supplied worldwide. This would be an extremely difficult and costly effort if possible. In this scenario coal or shale will never become a major energy source. Figure 10 shows the future world energy demand by fuel for this scenario.

The atmospheric CO_2 concentration trends for this scenario are shown in Figure 11. To satisfy the limits of this scenario the yearly CO_2 emissions would have to peak in 1995 at 2.0 ppm,

and then rapidly decrease reaching a value of 0.04 ppm in 2100. A 0.04 ppm maximum allowable increase means that unless removal/disposal methods for CO_2 emissions are available only one billion B.O.E. of coal may be directly combusted in 2100 (or 1.4 billion Barrels of Oil). This would be less than 1% of the total energy demanded by the world in 2100.

To adhere to the 440 ppm limit, non-fossil fuels will have to account for 28 billion B.O.E. in 2000 as compared to 20 billion B.O.E. in scenario B and 18 billion B.O.E. in scenario A. This difference between scenarios A and C of 10 billion B.O.E. is equivalent to over 1000, 1000 MW nuclear power plants operating at 60% of capacity. Ten billion B.O.E. is also approximately equivalent to 400,000 square miles of biomass at 35% conversion efficiency to methane. This is equivalent to almost one-half the total U.S. forest land.

By 2025 the 110 billion B.O.E. input from non-fossil fuels called for in this scenario is more than twice as much as the 45 billion B.O.E. input predicted in scenario A. This difference of 65 billion is approximately equal to the amount of energy the entire world will consume in 1980. In terms of power plants, 65 billion B.O.E. is equivalent to almost 7000, 1000 MW nuclear power plants operating at 60% of capacity.

An atmospheric CO_2 concentration of 440 ppm is assumed to be a relatively safe level for the environment. A slight global warming trend should be noticeable but not so extreme as to cause major changes. Slight changes in precipitation might also be noticeable as the atmospheric CO_2 concentration nears 400 ppm.

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Table 1

CO_2 EMISSIONS

Fuel	lb CO_2 Emitted* / 1000 Btu Fuel	% of Present CO_2 Output
SNG from Coal	0.35	0
Coal Liquids	0.32	0
Methanol from Coal	0.38	0
H_2 from Coal Gasification	0.38	0
Shale Oil	0.23	0
Bituminous Coal	.21	38%
Petroleum	.15	49%
Natural Gas	.11	13%
Fission/Fusion	0	0
Biomass	0	0
Solar	0	0

* Includes conversion losses where applicable.

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APPENDIX A

ECOLOGICAL CONSEQUENCES OF INCREASED CO_2 LEVELS

From:

Peterson, E.K., "Carbon Dioxide Affects Global Ecology," Environmental Science and Technology 3 (11), 1162-1169 (Nov '69).

1. Environmental effects of increasing the CO_2 levels to 500 ppm. (1.7 times 1860 level)

   - A global temperature increase of 3°F which is the equivalent of a 1°-4° southerly shift in latitude. A 4° shift is equal to the north to south height of the state of Oregon.
   - The southwest states would be hotter, probably by more than 3°F, and drier.
   - The flow of the Colorado River would diminish and the southwest water shortage would become much more acute.
   - Most of the glaciers in the North Cascades and Glacier National Park would be melted. There would be less of a winter snow pack in the Cascades, Sierras, and Rockies, necessitating a major increase in storage reservoirs.
   - Marine life would be markedly changed. Maintaining runs of salmon and steelhead and other subarctic species in the Columbia River system would become increasingly difficult.
   - The rate of plant growth in the Pacific Northwest would increase 10% due to the added CO_2, and another 10% due to increased temperatures.

2. Effects of a doubling of the 1860 CO_2 concentration. (580 ppm)

   - Global temperatures would be 9°F above 1950 levels.
   - Most areas would get more rainfall, and snow would be rare in the contiguous states, except on higher mountains.
   - Ocean levels would rise four feet.
   - The melting of the polar ice caps could cause tremendous redistribution of weight and pressure exerted on the earth's crust. This could trigger major increases in earthquakes and volcanic activity resulting in even more atmospheric CO_2 and violent storms.
   - The Arctic Ocean would be ice free for at least six months each year, causing major shifts in weather patterns in the northern hemisphere.

- The present tropics would be hotter, more humid, and less habitable, but the present temperature latitude would be warmer and more habitable.

APPENDIX B

FOSSIL FUEL RESOURCES

Oil	- Assume 1.6 trillion barrels of oil potentially recoverable as of 1975 (assuming the future recovery rate to be 40%). The minimum allowable Reserve to Production (R/P) ratio is ten one.
Shale Oil	- Potential of 3.0 trillion B.O.E. but assuming 1977 technology only 200 billion B.O.E. actually recoverable.
Natural Gas	- Approximately 1.6 trillion B.O.E. potentially recoverable. Minimum allowable R/P = 7.1.
Coal	- Potential recoverable reserves equal approximately 12 trillion B.O.E. assuming a conservative 25% recoverability.

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APPENDIX C

CONSTRUCTION OF SCENARIOS B AND C
(Scenario A requires no CO_2 emissions control)

1. Scenario B

The CO_2 concentration vs. year curve in Figure 9 was generated by the following equation:

after 1970 ($t = 0$), then

$$*C = 292 \text{ ppm} + 219 \text{ ppm}/[1 + 5.37 \exp.(-t/24 \text{ years})]$$

where C = concentration in ppm

The curve on the lower section of Figure 9, atmospheric CO_2 increase vs. years, is generated by finding the difference in the concentrations of successive years. This curve gives the maximum yearly increases allowable to stay within the limits placed on this scenario. The amount of fossil fuel that may be consumed in any given year can then be calculated by the lower curve. For example:

In 2100 the maximum allowable CO_2 increase equals 0.2 ppm.

This is equivalent to:

$$\frac{2 \text{ ppm}}{} \times \frac{2.1 \times 10^9 \text{ ton C}}{1 \text{ ppm}} \times \frac{2000 \text{ lb}}{\text{ton}} \times \frac{44 \text{ lb } CO_2}{12 \text{ lb C}} = 3.1 \times 10^{12} \text{ lb } CO_2$$

3.1×10^{12} lb CO_2 may be released by the combustion of:

for coal: $$\frac{3.1 \times 10^{12} \text{ lb } CO_2}{} \times \frac{1000 \text{ Btu}}{.21 \text{ lb } CO_2} \times \frac{1 \text{ B.O.E.}}{5.8 \times 10^6 \text{ Btu}}$$

= 2.5 billion B.O.E. of coal

This scenario is based on the assumption that 50% of CO_2 released each year will always be absorbed by the ocean and the rest will remain in the atmosphere.

*Derived from an equation presented by U. Siegenthaler and H. Oeschger (1978) (see references).

2. Scenario C

The equation for the generation of Figure 11 is derived to be,

after 1970 ($t = 0$), then

$$*C = 292 \text{ ppm} + 146 \text{ ppm}/[1 + 3.37 \exp. (-t/20 \text{ years})]$$

This scenario is the same as Scenario B only with different limits.

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However, the quantitative effect is very speculative because the data base supporting it is weak. The CO_2 balance between the atmosphere, the biosphere and the oceans is very ill-defined. Also, the overall effect of increasing atmospheric CO_2 concentration on the world environment is not well understood. Finally, the relative effect of other impacts on the earth's climate, such as solar activity, volcanic action, etc. may be as great as that of CO_2.

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The potential problem is great and urgent. Too little is known at this time to recommend a major U.S. or worldwide change in energy type usage but it is very clear that immediate research is necessary to better model the atmosphere/terrestrial/oceanic CO_2 balance. Only with a better understanding of the balance will we know if a problem truly exists.

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Since the beginning of industrialization, the atmospheric carbon dioxide concentration has increased from approximately 290 ppm in 1860 to 336 ppm today. Atmospheric CO_2 concentrations have been recorded on a monthly basis by C. D. Keeling since 1958 at Mauna Loa Observatory in Hawaii (see Figure 2). Seasonal variations are clearly shown with the CO_2 concentrations lowest during the North American and Eurasian summers, due to increased photosynthetic activities. Over the last ten years, the atmospheric concentration has been increasing at an average rate of about 1.2 ppm/year.

The present consumption of fossil fuels releases more than 5 billion tons of carbon as CO_2 into the atmosphere each year. Data to date indicate that of the amount released approximately one-half is absorbed by the oceans. The other half remains in the atmosphere. There is some question as to whether the terrestrial biosphere is a sink, absorbing atmospheric CO_2, or a source of CO_2 emissions, due to man's land clearing activities. Current opinion attributes the atmospheric CO_2 increase to fossil fuels and considers the biosphere input to be negligible.

Figure 3 shows the carbon cycle with the ocean and the biosphere as sinks for approximately 50% of the fossil fuel emissions. Most models show the ocean to be a major sink while the biosphere appears to be a much smaller sink if it absorbs any CO_2 at all. It is clear from Figure 3 that the net atmospheric increase in CO_2 is quite small compared to the quantities of CO_2 exchanged between the atmosphere and the earth. This makes it very difficult to analyze the fossil fuel impact on the overall carbon cycle.

The fossil fuel resource is very large compared to the quantity of carbon in the atmosphere. Therefore, if one half of the CO_2 released by combustion of fossil fuels remains in the atmosphere, only about 20% of the recoverable fossil fuel could be used before doubling the atmospheric CO_2 content.

The concern over the increasing CO_2 levels arises because of the radiative properties of the gas in the atmosphere. CO_2 does not affect the incoming short-wave (solar) radiation to the earth but it does absorb long-wave energy reradiated from the earth. The absorption of long-wave energy by CO_2 leads to a warming of the atmosphere. This warming phenomenom is known as the "greenhouse effect."

A vast amount of speculation has been made on how increased CO_2 levels will affect atmospheric temperatures. Many models today predict that doubling the 1860 atmospheric CO_2 concentration will cause a 1^{o} to $5^{o}C$ global temperature increase (see Figure 4). Extrapolation of present fossil fuel trends would predict this doubling of the CO_2 concentration to occur about 2050. A temperature difference of $5^{o}C$ is equal to the difference between a glacial and an interglacial period. The temperature increases will also tend to vary with location being much higher in the polar region (see Figure 5). These temperature predictions may turn out too high or low by several fold as a result of many feedback mechanisms that may arise due to increased temperatures and have not been properly accounted for in present models.

These mechanisms include:

- A decrease in average snow and ice coverage. This is a positive feedback mechanism since it would result in a decrease of the earth's albedo (reflectivity) which would produce an added warming effect.

- Cloud Cover. This is considered the most important feedback mechanism not accounted for in present models. A change of a few percent in cloud cover could cause larger temperature changes than those caused by CO_2. Increased atmospheric temperature could cause increased evaporation from the oceans and increased cloud cover.

- Ocean and Biosphere Responses. As the CO_2 level is increased and the ambient temperature rises, the ocean may lose some of its capacity to absorb CO_2 resulting in a positive feedback. However, increased CO_2 levels could increase photosynthetic activities which would then be a negative feedback mechanism.

As evidenced by the balance shown in Figure 3, the atmospheric carbon exchange with the terrestrial biosphere and the oceans is so large that small changes due to these feedback mechanisms could drastically offset or add to the impact of fossil fuel combustion on the earth's temperature.

Appendix A gives one, but not unanimous, viewpoint of how the environment might change if the feedback mechanisms are ignored. The contribution that will ultimately be made by these feedback mechanisms is unknown at present.

Energy Scenarios for Various CO_2 Limits

Using the CO_2 atmospheric concentration data recorded to date, the correlation of these data with fossil fuel consumption and the proposed "greenhouse effect" models, this study reviews various world energy consumption scenarios to limit CO_2 atmospheric buildup. The concentration of CO_2 in the atmosphere is controlled in these studies by regulating the quantity of each type of fossil fuel used and by using non-fossil energy sources when required. The quantity of CO_2 emitted by various fuels is shown in Table 1. These factors were calculated based on the combustion energy/carbon content ratio of the fuel and the thermal efficiency of the overall conversion process where applicable. They show the high CO_2/energy ratio for coal and shale and the very high ratios for synthetic fuels from these base fossil fuels which are proposed as fuels of the future.

The total world energy demand used in these scenarios is based upon the predictions in the Exxon Fall 1977 World Energy Outlook for the high oil price case for the years 1976 to 1990. It is assumed that no changes in the sources of supply of energy could be made during this period of time. Case A, which has no restrictions on CO_2 emissions, follows the high oil price predictions until 2000.

Petroleum production and consumption is the same in each scenario. The high oil price case predictions are followed until 2000. After 2000 petroleum production continues to increase until a reserve to production ratio (R/P) equals ten to one. Production peaks at this point and then continues at a ten to one R/P ratio until supplies run out.

The consumption of coal, natural gas and non-fossil fuels (fission/fusion, geothermal, biomass, hydroelectric and solar power) vary with each scenario. Shale oil makes small contributions past the year 2000. It is not predicted to be a major future energy source due to environmental damage associated with the mining of shale oil, and also due to rather large amounts of CO_2 emitted per unit energy generated (see Table 1). If more shale oil were used, it would have the same effect on CO_2 emissions as the use of more coal. The fossil fuel resources assumed to be recoverable are tabulated in Appendix B.

A. No Limit on CO_2 Emissions

In this scenario no limitations are placed upon future fossil fuel use. The use of coal is emphasized for the rest of this century and continues on into the next century. The development and use of non-fossil fuels continue to grow but without added emphasis. Natural gas production continues at a slowly increasing rate until an R/P ratio of 7/1 is reached around 2030. Production after 2030 continues at a 7/1 ratio until reserves run out. Figure 6 shows the future energy demand for this scenario.

Figure 7 shows that the CO_2 buildup from this energy strategy is quite rapid. The yearly atmospheric CO_2 increase rises from 1.3 ppm in 1976 to 4.5 ppm in 2040. Noticeable temperature changes would occur around 2010 as the concentration reaches 400 ppm. Significant climatic changes occur around 2035 when the concentration approaches 500 ppm. A doubling of the pre-industrial concentration occurs around 2050. The doubling would bring about dramatic changes in the world's environment (see Appendix A). Continued use of coal as a major energy source past the year 2050 would further increase the atmospheric CO_2 level resulting in increased global temperatures and environmental upsets.

B. CO_2 Increase Limited to 510 ppm

This energy scenario is limited to a 75% increase over the pre-industrial concentration of 290 ppm. No limitations are placed on petroleum production. Natural gas production is encouraged beginning in 1990 to minimize coal combustion until non-fossil fuels are developed. Production of natural gas would increase until 2010 when an R/P ratio of 7/1 would be reached. Production would then continue at a R/P of 7/1 until supplies ran out. The development and use of nonfossil fuels are emphasized beginning the 1990's. Non-fossil fuels start to be substituted for coal in 1990's. Figure 8 shows the future energy demand by fuel for this scenario.

Figure 9 shows the atmospheric CO_2 concentration trends for this scenario. The lower graph shows the maximum yearly atmospheric CO_2 increase allowable for the 510 ppm limit. The yearly CO_2 increase peaks in 2005 when it amounts to 2.3 ppm and then steadily decreases reaching 0.2 ppm in 2100. A 0.2 ppm increment is equivalent to the direct combustion of 5.1 billion B.O.E. of coal. This would be approximately 2 to 3% of the total world energy demanded in 2100. (For more detail on the construction of Figure 9, see Appendix C.)

A comparison of the Exxon year 2000 predictions and this scenario's year 2000 requirements shows the magnitude of possible future energy source changes. The Exxon predictions call for nonfossil fuels to account for 18 billion B.O.E. in 2000. This scenario requires that 20 billion B.O.E. be supplied by non-fossil fuels by

2000. This difference of 2 billion B.O.E. is equivalent to the power supplied by 214-1000 MW nuclear power plants operating at 60% of capacity. If it were supplied by methane produced from biomass, it would be equivalent to 80,000 square miles of biomass at a yield of 50 ton/acre, heat value of 6500 Btu/dry pound and a 35% conversion efficiency to methane. Therefore even a 20% increase in non-fossil fuel use is a gigantic undertaking.

The magnitude of the change to non-fossil fuels as major energy sources is more apparent when scenarios A and B are compared in the year 2025. Scenario B requires an 85 billion B.O.E. input from non-fossil fuels in 2025. This is almost double the 45 billion B.O.E. input predicted in scenario A. This 35 billion B.O.E. difference is approximately equal to the total energy consumption for the entire world in 1970.

The environmental changes associated with this scenario wouldn't be as severe as if the CO_2 concentration were allowed to double as in scenario A. Noticeable temperature changes would occur around 2010 when the CO_2 concentration reaches 400 ppm. Significant climate changes would occur as the atmospheric concentration nears 500 ppm around 2080. Even though changes in the environment due to increased atmospheric CO concentrations are uncertain, an increase to 500 ppm would probably bring about undesirable climatic changes to many parts of the earth although other areas may be benefitted by the changes. (See Appendix A, part 1).

C. CO_2 Increase Limited to 440 ppm

This scenario limits future atmospheric CO_2 increases to a 50% increase over the pre-industrial concentration of 290 ppm. As in the previous case, no limitations are placed on petroleum production and increased natural gas production is encouraged. Much emphasis is placed on the development and use of non-fossil fuels. Non-fossil fuels are substituted for coal beginning in the 1990's. By 2010 they will have to account for 50% of the energy supplied worldwide. This would be an extremely difficult and costly effort if possible. In this scenario coal or shale will never become a major energy source. Figure 10 shows the future world energy demand by fuel for this scenario.

The atmospheric CO_2 concentration trends for this scenario are shown in Figure 11. To satisfy the limits of this scenario the yearly CO_2 emissions would have to peak in 1995 at 2.0 ppm,

and then rapidly decrease reaching a value of 0.04 ppm in 2100. A 0.04 ppm maximum allowable increase means that unless removal/disposal methods for CO_2 emissions are available only one billion B.O.E. of coal may be directly combusted in 2100 (or 1.4 billion Barrels of Oil). This would be less than 1% of the total energy demanded by the world in 2100.

To adhere to the 440 ppm limit, non-fossil fuels will have to account for 28 billion B.O.E. in 2000 as compared to 20 billion B.O.E. in scenario B and 18 billion B.O.E. in scenario A. This difference between scenarios A and C of 10 billion B.O.E. is equivalent to over 1000, 1000 MW nuclear power plants operating at 60% of capacity. Ten billion B.O.E. is also approximately equivalent to 400,000 square miles of biomass at 35% conversion efficiency to methane. This is equivalent to almost one-half the total U.S. forest land.

By 2025 the 110 billion B.O.E. input from non-fossil fuels called for in this scenario is more than twice as much as the 45 billion B.O.E. input predicted in scenario A. This difference of 65 billion is approximately equal to the amount of energy the entire world will consume in 1980. In terms of power plants, 65 billion B.O.E. is equivalent to almost 7000, 1000 MW nuclear power plants operating at 60% of capacity.

An atmospheric CO_2 concentration of 440 ppm is assumed to be a relatively safe level for the environment. A slight global warming trend should be noticeable but not so extreme as to cause major changes. Slight changes in precipitation might also be noticeable as the atmospheric CO_2 concentration nears 400 ppm.

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October 16, 1979

Controlling Atmospheric CO_2

79PE 554

Dr. R. L. Hirsch:

The attached memorandum presents the results of a study on the potential impact of fossil fuel combustion on the CO_2 concentration in the atmosphere. This study was made by Steve Knisely, a summer employee in Planning Engineering Division.

The study considers the changes in future energy sources which would be necessary to control the atmospheric CO_2 concentration at different levels. The principle assumption for the CO_2 balance is that 50% of the CO_2 generated by fossil fuels remains in the atmosphere. This corresponds to the recent data on the increasing CO_2 concentration in the atmosphere compared to the quantity of fossil fuel combusted.

Present climatic models predict that the present trend of fossil fuel use will lead to dramatic climatic changes within the next 75 years. However, it is not obvious whether these changes would be all bad or all good. The major conclusion from this report is that, should it be deemed necessary to maintain atmospheric CO_2 levels to prevent significant climatic changes, dramatic changes in patterns of energy use would be required. World fossil fuel resources other than oil and gas could never be used to an appreciable extent.

No practical means of recovering and disposing of CO_2 emissions has yet been developed and the above conclusion assumes that recovery will not be feasible.

It must be realized that there is great uncertainty in the existing climatic models because of a poor understanding of the atmospheric/terrestrial/oceanic CO_2 balance. Much more study and research in this area is required before major changes in energy type usage could be recommended.

W. L. Ferrall

W. L. FERRALL

WLF:ceg
Attachment

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R. L. Mastracchio
W. H. Mueller
H. Shaw
G. O. Wilhelm

CONTROLLING THE CO_2 CONCENTRATION IN THE ATMOSPHERE

The CO_2 concentration in the atmosphere has increased since the beginning of the world industrialization. It is now 15% greater than it was in 1850 and the rate of CO_2 release from anthropogenic sources appears to be doubling every 15 years. The most widely held theory is that:

- The increase is due to fossil fuel combustion
- Increasing CO_2 concentration will cause a warming of the earth's surface
- The present trend of fossil fuel consumption will cause dramatic environmental effects before the year 2050.

However, the quantitative effect is very speculative because the data base supporting it is weak. The CO_2 balance between the atmosphere, the biosphere and the oceans is very ill-defined. Also, the overall effect of increasing atmospheric CO_2 concentration on the world environment is not well understood. Finally, the relative effect of other impacts on the earth's climate, such as solar activity, volcanic action, etc. may be as great as that of CO_2.

Nevertheless, recognizing the uncertainty, there is a possibility that an atmospheric CO_2 buildup will cause adverse environmental effects in enough areas of the world to consider limiting the future use of fossil fuels as major energy sources. This report illustrates the possible future limits on fossil fuel use by examining different energy scenarios with varying rates of CO_2 emissions. Comparison of the different energy scenarios show the magnitude of the switch from fossil fuels to non-fossil fuels that might be necessary in the future. Non-fossil fuels include fission/fusion, geothermal, biomass, hydroelectric and solar power. The possible environmental changes associated with each scenario are also discussed.

CONCLUSIONS

As stated previously, predictions of the precise consequences of uncontrolled fossil fuel use cannot be made due to all of the uncertainties associated with the future energy demand and the global CO_2 balance. On the basis that CO_2 emissions must be controlled, this study examined the possible future fuel consumptions to achieve various degrees of control. Following are some observations and the principle conclusions from the study:

- The present trends of fossil fuel combustion with a coal emphasis will lead to dramatic world climate changes within the next 75 years, according to many present climatic models.

- The CO_2 buildup in the atmosphere is a worldwide problem. U.S. efforts to restrict CO_2 emission would delay for a short time but not solve the problem.

- Warming trends which would move the temperate climate northward may be beneficial for some nations (i.e., the USSR, see Figure 1) and detrimental for others. Therefore, global cooperation may be difficult to achieve.

- Removal of CO_2 from flue gases does not appear practical due to economics and lack of reasonable disposal methods.

- If it becomes necessary to limit future CO_2 emissions without practical removal/disposal methods, coal and possibly other fossil fuel resources could not be utilized to an appreciable extent.

- Even with dramatic changes in current energy resource use, it appears unlikely that an increase of 50% over the pre-industrial CO_2 level can be avoided in the next century. This would be likely to cause a slight increase in global temperatures but not a significant change in climate, ocean water level or other serious environmental efforts.

The potential problem is great and urgent. Too little is known at this time to recommend a major U.S. or worldwide change in energy type usage but it is very clear that immediate research is necessary to better model the atmosphere/terrestrial/oceanic CO_2 balance. Only with a better understanding of the balance will we know if a problem truly exists.

Existing Data and Present Models

Since the beginning of industrialization, the atmospheric carbon dioxide concentration has increased from approximately 290 ppm in 1860 to 336 ppm today. Atmospheric CO_2 concentrations have been recorded on a monthly basis by C. D. Keeling since 1958 at Mauna Loa Observatory in Hawaii (see Figure 2). Seasonal variations are clearly shown with the CO_2 concentrations lowest during the North American and Eurasian summers, due to increased photosynthetic activities. Over the last ten years, the atmospheric concentration has been increasing at an average rate of about 1.2 ppm/year.

The present consumption of fossil fuels releases more than 5 billion tons of carbon as CO_2 into the atmosphere each year. Data to date indicate that of the amount released approximately one-half is absorbed by the oceans. The other half remains in the atmosphere. There is some question as to whether the terrestrial biosphere is a sink, absorbing atmospheric CO_2, or a source of CO_2 emissions, due to man's land clearing activities. Current opinion attributes the atmospheric CO_2 increase to fossil fuels and considers the biosphere input to be negligible.

Figure 3 shows the carbon cycle with the ocean and the biosphere as sinks for approximately 50% of the fossil fuel emissions. Most models show the ocean to be a major sink while the biosphere appears to be a much smaller sink if it absorbs any CO_2 at all. It is clear from Figure 3 that the net atmospheric increase in CO_2 is quite small compared to the quantities of CO_2 exchanged between the atmosphere and the earth. This makes it very difficult to analyze the fossil fuel impact on the overall carbon cycle.

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As evidenced by the balance shown in Figure 3, the atmospheric carbon exchange with the terrestrial biosphere and the oceans is so large that small changes due to these feedback mechanisms could drastically offset or add to the impact of fossil fuel combustion on the earth's temperature.

Appendix A gives one, but not unanimous, viewpoint of how the environment might change if the feedback mechanisms are ignored. The contribution that will ultimately be made by these feedback mechanisms is unknown at present.

Energy Scenarios for Various CO_2 Limits

Using the CO_2 atmospheric concentration data recorded to date, the correlation of these data with fossil fuel consumption and the proposed "greenhouse effect" models, this study reviews various world energy consumption scenarios to limit CO_2 atmospheric buildup. The concentration of CO_2 in the atmosphere is controlled in these studies by regulating the quantity of each type of fossil fuel used and by using non-fossil energy sources when required. The quantity of CO_2 emitted by various fuels is shown in Table 1. These factors were calculated based on the combustion energy/carbon content ratio of the fuel and the thermal efficiency of the overall conversion process where applicable. They show the high CO_2/energy ratio for coal and shale and the very high ratios for synthetic fuels from these base fossil fuels which are proposed as fuels of the future.

The total world energy demand used in these scenarios is based upon the predictions in the Exxon Fall 1977 World Energy Outlook for the high oil price case for the years 1976 to 1990. It is assumed that no changes in the sources of supply of energy could be made during this period of time. Case A, which has no restrictions on CO_2 emissions, follows the high oil price predictions until 2000.

Petroleum production and consumption is the same in each scenario. The high oil price case predictions are followed until 2000. After 2000 petroleum production continues to increase until a reserve to production ratio (R/P) equals ten to one. Production peaks at this point and then continues at a ten to one R/P ratio until supplies run out.

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In this scenario no limitations are placed upon future fossil fuel use. The use of coal is emphasized for the rest of this century and continues on into the next century. The development and use of non-fossil fuels continue to grow but without added emphasis. Natural gas production continues at a slowly increasing rate until an R/P ratio of 7/1 is reached around 2030. Production after 2030 continues at a 7/1 ratio until reserves run out. Figure 6 shows the future energy demand for this scenario.

Figure 7 shows that the CO_2 buildup from this energy strategy is quite rapid. The yearly atmospheric CO_2 increase rises from 1.3 ppm in 1976 to 4.5 ppm in 2040. Noticeable temperature changes would occur around 2010 as the concentration reaches 400 ppm. Significant climatic changes occur around 2035 when the concentration approaches 500 ppm. A doubling of the pre-industrial concentration occurs around 2050. The doubling would bring about dramatic changes in the world's environment (see Appendix A). Continued use of coal as a major energy source past the year 2050 would further increase the atmospheric CO_2 level resulting in increased global temperatures and environmental upsets.

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This energy scenario is limited to a 75% increase over the pre-industrial concentration of 290 ppm. No limitations are placed on petroleum production. Natural gas production is encouraged beginning in 1990 to minimize coal combustion until non-fossil fuels are developed. Production of natural gas would increase until 2010 when an R/P ratio of 7/1 would be reached. Production would then continue at a R/P of 7/1 until supplies ran out. The development and use of nonfossil fuels are emphasized beginning the 1990's. Non-fossil fuels start to be substituted for coal in 1990's. Figure 8 shows the future energy demand by fuel for this scenario.

Figure 9 shows the atmospheric CO_2 concentration trends for this scenario. The lower graph shows the maximum yearly atmospheric CO_2 increase allowable for the 510 ppm limit. The yearly CO_2 increase peaks in 2005 when it amounts to 2.3 ppm and then steadily decreases reaching 0.2 ppm in 2100. A 0.2 ppm increment is equivalent to the direct combustion of 5.1 billion B.O.E. of coal. This would be approximately 2 to 3% of the total world energy demanded in 2100. (For more detail on the construction of Figure 9, see Appendix C.)

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The environmental changes associated with this scenario wouldn't be as severe as if the CO_2 concentration were allowed to double as in scenario A. Noticeable temperature changes would occur around 2010 when the CO_2 concentration reaches 400 ppm. Significant climate changes would occur as the atmospheric concentration nears 500 ppm around 2080. Even though changes in the environment due to increased atmospheric CO concentrations are uncertain, an increase to 500 ppm would probably bring about undesirable climatic changes to many parts of the earth although other areas may be benefitted by the changes. (See Appendix A, part 1).

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This scenario limits future atmospheric CO_2 increases to a 50% increase over the pre-industrial concentration of 290 ppm. As in the previous case, no limitations are placed on petroleum production and increased natural gas production is encouraged. Much emphasis is placed on the development and use of non-fossil fuels. Non-fossil fuels are substituted for coal beginning in the 1990's. By 2010 they will have to account for 50% of the energy supplied worldwide. This would be an extremely difficult and costly effort if possible. In this scenario coal or shale will never become a major energy source. Figure 10 shows the future world energy demand by fuel for this scenario.

The atmospheric CO_2 concentration trends for this scenario are shown in Figure 11. To satisfy the limits of this scenario the yearly CO_2 emissions would have to peak in 1995 at 2.0 ppm,

and then rapidly decrease reaching a value of 0.04 ppm in 2100. A 0.04 ppm maximum allowable increase means that unless removal/disposal methods for CO_2 emissions are available only one billion B.O.E. of coal may be directly combusted in 2100 (or 1.4 billion Barrels of Oil). This would be less than 1% of the total energy demanded by the world in 2100.

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An atmospheric CO_2 concentration of 440 ppm is assumed to be a relatively safe level for the environment. A slight global warming trend should be noticeable but not so extreme as to cause major changes. Slight changes in precipitation might also be noticeable as the atmospheric CO_2 concentration nears 400 ppm.

S. KNISELY

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Table 1

CO_2 EMISSIONS

Fuel	lb CO_2 Emitted* / 1000 Btu Fuel	% of Present CO_2 Output
SNG from Coal	0.35	0
Coal Liquids	0.32	0
Methanol from Coal	0.38	0
H_2 from Coal Gasification	0.38	0
Shale Oil	0.23	0
Bituminous Coal	.21	38%
Petroleum	.15	49%
Natural Gas	.11	13%
Fission/Fusion	0	0
Biomass	0	0
Solar	0	0

* Includes conversion losses where applicable.

APPENDIX A

ECOLOGICAL CONSEQUENCES OF INCREASED CO_2 LEVELS

From:

Peterson, E.K., "Carbon Dioxide Affects Global Ecology," Environmental Science and Technology 3 (11), 1162-1169 (Nov '69).

1. Environmental effects of increasing the CO_2 levels to 500 ppm. (1.7 times 1860 level)

   - A global temperature increase of 3°F which is the equivalent of a 1°-4° southerly shift in latitude. A 4° shift is equal to the north to south height of the state of Oregon.

   - The southwest states would be hotter, probably by more than 3°F, and drier.

   - The flow of the Colorado River would diminish and the southwest water shortage would become much more acute.

   - Most of the glaciers in the North Cascades and Glacier National Park would be melted. There would be less of a winter snow pack in the Cascades, Sierras, and Rockies, necessitating a major increase in storage reservoirs.

   - Marine life would be markedly changed. Maintaining runs of salmon and steelhead and other subarctic species in the Columbia River system would become increasingly difficult.

   - The rate of plant growth in the Pacific Northwest would increase 10% due to the added CO_2, and another 10% due to increased temperatures.

2. Effects of a doubling of the 1860 CO_2 concentration. (580 ppm)

   - Global temperatures would be 9°F above 1950 levels.

   - Most areas would get more rainfall, and snow would be rare in the contiguous states, except on higher mountains.

   - Ocean levels would rise four feet.

   - The melting of the polar ice caps could cause tremendous redistribution of weight and pressure exerted on the earth's crust. This could trigger major increases in earthquakes and volcanic activity resulting in even more atmospheric CO_2 and violent storms.

   - The Arctic Ocean would be ice free for at least six months each year, causing major shifts in weather patterns in the northern hemisphere.

- The present tropics would be hotter, more humid, and less habitable, but the present temperature latitude would be warmer and more habitable.

b1798

APPENDIX B

FOSSIL FUEL RESOURCES

Oil	- Assume 1.6 trillion barrels of oil potentially recoverable as of 1975 (assuming the future recovery rate to be 40%). The minimum allowable Reserve to Production (R/P) ratio is ten one.
Shale Oil	- Potential of 3.0 trillion B.O.E. but assuming 1977 technology only 200 billion B.O.E. actually recoverable.
Natural Gas	- Approximately 1.6 trillion B.O.E. potentially recoverable. Minimum allowable R/P = 7.1.
Coal	- Potential recoverable reserves equal approximately 12 trillion B.O.E. assuming a conservative 25% recoverability.

APPENDIX C

CONSTRUCTION OF SCENARIOS B AND C
(Scenario A requires no CO_2 emissions control)

1. Scenario B

The CO_2 concentration vs. year curve in Figure 9 was generated by the following equation:

after 1970 ($t = 0$), then

$$*C = 292 \text{ ppm} + 219 \text{ ppm}/[1 + 5.37 \exp. (-t/24 \text{ years})]$$

where C = concentration in ppm

The curve on the lower section of Figure 9, atmospheric CO_2 increase vs. years, is generated by finding the difference in the concentrations of successive years. This curve gives the maximum yearly increases allowable to stay within the limits placed on this scenario. The amount of fossil fuel that may be consumed in any given year can then be calculated by the lower curve. For example:

In 2100 the maximum allowable CO_2 increase equals 0.2 ppm.

This is equivalent to:

$$\frac{2 \text{ ppm}}{} \times \frac{2.1 \times 10^9 \text{ ton C}}{1 \text{ ppm}} \times \frac{2000 \text{ lb}}{\text{ton}} \times \frac{44 \text{ lb } CO_2}{12 \text{ lb C}} = 3.1 \times 10^{12} \text{ lb } CO_2$$

3.1×10^{12} lb CO_2 may be released by the combustion of:

for coal: $$\frac{3.1 \times 10^{12} \text{ lb } CO_2}{} \times \frac{1000 \text{ Btu}}{.21 \text{ lb } CO_2} \times \frac{1 \text{ B.O.E.}}{5.8 \times 10^6 \text{ Btu}}$$

= 2.5 billion B.O.E. of coal

This scenario is based on the assumption that 50% of CO_2 released each year will always be absorbed by the ocean and the rest will remain in the atmosphere.

*Derived from an equation presented by U. Siegenthaler and H. Oeschger (1978) (see references).

Figure 1


MOST OF THE USSR'S VAST AGRICULTURAL LAND BASE LIES LATITUDINALLY NORTH OF THE UNITED STATES
Fairbanks
Leningrad
Kiev
Moscow
Arctic Circle
60
40
40
Minneapolis
Philadelphia
Washington
San Francisco
Denver
Springfield
SOVIET AGRICULTURAL LANDS

Figure 1


MOST OF THE USSR'S VAST AGRICULTURAL LAND BASE LIES LATITUDINALLY NORTH OF THE UNITED STATES
Fairbanks
Leningrad
Kiev
Moscow
Arctic Circle
60
40
40
Minneapolis
Philadelphia
Washington
San Francisco
Denver
Springfield
SOVIET AGRICULTURAL LANDS

CONCENTRATION OF ATMOSPHERIC CO_2 AT MAUNA LOA OBSERVATORY, HAWAII

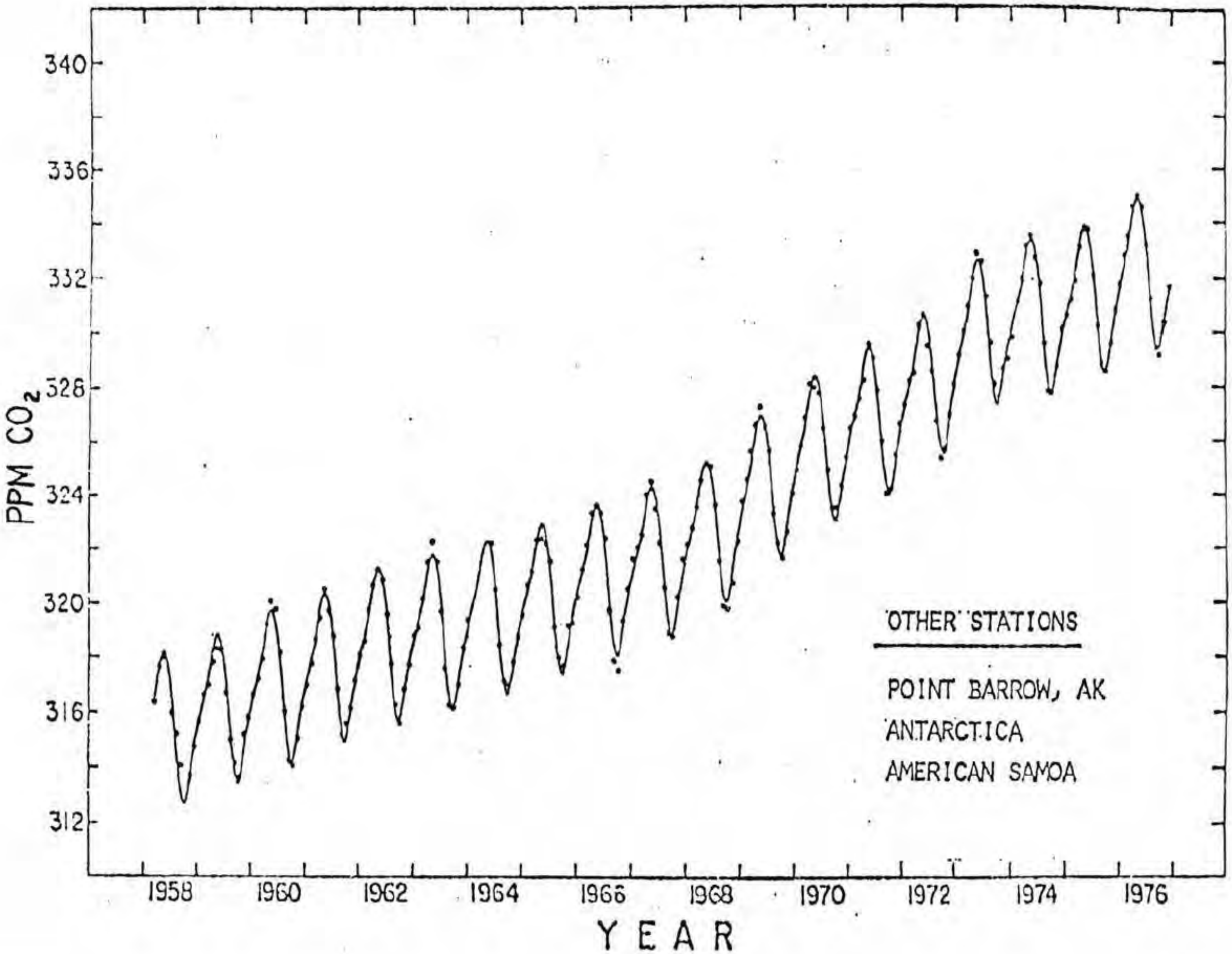

Figure 3

The Carbon Cycle

Current

Fluxes in Gt/a
Pool sizes in Gt

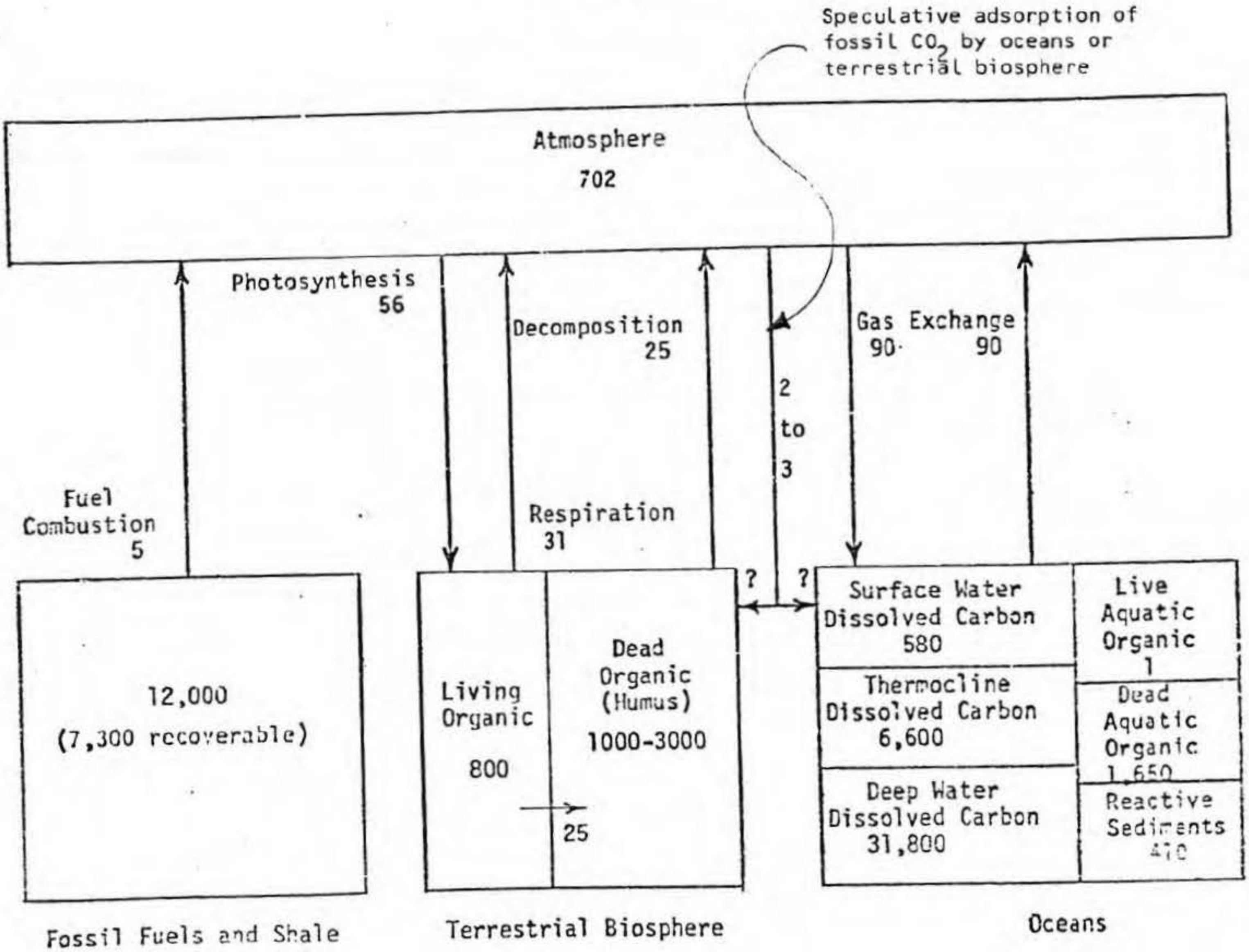

Figure 4

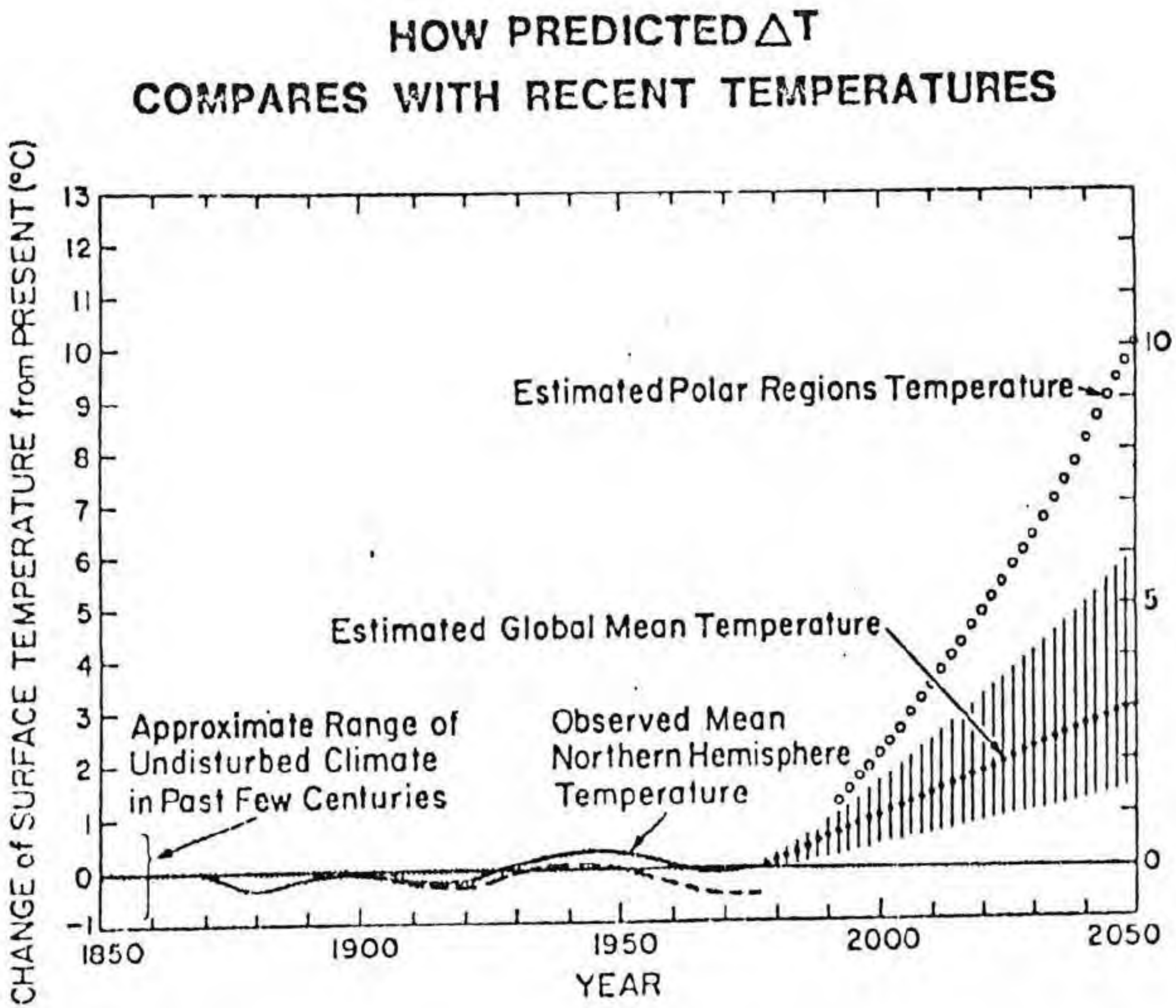
HOW PREDICTED ΔT
COMPARES WITH RECENT TEMPERATURES
CHANGE of SURFACE TEMPERATURE from PRESENT (°C)
Estimated Polar Regions Temperature
Estimated Global Mean Temperature
Approximate Range of
Undisturbed Climate
in Past Few Centuries
Observed Mean
Northern Hemisphere
Temperature
YEAR
1850
1900
1950
2000
2050
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
10
5
0

Figure 5

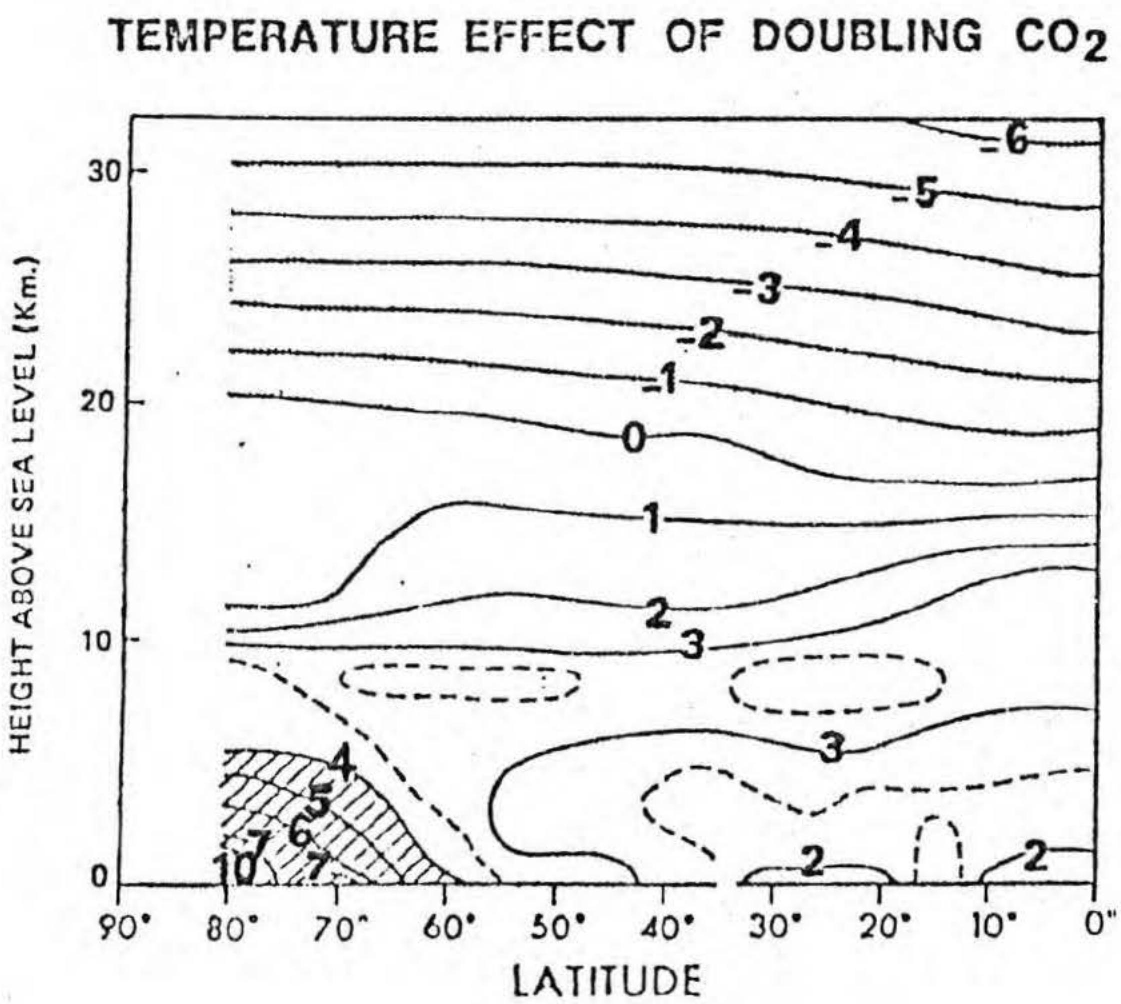
TEMPERATURE EFFECT OF DOUBLING CO_2
HEIGHT ABOVE SEA LEVEL (Km.)
30
20
10
0
-6
-5
-4
-3
-2
-1
0
1
2
3
3
4
5
6
7
7
10
2
2
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
LATITUDE

Figure 6

WORLD ENERGY DEMAND BY FUEL

UNLIMITED CO_2 INCREASE
(COAL EMPHASIS)

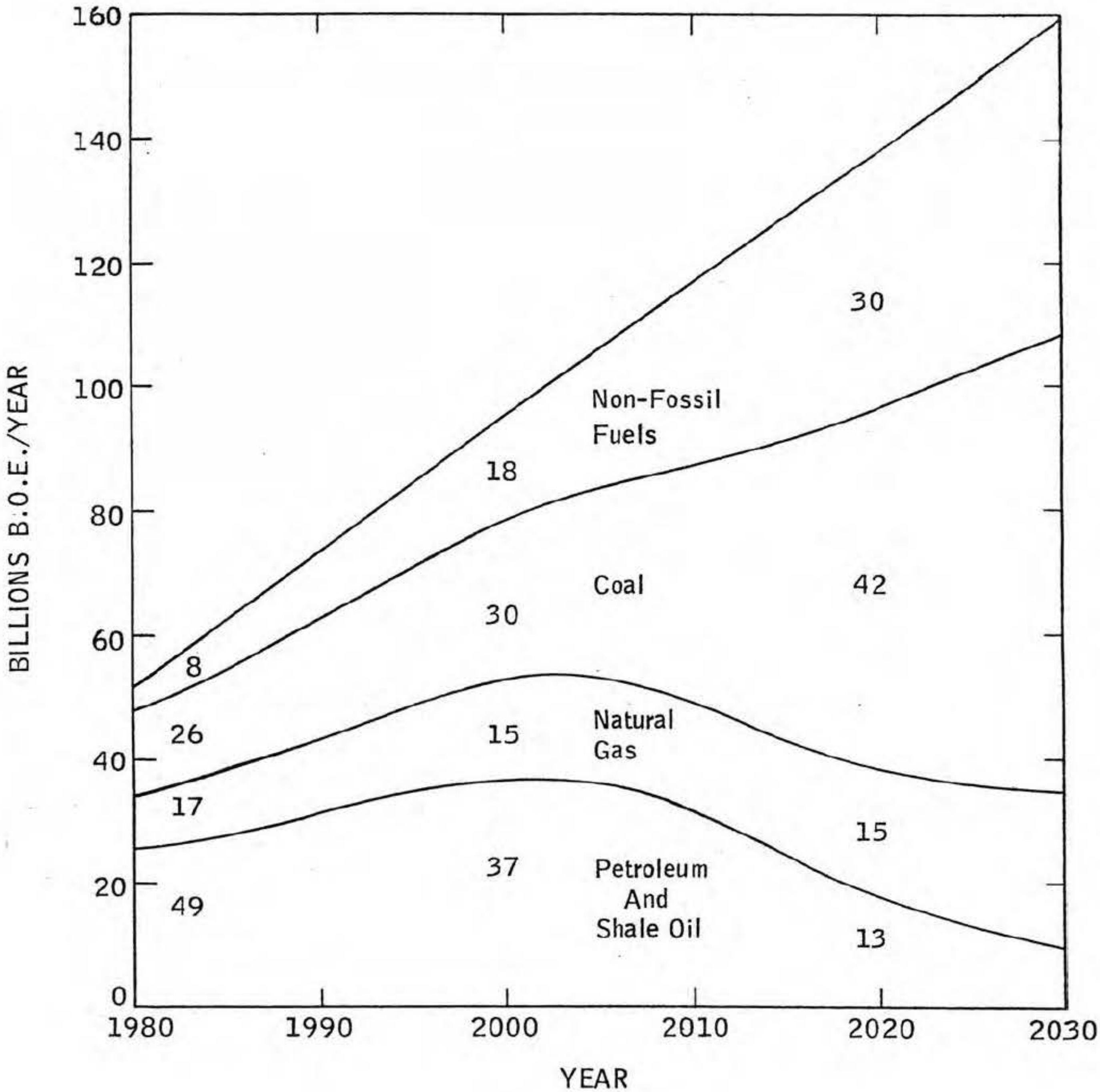

Figure 7

CO_2 IN ATMOSPHERE

RATE OF CO_2 BUILDUP

UNLIMITED INCREASE

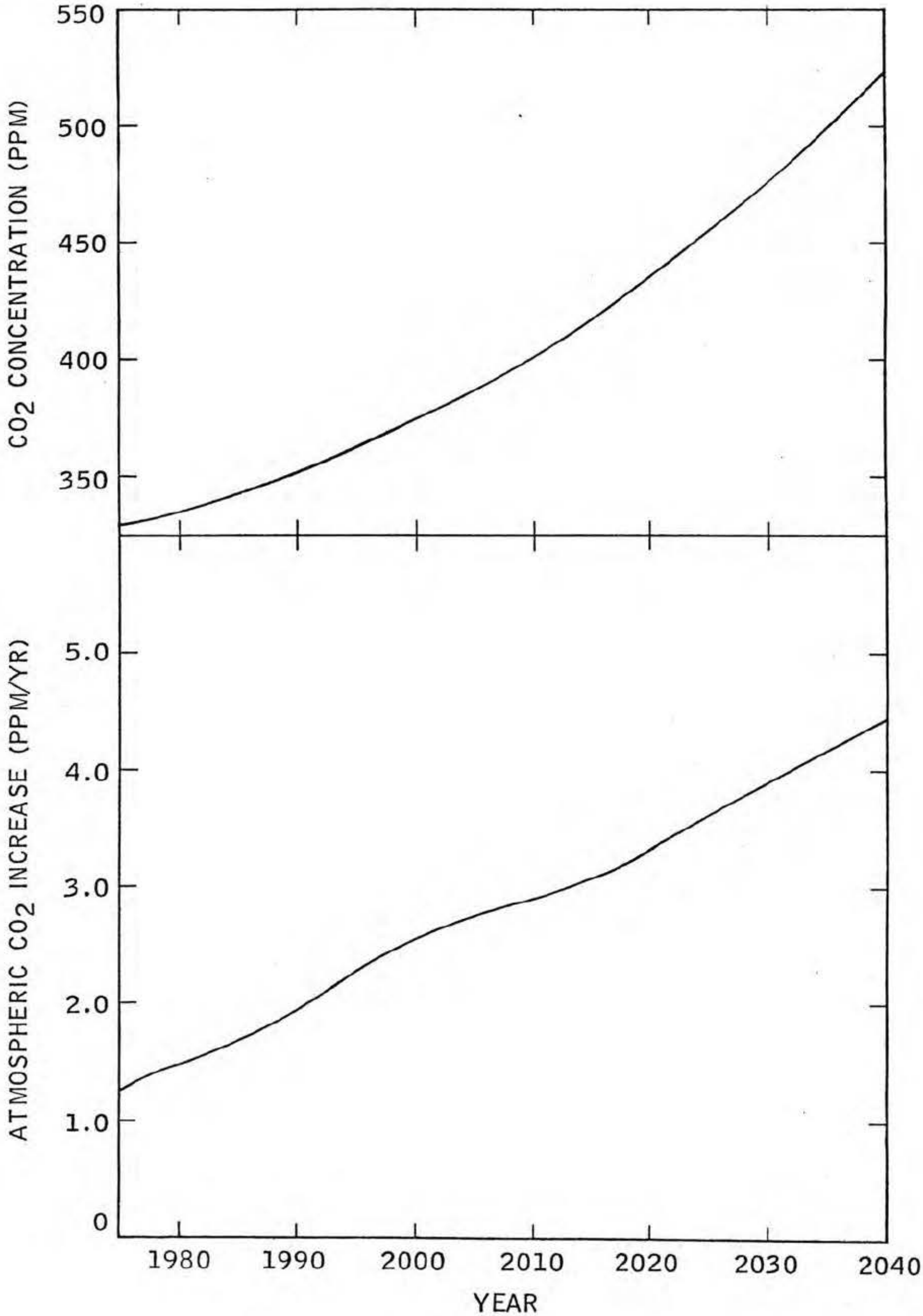

Figure 8

WORLD ENDERGY DEMAND BY FUEL
LIMITED TO A 75% CO_2 INCREASE

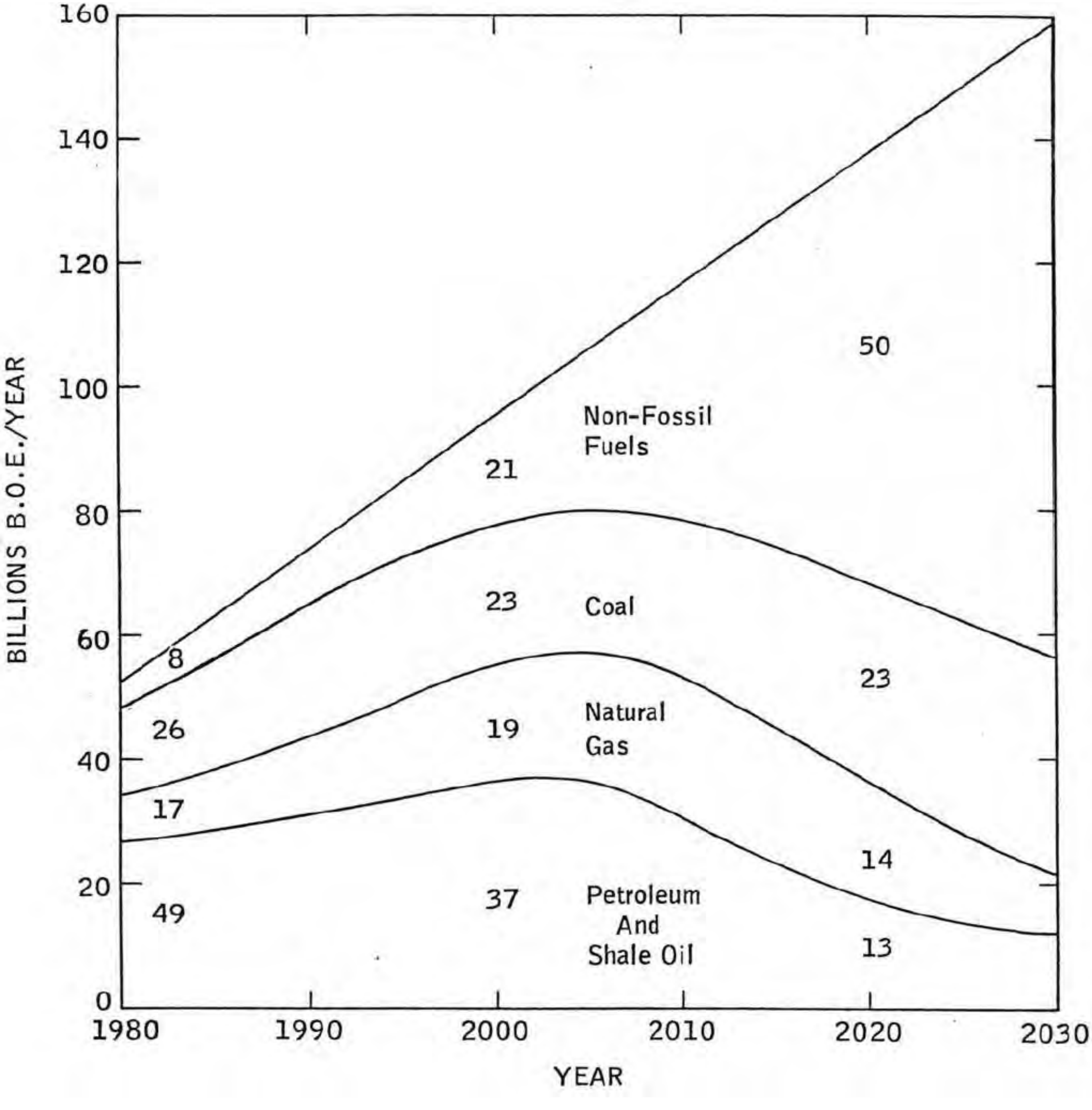

Figure 9

CO_2 IN ATMOSPHERE

RATE OF CO_2 BUILDUP
LIMITED TO 75% INCREASE

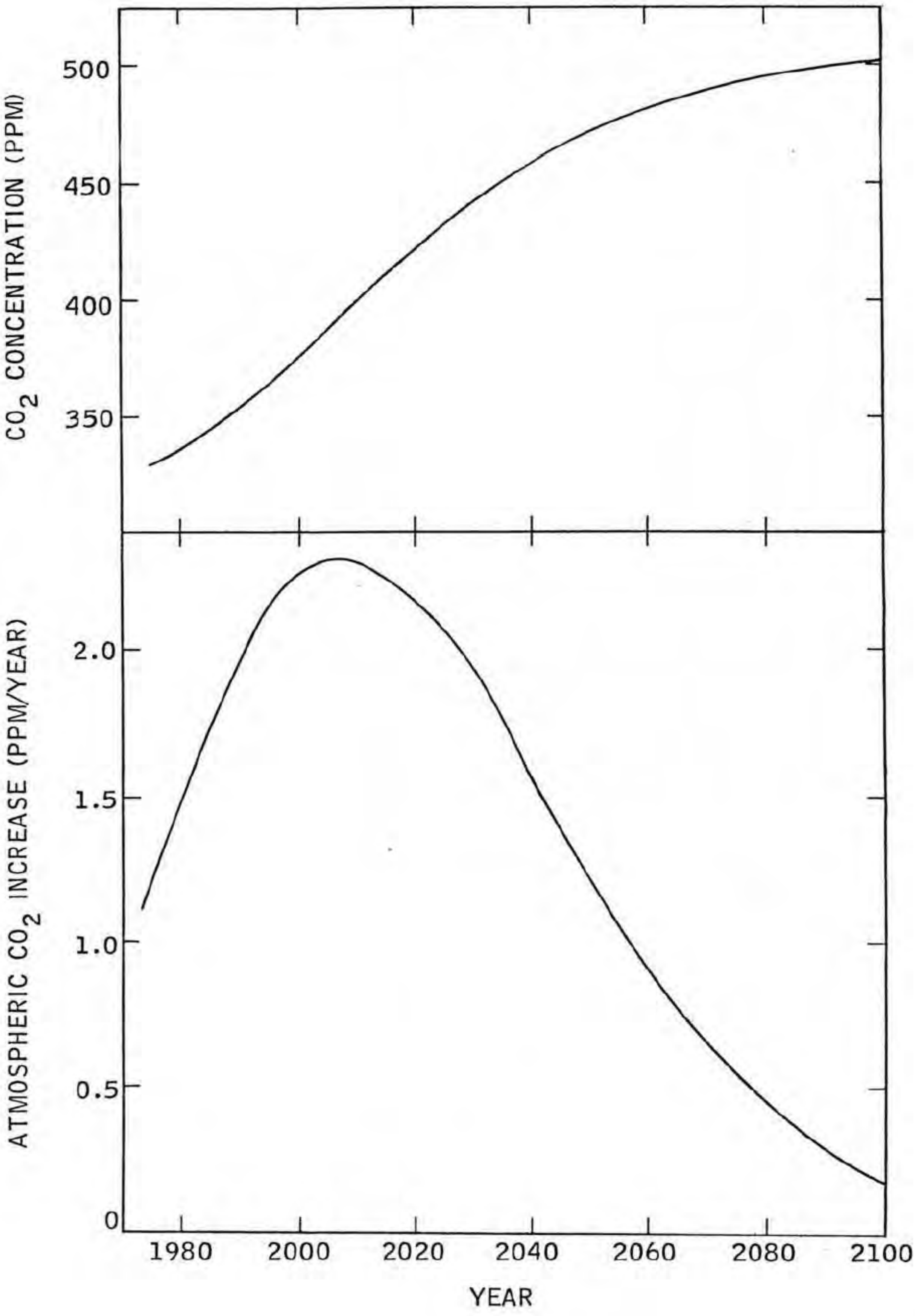

Figure 11

CO_2 IN ATMOSPHERE

RATE OF CO_2 BUILDUP

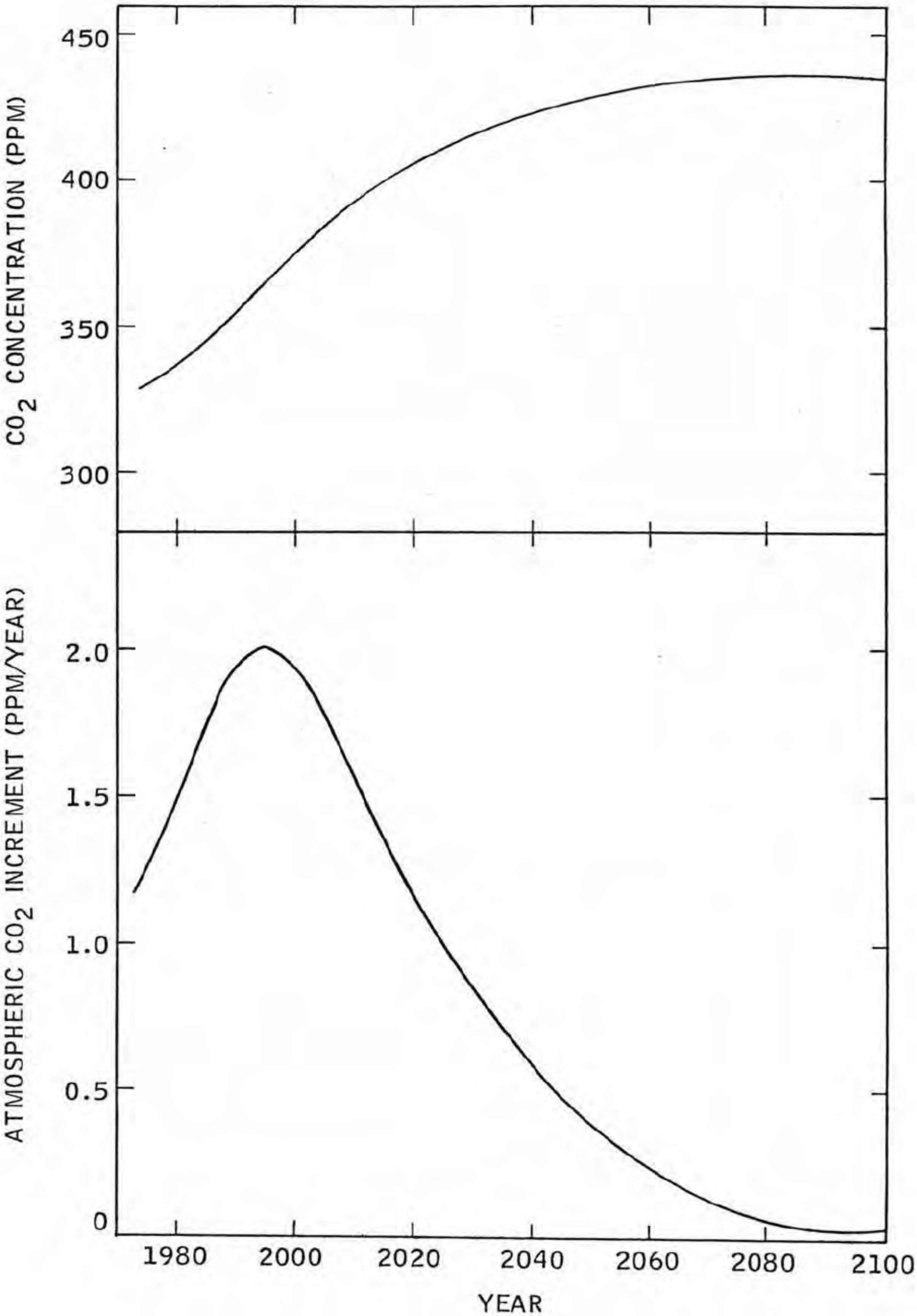

EXHIBIT 5

GENERAL – 154-[illegible]

INTER-OFFICE CORRESPONDENCE

DATE November 19, 1979

TO H. N. Weinberg	REFERENCE 79CR 184
FROM H. Shaw	SUBJECT Research in Atmospheric Science

Atmospheric Science will be of critical importance to Exxon in the next decade. This area emcompasses the complex interdisciplinary research that is needed for in-depth understanding of:

(1) the long range atmospheric transport of sulfates and nitrates across continents and oceans

(2) the impact of anthropogenic sources on climate

(3) the mechanism of acid rain formation

(4) the formation mechanism and dispersion of fine particulates

(5) the enhanced sorption of carcinogens and trace metals on fine particulates

(6) the effect of hydrocarbons, halocarbons and other components on atmospheric ozone depletion

(7) the effect of oxygen depletion in the oceans

(8) the potential greenhouse effect

H. N. WEINBERG
NOV 1 9 1979

All these critical ecological questions involve a number of disciplines which generally do not interact at Exxon Research, viz., dispersion modeling, climatology, oceanography, atmosphere chemistry, and environmental engineering. See attached articles on the subject.

why?

We should determine how Exxon can best participate in all these areas and influence possible legislation on environmental controls. It is important to begin to anticipate the strong intervention of environmental groups and be prepared to respond with reliable and credible data. Such groups have already attempted to curb the budding synfuels industry because it could accelerate the build-up of CO_2 in the atmosphere. In many respects, the potential environmental problems the energy industry may be facing are similar to those that affected the aircraft industry a decade ago. This industry was caught unprepared when confronted with atmospheric ozone depletion due to Supersonic Transports (SST). As it turned out, this rationale for discontinuing further development of the SST is currently believed to be erroneous by the scientific community. A well prepared aircraft industry should have been able to present data indicating that the ozone layer would not suffer irreparable harm due to the NO emissions from a projected fleet of SST's. On the other hand, the apparent damage that can be caused to the ozone layer by Freons is believed to be significant. When Freon based aerosol containers were baned, the chemical industry was also caught unprepared. If the industry had anticipated the problem, it could have been working on substitute propellants, and might have enhanced its image and public credibility by voluntarily stopping the use of Freons. Such a procedure could have avoided government intervention.

It behooves us to start a very aggressive defensive program in the indicated areas of atmospheric science and climate because there is a good probability that legislation affecting our business will be passed. Clearly, it is in our interest for such legislation to be based on hard scientific data. The data obtained from research on the global damage from pollution, e.g., from coal combustion, will give us the needed focus for further research to avoid or control such polutants. We should be prepared for, and ahead of the government in making the public aware of pollution problems.

Fall-out from intensive study of climate, oceanography, etc., could provide data to better plan fuel distribution systems, and possibly anticipate fuel needs. A first step in evaluating the importance of an atmospheric science program is to form a small task force of knowledgeable people to assess it. I would recommend that a team consisting of a gas phase kineticist, an environmental engineer, and an oceanographer or climatologist develop a list of specific research questions which would be of relevance to Exxon. We should also invite outstanding consultants to consider the possible impact of global ecological factors to Exxon. At some early point we will need to hire a scientist with a national reputation to provide leadership to the area and attract talent. This individual could head the part of the program that we are already committed to, viz., the greenhouse study. I suggest that Dr. Stephen H. Schneider, who will be visiting us on November 20th, may be such an individual, and we should take advantage of his visit here to begin to discuss the subject.

Henry

Henry Shaw

HS/lw

Attachment

cc: N. R. Werthamer

EXHIBIT 6

American Petroleum Institute
2101 L Street, Northwest
Washington, D.C. 20037
202-457-7000

J. J. Nelson
(202) 457-6381

March 18, 1980

To: AQ-9 Task Force

Attached please find a copy of the minutes of the February 9, 1980 AQ-9 Task Force meeting. Please inform me of any errors or omissions.

Cordially,

J. J. Nelson

Attachment--minutes

/mi

CO_2 AND CLIMATE TASK FORCE (AQ-9)

Minutes of Meeting

9:15 a.m.
Friday, February 29, 1980

Manhatten Room
LaGuardia Airport
New York City, New York

MEMBERS PRESENT

K. Blower, Chairman	SOHIO
B. Bailey	Texaco
H. Shaw	Exxon R&E

OTHERS PRESENT

J. Laurman	Consultant
J. Nelson	API/EAD
C. Showers	SOHIO

OPENING REMARKS

K. Blower, Chairman, opened the meeting by listing the following goals of this meeting:

1. Increase industry's understanding of the CO_2 and climate problem.

2. Determine if there are feasibile and valuable research projects that could be accomplished by API.

3. Establish a mechanism to prepare any needed issue papers.

B. Bailey added the following items for consideration:

1. This Task Force should be the focal point and establish a basis for providing API comments on CO_2 and climate matters.

2. An overall goal of the Task Force should be to help develop ground rules for energy release of fuels and the cleanup of fuels as they relate to CO_2 creation.

CONSULTANT REPORT

Dr. J. A. Laurman, a consultant and a recognized expert in the field of CO_2 and climate, made a presentation to the Task Force entitled, "The CO_2 Problem; Addressing Research Agenda Development."

An outline is included as Attachment A.

In addition, a complete technical discussion, led by Dr. Laurman identified the problem, discussed the scientific basis and technical evidence of CO_2 buildup, impact on society, methods of modeling and their consequences, uncertainties, policy implications, and conclusions that can be drawn from present knowledge. A series of summary charts are attached as Attachment B.

API RESEARCH NEEDS

One area of possible API research was identified: Preparatory research to be able to answer questions dealing with the CO_2 problem and synthetic fuels.

COMMENTS ON DOE TECHNICAL PAPER

K. Blower and Bruce Bailey will modify the draft API letter back to DOE concerning an article submitted to the Task Force for comment. When the Task Force has approved the letter, it will be coordinated within API staff.

OTHER BUSINESS

The Task Force should set up a rationale and system for review of technical articles and responses to inquiries.

One potential area for R&D was discussed by the Task Force: "Investigate the Market Penetration Requirements of Introducing A New Energy Source into World Wide Use." This would include the technical implications of energy source changeover, research timing and requirements.

The meeting was adjourned at 4:25 p.m.

Prepared by:

J J Nelson

Jimmie J. Nelson

THE CO_2 PROBLEM; ADDRESSING RESEARCH AGENDA DEVELOPMENT

The difficulties of dealing with the pragmatic questions related to the CO_2/fossil fuel problem all relate to certain general features, these having A) high impact cost, B) large uncertainty, and being C) far distant and D) global. The problem is interdisciplinary in its scientific aspects and it has ramifications in many economic sectors and in most nations. Therefore, not only is addressing it difficult in anlytic terms, but the mulitiplicity of possible interest groups that can be affected means that choice of what constitute the critical research issues depends on the user. In the most general terms we can subdivide the motivational aspect into those who see the need as to

A) better understand the CO_2/climate system, resulting in an ability to predict a) short range and b) long range effects.

or to

B) assess the present day importance of the future impact, as viewed
  i) from a world viewpoint
  ii) by national entities
  iii) by specific industrial sectors or interest groups

Highest priority investigations depend on which of these groups is involved. In particular, a highly relevant aspect for all of these groups is the influence of present and future information on public perception and governmental attitudes regarding the problem and the resultant effect on energy policy.

Instead of attempting to research all aspects of the CO_2 problem that bear on the concern of any particular group, we may select a feature that appears to be particularly important to that sector - for example, nuclear energy proponents might wish to address the problem of market penetration time lags as the most critical for making their case.

A) Reducing uncertainty in projections

CO_2 input

a) deforestation, past present and future.

b) effect of various energy use policies - coal, oil shale, nuclear, biomass, solar, synthetics.

c) turn-around scenarios for non-carbon based fuel use, impact calculations.

d) remedial measures: biomass, scrubbing, bacterial enzymes, fertilizing oceans.

Carbon cycle

a) CO_2 growth and photosynthesis

b) missing CO_2 since - detritus, humus, regrowth of deforested areas, oceans, non-stationary biosphere.

c) validity of box-model projections in short (50 yr) range.

d) organic material in oceans (detritus, dissolution, nutriant limitations)

e) estuarian regions

f) ground water

g) carbonate distribution

h) use of tracers

i) cataloguing on the biosphere

j) climatic change feedback effects - ocean temperature, plant growth.

Climate modeling

a) ocean dynamics

b) simplifying models

c) feedback effects : clouds, sea ice, vegitation change(albedo).

d) regional climatic change

B) Impact of climatic change

Socio-economic

I) General problems:

a) how to make estimates of costs of large perturbations, even assuming climatic changes are known?

b) how do we discount the future?

c) geopolitical problems, either from climatic change or from remediation measures

d) building in resilience. Can severity be versed in terms of critical rates of change of forcing of the societal system? Is a generic non-specific formulation possible?

II) Immediate policy questions. The physical facts agree on the probability of large effects 50 years away, but with large probable error. Source of the uncertainty arises from deforestation, poor climate models and uncertainty in CO_2 input (energy projections). The first may be settled in a year or two; the second will not. Hence we have to treat an unsure situation, which may be possible via decision analysis if error distribution can be quantified. This has not been done for impact costs, so first
a) can it be? If yes, there still remain two major difficulties:
b) what are market penetration times for new energy sources? and
c) what future (social) discounting rate should be used?

If fossil fuel use rates are reduced to 2% p.a. or under, it looks as if the immediate problem is considerably eased (but needs checking). So another question is
d) what is the 50 year future of fossil fuel use?

Of more parochial interest is
e) what roles do the different catagories of fossil or synthetic fuel play in future projections?

The Natural Biosphere

The Managed Biosphere

REASONS FOR INCREASED CONCERN WITH THE CO_2 PROBLEM

- DEVELOPMENT OF RELIABLE ATMOSPHERIC CO_2 GROWTH RATE MEASUREMENTS
- ITS CORRELATION WITH GLOBAL INDUSTRIAL CO_2 EMISSIONS, MOSTLY FROM FOSSIL FUEL COMBUSTION
- SCIENTIFIC CONSENSUS ON THE POTENTIAL FOR LARGE FUTURE CLIMATIC RESPONSE TO INCREASED CO_2 LEVELS
- REALIZATION THAT REMEDIAL ACTIONS WOULD TAKE A LONG TIME TO BECOME EFFECTIVE

ATTACHMENT B

OBSERVATIONAL EVIDENCE - CONCLUSIONS

- TWENTY YEARS OF GOOD CO_2 DATA, BUT ESSENTIALLY FROM ONE SOURCE
- PRESENT ATMOSPHERIC CO_2 CONCENTRATION = 335 ppm
  PRE-INDUSTRIAL (1860) " " ≈ 290 ppm
- CURRENT GROWTH RATE = 4.3% p.a. OF INCREASE SINCE 1860
- STRONG EMPIRICAL EVIDENCE THAT RISE CAUSED BY ANTHROPOGENIC RELEASE OF CO_2, MAINLY FROM FOSSIL FUEL BURNING
- ATMOSPHERIC RETENTION IS 56% OF RELEASE, ASSUMING NO EFFECTS FROM DEFORESTATION

ENERGY USE PROJECTIONS - CONCLUSIONS

- AVERAGE GROWTH RATE 3-4% p.a. FOR NEXT FIFTY YEARS, FOSSIL FUEL SLIGHTLY LESS
- THIS IS NOT CONSISTANT WITH LONG TERM PAST TREND
- PROJECTED CO_2 RELEASE INCREASE ~~RATE~~ (PROPORTIONAL TO INTEGRATED FOSSIL FUEL OUTPUT) CLOSE TO 3% p.a. UNTIL MID-21ST CENTURY; SUBJECT TO ERROR OF ABOUT ± 1% p.a.
- EFFECT OF FOSSIL FUEL DEPLETION MINOR IN NEXT FIFTY YEARS

CARBON CYCLE - CONCLUSIONS

- POSSIBLE CO_2 RELEASE CONTRIBUTION FROM DEFORESTATION, PERHAPS RIVALLING FOSSIL FUEL SOURCE
- ALL CARBON CYCLE MODELS BEHAVE LINEARLY UP TO 3-4 TIMES PRE-INDUSTRIAL ATMOSPHERIC CO_2 LEVELS
- HENCE GIVE THE SAME PROJECTED ATMOSPHERIC CO_2 LEVELS FOR THE SAME INPUT
- FOSSIL FUEL DEPLETION EFFECTS SMALL
- DEFORESTATION EFFECT ON PROJECTIONS ONLY SIGNIFICANT IF IT BECOMES DEPLETED
- CO_2 "DOUBLING" DATE IS 2038 AT A 3% p.a. GROWTH OF ATMOSPHERIC RELEASE RATE
- ERROR IN THIS ESTIMATE IS SMALL COMPARED WITH OTHER SOURCES OF ERROR

CLIMATE MODELING - CONCLUSIONS

- GLOBAL AVERAGED 2.5°C RISE EXPECTED BY 2038 AT A 3% p.a. GROWTH RATE OF ATMOSPHERIC CO_2 CONCENTRATION
- LARGE ERROR IN THIS ESTIMATE - 1 IN 10 CHANCE OF THIS CHANGE BY 2005
- NO REGIONAL CLIMATE CHANGE ESTIMATES YET POSSIBLE
- LIKELY IMPACTS:

  1°C RISE (2005): BARELY NOTICEABLE

  2.5°C RISE (2038): MAJOR ECONOMIC CONSEQUENCES, STRONG REGIONAL DEPENDENCE

  5°C RISE (2067): GLOBALLY CATASTROPHIC EFFECTS

UNCERTAINTY IN ESTIMATES

1) CARBON CYCLE MODELING - MINOR

2) DEFORESTATION - MAJOR EFFECT ONLY IF RATE IS LARGE <u>AND</u> DEPLETION SETS IN

3) NATURAL CLIMATE VARIABILITY - SMALL, ABOUT 0.5° C IN 50 YEARS

4) OTHER ANTHROPOGENIC SOURCES - LESS THAN CO_2, BUT POTENTIALLY MAJOR IF CONSIDERED IN TOTO

5) EFFECT OF A ± 1% VARIATION IN FOSSIL FUEL GROWTH RATE RELATIVELY MINOR

6) CLIMATE MODELING ERROR VERY LARGE; ALLOWANCE IN POLICY ANALYSIS ESSENTIAL

POLICY IMPLICATIONS

- GLOBAL PROBLEM, BOTH IN SOURCE AND FOR REMEDIES
- TIME SCALE FOR SIGNIFICANT IMPACT, VERY ROUGHLY 50 YRS
- HIGH RISK, HIGH UNCERTAINTY SITUATION, RELATIVELY FAR AWAY
- TIME FOR ACTION ? MARKET PENETRATION TIME THEORY SAYS
  THERE IS <u>NO</u> LEEWAY

CONCLUSIONS

- AT A 3% PER ANNUM GROWTH RATE OF CO_2, A 2.5°C RISE BRINGS WORLD ECONOMIC GROWTH TO A HALT IN ABOUT 2025.

Even if this estimate is grossly wrong it is still probable that

- WHETHER THERE ARE GROUNDS FOR IMMEDIATE RESPONSE TO THE THREAT DEPENDS ON THE VALIDITY OF THE LONG MARKET PENETRATION TIME CONCEPT.
- EVEN IF THE LATTER IS APPLICABLE, PRESENT DAY SIGNIFICANCE OF THE IMPACT DEPENDS STRONGLY ON CHOICE OF A FUTURE DISCOUNTING FACTOR.
- NEED FOR IMMEDIATE POLICY ACTION HINGES ON THESE LAST TWO FEATURES.

EXHIBIT 7

GENERAL - 184-1-1B
INTER-OFFICE

DATE August 18, 1981

TO W. Glass	REFERENCE
FROM R. W. Cohen	SUBJECT

I have looked over the draft of the EED reply to the request from O'Loughlin. The only real problem I have is with the second clause of the last sentence in the first paragraph: "but changes of a magnitude well short of catastrophic..." I think that this statement may be too reassuring. Whereas I can agree with the statement that our best guess is that observable effects in the year 2030 are likely to be "well short of catastrophic", it is distinctly possible that the CPD scenario will later produce effects which will indeed be catastrophic (at least for a substantial fraction of the earth's population). This is because the global ecosystem in 2030 might still be in a transient, headed for much more significant effects after time lags perhaps of the order of decades. If this indeed turns out to be case, it is very likely that we will unambiguously recognize the threat by the year 2000 because of advances in climate modeling and the beginning of real experimental confirmation of the CO_2 effect. The effects of such a recognition on subsequent fossil fuel combustion are unpredictable, but one can say that predictions based only on our knowledge of availability and economics become hazardous.

I would feel more comfortable if the first paragraph concluded with a statement to the effect that future developments in global data gathering and analysis, along with advances in climate modeling, may provide strong evidence for a delayed CO_2 effect of a truly substantial magnitude, a possibility which increases the uncertainty surrounding the post-2000 CPD scenario.

ROGER W. COHEN

RWC:tmw

Attachment

cc: H. N. Weinberg
A. J. Callegari

ENERAL - 154-1-1B

TER-OFFICE CORRESPONDENCE

DATE 8/14/81

O See Below	REFERENCE
ROM W. Glass	SUBJECT

J. F. Black
R. W. Cohen
S. A. Diamond
H. Shaw

Morey O'Loughlin has asked Ed David for ER&E's views on the realism of CPD's projections for fossil fuel combustion out to 2030 (attached) in view of potential "greenhouse" and "acid rain" problems. I have been asked to draft a short reply.

A preliminary draft for EED's reply is attached. It is based not on any calculations but on my "understanding" of what I think I've heard you say and write in the past. I would appreciate your reviewing this preliminary draft very critically and letting me know promptly of any changes you would like to see. EED wants to get am answer back to MEJO'L by August 21.

Thank you for your cooperation.

WG:bl
Attachments

c: T. K. Kett

DRAFT
EED TO MEJO'L

You asked about our views on possible emission consequences of the CPD-projected fossil fuel consumption levels out to 2030. Much is still unknown about the sources and sinks for atmospheric CO_2, as well as about the climatic effect of increasing CO_2 levels in the air, so that prognostications remain highly speculative. The models that appear most credible (to us) do predict measurable changes in temperature, rainfall pattern, and sea-level by the year 2030 for the postulated fossil fuel combustion rates, but changes of a magnitude well short of catastrophic and probably below the magnitude that need trigger otherwise noneconomic responses to the problem of energy supply.

The fossil fuel contribution to the localized problem of acid rain appears handlable by limiting the release of SO_x, NO_x, and chlorides to the atmosphere--which would decrease but by no means eliminate the economic advantage of fossil fuels.

We would be happy to discuss this with you in greater detail.

WORLD ENERGY SUPPLY

(EXCLUDES CPE)

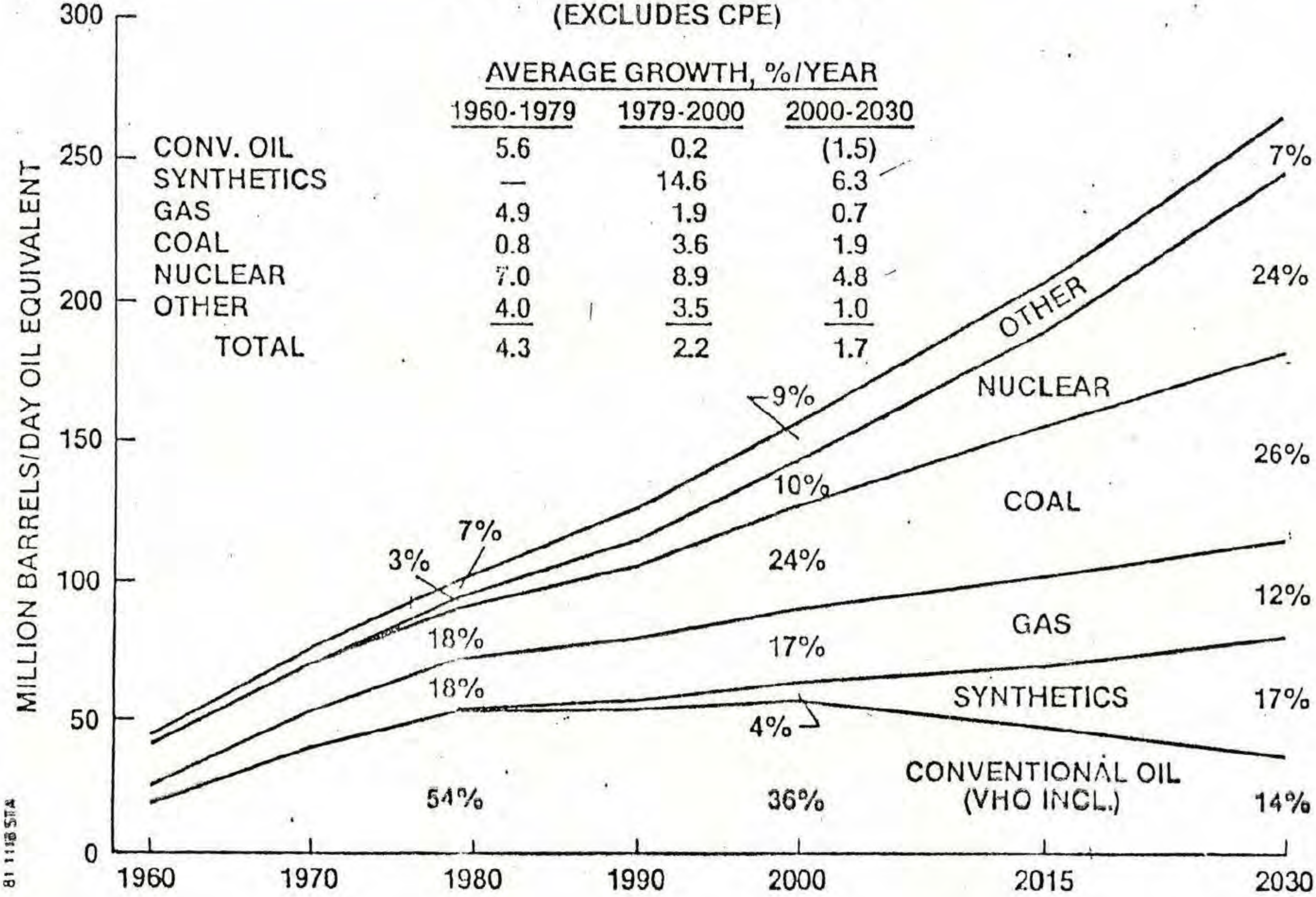

EXHIBIT 8

GENERAL - 154-1-1B

INTER-OFFICE CORRESPONDENCE

DATE May 15, 1981

TO: Dr. E. E. David, Jr.	REFERENCE
FROM: Henry Shaw	SUBJECT: CO_2 Position Statement

In case the issue comes up at the San Francisco Symposium, attached is a brief summary of our current position on the CO_2 Greenhouse effect.

HS:ksc
Attachment

c: R. E. Barnum
C. M. Eidt, Jr.
D. Fiske
L. E. Furlong
H. C. Hayworth
T. K. Kett
P. J. Lucchesi
F. B. Sprow
H. N. Weinberg
G. O. Wilhelm
M. Held

PRELIMINARY STATEMENT OF EXXON'S POSITION ON THE GROWTH OF ATMOSPHERIC CARBON DIOXIDE

Position:

There is sufficient time to study the problem before corrective action is required.

- An indication of the average global temperature increase due to CO_2 will not be measurable above normal climatic fluctuations (noise) until about 2000.
- Effective energy conservation and high price for fossil fuels over the last few years have now delayed the projected doubling time of CO_2. We estimate now that the doubling time is about 100 years.
- This permits time for an orderly transition to non-fossil fuel technologies should restrictions on fossil fuel use be deemed necessary.

Synthetics Impact:

There is no reason to stifle or halt development of synthetics industry.

- Impact of synthetics on doubling time is very small (4%/yr average synthetics growth rate reduces doubling time by only 5 years = 15 MB/D synthetics in 2010).
- Coal liquids contribute about 100% more CO_2 than burning coal directly; shale oil about 50% more.

Background:

- Average atmospheric CO_2 increased 7% since 1957 (315 to 338 ppm). We project CO_2 will reach about 380 ppm by 2000.
- Atmospheric CO_2 will double in 100 years if fossil fuels grow at 1.4%/a.
- 3^oC global average temperature rise and 10^oC at poles if CO_2 doubles.
  - Major shifts in rainfall/agriculture
  - Polar ice may melt
- U. S. Government conducting 10-year study at 10M$/a to reduce large scientific uncertainties and recommend appropriate energy policy.
- ER&E contributing to the research effort by monitoring atmospheric and oceanic CO_2 from a tanker.

EXHIBIT 9

Climate Models and CO_2 Warming
A Selective Review and Summary

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CLIMATE MODELS AND CO_2 WARMING

A Selective Review and Summary

Prepared for the American Petroleum Institute

by

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Contribution No. 3310

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CONTENTS

SUMMARY

This report is a selective summary and discussion of the types of models that have been applied to the prediction of the anthropogenic warming of the atmosphere. All of the quantitative predictions involve only the CO_2 effect although it is recognized that other trace gases may contribute from 50 to 100 percent additional warming. The types of models discussed are, from simple to complex: radiation balance, energy balance, radiative-convective, thermodynamic and general circulation models. The results given in the summary table below have been generated by the most physically complete versions of the models in each category. Additional results, discussed in the report, are omitted from this selection. It seems clear from the discussion herein that all models are still sufficiently unrealistic that a definitive evaluation of the problem requires continued effort.

Table 1.

Model Predictions of 2 × CO_2 Warming of Atmosphere

Model Type and Source	Mean Surface Effect	High-Latitude Effect
Radiation Balance		
Jason Group [2]	Globe: 3.0°C	
Energy Balance		
Jason Group [2]	Globe: 2.4°	7.5°C
Budyko [12]	Globe: 3.1°	9.0
Radiative-Convective		
Augustsson & Ramanathan [18]	Globe: 2°	
Hansen *et al.* [17]	Globe: 2.8°	
Hummel and Reck [39]	Globe: 2.1°	
Thermodynamic		
Adem (Preliminary)	Hem: 0.6°	2°
General Circulation Model		
Manabe & Stouffer [26]	Globe: 2°	7°
Hansen *et al.* [1]	Globe: 3.5°	7°

I. INTRODUCTION

In this report we summarize and discuss with some qualitative evaluation the types of models that have been applied to the prediction of the atmospheric warming consequent upon the increasing CO_2 content of the atmosphere. The examples selected in each of the climate model categories are those that have been developed to the highest state of the art in each category at this time. The report is organized so as to first explain the problem, including an explanation of what is meant by climate, followed by a qualitative summary of the types of models in order of increasing complexity. This is followed by a discussion of the key scientific problems involved, namely the quantitative evaluation of the increased "greenhouse effect". After this discussion a more detailed presentation of the appropriate climate models is given followed by an appraisal of each of the models and categories discussed.

Carbon dioxide is the most studied of the combustion gases since it plays an important role in the interaction between the sun's radiation and the atmosphere. The carbon dioxide concentration has increased steadily since the beginning of the industrial revolution from about 290 parts per million (ppm) to about 340 ppm today (1981). It is expected to double some time in the next century. Just when depends on the particular estimate of the level of increasing energy use per year and the mixture of carbon based fuels [1, 2]. None of these estimates includes the role of the oceans and the biosphere as sources or sinks of CO_2 since the mechanisms of their exchange with the atmosphere are too uncertain at this time. Climate modelers begin with the assumption that atmospheric CO_2 will double (with corresponding increases in other combustion gases) and try to predict what climate changes will occur.

They all predict some kind of increase in temperature within a global mean range of 4°C. The consensus is that high latitudes will be heated more than the equator and the land areas more than the oceans. Such a warming can have serious consequences for man's comfort and survival since patterns of aridity and rainfall can change, the height of the sea level can increase considerably and the world food supply can be affected. The detailed consequences of a CO_2 warming are not yet known. The conclusion is that optimum forecasting of climate changes is a necessity for any realistic long term planning by government and industry.

II. THE NATURE OF CLIMATE AND CLIMATE MODELS

An operational definition of 'climate' is that it is a time-mean state of the atmosphere [3]. Time means are averaged over a given period of time such as 30 days, a season, a year, etc. 'Climate changes' refer to changes of state of the atmosphere over intervals greater than the averaging time.

'Climate models' are mathematical descriptions of the earth-atmosphere system as it is driven by the radiation from the sun. The models range in complexity from a crude picture of the earth as a uniform rotating ball in radiation balance with the solar radiation to the complex general circulation models (GCM) that treat atmospheric dynamics by numerical solutions of fluid dynamical equations. Regardless of complexity, all climate model studies indicate that a doubling of CO_2 will produce a significant increase in the global and annual mean temperature of the earth. Climate model predictions range from 0.6°C to over 4°C, depending more on the physical assumptions than upon the complexity of the model. Several empirical studies [4, 5] give a lower estimate of about 0.26°C. There is sufficient uncertainty in the range of predictions to leave the consequences of the CO_2 doubling in considerable doubt. The difference between the low end of 0.26°C and the high end of ~4.°C has obvious consequences regarding the amount and speed of polar ice melting and the degree of sea level rise. Other uncertainties are the effect of the warming on: snow and sea-ice cover, the distributions of temperature, rainfall and aridity over the globe, the ocean circulation and oxygen budget, and the related world food supply [1, 6].

A summary of the models to be given further elaboration in Section III is given here for a quick overview of approaches to the CO_2 problem. These do not exhaust the different kinds of models used for climate studies but they are the principal tools, either singly or in combination, applied for predicting the outcome of a CO_2 doubling. (Schneider and Dickinson [3] give a thorough and readable survey of the many approaches to climate modeling that is still current.)

A. The Lowest Order: Radiation Balance Model

In this model the earth is treated as a uniformly rotating sphere with a homogeneous atmosphere in radiative equilibrium with the sun's energy flux. What this means is that the sun bathes the earth with radiation (that is primarily in the visible), that the earth absorbs some of that radiation and in the equilibrium state reradiates it back to space with a spectrum that is primarily in the infrared. All that is needed to compute the "effective radiation temperature" of the earth T_e is to give the known solar energy flux at the top of the atmosphere and that fraction of the solar flux absorbed by the earth-atmosphere system and radiated back as infrared radiation.

It turns out that the mean surface temperature of the earth T_s is about 30°K larger than T_e. This is accounted for by the "greenhouse gases" that absorb and trap thermal (infrared) energy in the atmosphere. Some atmospheric structure must be added to the originally simple picture to compute the absorption of the constituent gases and to maintain the mechanical stability of the lower troposphere. The model as amended is used to estimate a global warming due to the doubling of CO_2 when the remaining physics is unchanged.

B. Energy Balance Models (EBM)

These models add a latitude dependence by dealing with quantities such as surface temperature, heat capacity and albedo that are averaged over a complete latitude strip. One more term is needed to balance the energy equation in each strip. The new term represents horizontal heat transported out of the strip by fluid motions. In equilibrium, the energy balance for each strip would now read: (net transport out) + (infrared out) = (solar in). The transport term is usually parameterized as a diffusion operator (familiar from ordinary heat transfer theory).

Energy balance models have the added attraction that they can be used to estimate the latitude distribution of a CO_2 warming with its effects on the polar ice caps. As with the original radiation balance model, separate calculations with vertical structure in the atmosphere are required to give the infrared terms. The EBM diffusion equation itself, however, admits only a latitude dependence in the equilibrium case with the addition of a time dependence when seasonal and other time varying conditions are treated.

C. Radiative - Convective Models

Radiative-convective models are more complex versions of the radiation balance model described above. Physical parameters are treated as global averages with spatial variation only in the vertical direction. Mathematical computations are performed for convenience in a plane parallel configuration. The atmosphere is divided up into many uniform layers for numerical computation. For such models the principal equations to be solved are those of radiative transport with the convective part appearing as adjustments to the temperature structure to prevent the lower troposphere from becoming mechanically unstable. These models are applied principally to numerical experimentation in which atmospheric parameters can be varied one at a time to estimate the sensitivity of the atmosphere to change. These include experiments with radiative models of clouds, changes in distribution of particulate matter with height, the effects of CO_2 and other combustion gases, solar constant, volcanic dust, aerosols and atmospheric chemistry. Occasionally experiments are performed in which the physical parameters of a particular latitude strip are taken as the global mean values in order to get a sense of the changes in vertical structure to be expected at different latitudes and in particular to estimate how the structure varies under perturbation.

Much of the mathematical details of the radiative transport calculations of these models can, with some modification, be used in tandem with those models that treat horizontal transport since the radiative part is calculated separately to give heating rates.

D. The Thermodynamic (Adem) Model

The thermodynamic model of Adem is an operating climate model developed on the basis of the assumption that for periods of a month or longer climate can best be described by determining the mean thermal state of the atmosphere. The model uses two basic equations, one for the conservation of thermal energy for the atmospheric layer and one for the conservation of thermal energy for the ocean layer. The two layers are coupled in the full model. In each equation there is a two dimensional horizontal eddy diffusion term (the two dimensional version of the one dimensional transport term in the energy balance equation of section II.B). In addition to the eddy diffusion terms there is a term that parameterizes the transport by the mean winds in the atmospheric equation and a term that parameterizes transport by horizontal currents in the ocean equation. Continents and oceans have appropriate values of the albedo - the fraction of solar energy reflected to space - as functions of position on the globe. The chief effect of the continents is a varying albedo due to changing snow and ice cover. Although an initial input variable, albedo-feedback permits computation of changes in snow cover extent.

At present the model computes thermal and solar radiative absorption for each grid point as a function of time with a computed cloud cover. As with all global models the amount of atmospheric structure required for transport by diffusion and advection need not be the same as for the radiative terms, since the time scale for radiative equilibrium is so much smaller.

E. General Circulation Models (GCM)

General circulation models differ from the previously described models in that they treat horizontal momentum directly. That is, they use the analogue of Newton's second law relating the change in momentum to the applied forces. The atmosphere is broken up into several layers and in each layer there are equations for the energy and the horizontal components of the wind velocity. As with the previous models the radiative transport equations must be solved in order to get the radiative heating or cooling at each layer and at each grid point. In order to follow the horizontal velocity components the GCM requires much shorter time steps than is necessary for the other models. The GCM also differs from the prior models in starting with an initial condition and then integrating forward in time from basic principles. It uses more explicit dynamics and less parameterizations then other types of models.

Compared with GCMs, the thermodynamic model differs significantly in method, purpose and simplicity. The GCM attempts to predict climate from first principles while Adem's model generates climate anomalies based on the use of the stored data fields. These data fields represent analog solutions that contain implicitly whatever scales of motion contribute to climate. The model is limited by the quality and extent of the data fields and related parameterizations. In predicting perturbations from normal climate by the subtraction of computed normal from actual fields, the model avoids common biases or errors that may be introduced by computational schemes and common parameterizations.

III. THE 'GREENHOUSE-EFFECT'

A. Explanation of the Effect

The sun supplies the energy that drives the motions of the atmosphere and oceans. Solar radiation enters the top of the atmosphere with a characteristic spectrum that is mostly in the visible. A fraction of this radiation, called the planetary albedo, is reflected to space. The remainder is absorbed and transformed as it interacts with the earth and reaches equilibrium. The transformed radiation has a characteristic spectrum that is mostly in the infrared. It is referred to variously as long-wave or thermal radiation. The spectra of both incoming solar and outgoing thermal radiation are defined by the equilibrium black body emission function (the Planck formula). This is a strictly thermodynamic relation because radiation and matter come to equilibrium on time scales much shorter than those of the macroscopic motions.

The Planck formula depends on the absolute temperature of the emitting surface and wavelength. The solar radiation, shown in Fig. 1, has the spectrum of an emitting surface with a mean temperature of 6000°K. For contrast the spectrum corresponding to the present mean temperature of the earth of about 288°K appears on the right. Both curves have been normalized relative to their respective maxima so they appear to have the same height. The actual intensity of the solar curve is about four million times that of the thermal curve. Thermal radiation, for temperatures characteristic of the earth and its atmosphere, is predominantly in the range 4 to 40 μm.

As will be seen in Section IV.A where we elaborate on the lowest order radiation balance model, if we assume that the planetary albedo of the earth is 0.30, then the remaining fraction, 0.70, of the solar radiation will be

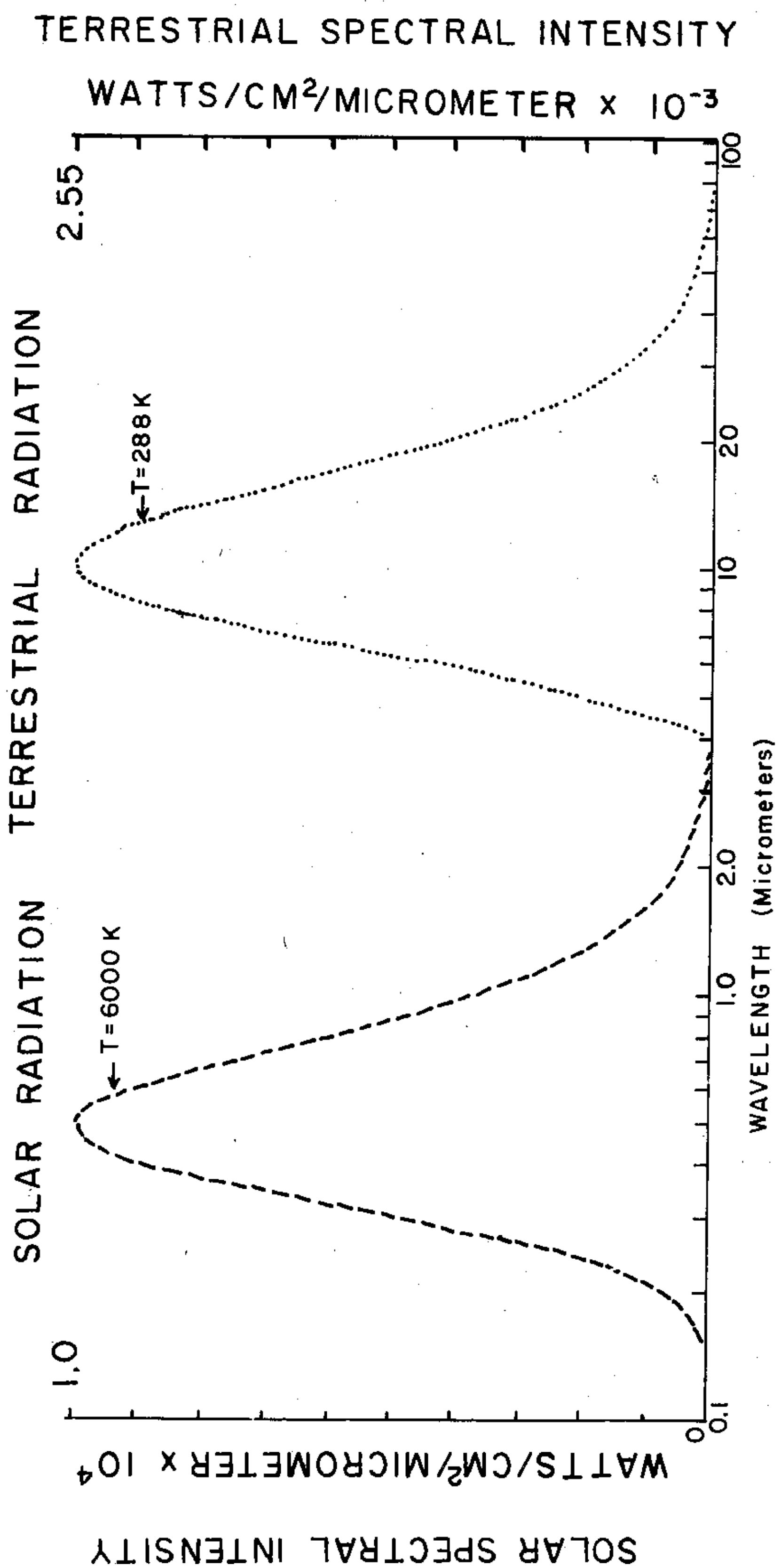

Figure 1. Comparison of solar spectral intensity (left-side scale) with terrestrial spectral intensity (right-side scale).

absorbed and transformed into thermal radiation with a mean temperature of T_e=255°K (or -18°C). T_e is called the effective radiation temperature of the earth. Just as the sun appears to be radiating at the relatively cool effective temperature of its outer layers (6000°K) there appears to be an effective radiating temperature for the earth from its relatively cooler upper troposphere (255°K). The surface temperature of the earth is 288°K. The reason that the surface temperature is warmer is due in part to the presence of the so called greenhouse gases that absorb strongly within the 4 to 40 μm thermal spectrum. Absorbing gases very quickly reradiate the energy they get from the surface of the earth, but in the atmosphere a gas radiates both upward and downward, while the surface merely radiates upward. The spectrum of the equilibrium radiation in the atmosphere will be determined by the actual temperature of the air. It is the mediating effect of the atmospheric absorbers and the fact that they radiate downward as well as upward that provides an additional bath of heat for the surface. This heating is called the "greenhouse effect" simply because the role of the absorbing gases resembles what was once thought to be the role of the glass of the greenhouse in trapping infrared radiation.

A key scientific problem to be solved is the evaluation of the increased greenhouse effect resulting from an increase in combustion gases in the atmosphere.

B. The Greenhouse Gases

The expected role of the greenhouse gases can be illustrated with use of Fig. 2. The figure shows part of the envelope of the thermal emission curve for T = 288°K from 4 to 20 μm. Estimates of the absorption curves of H_2O, CO_2

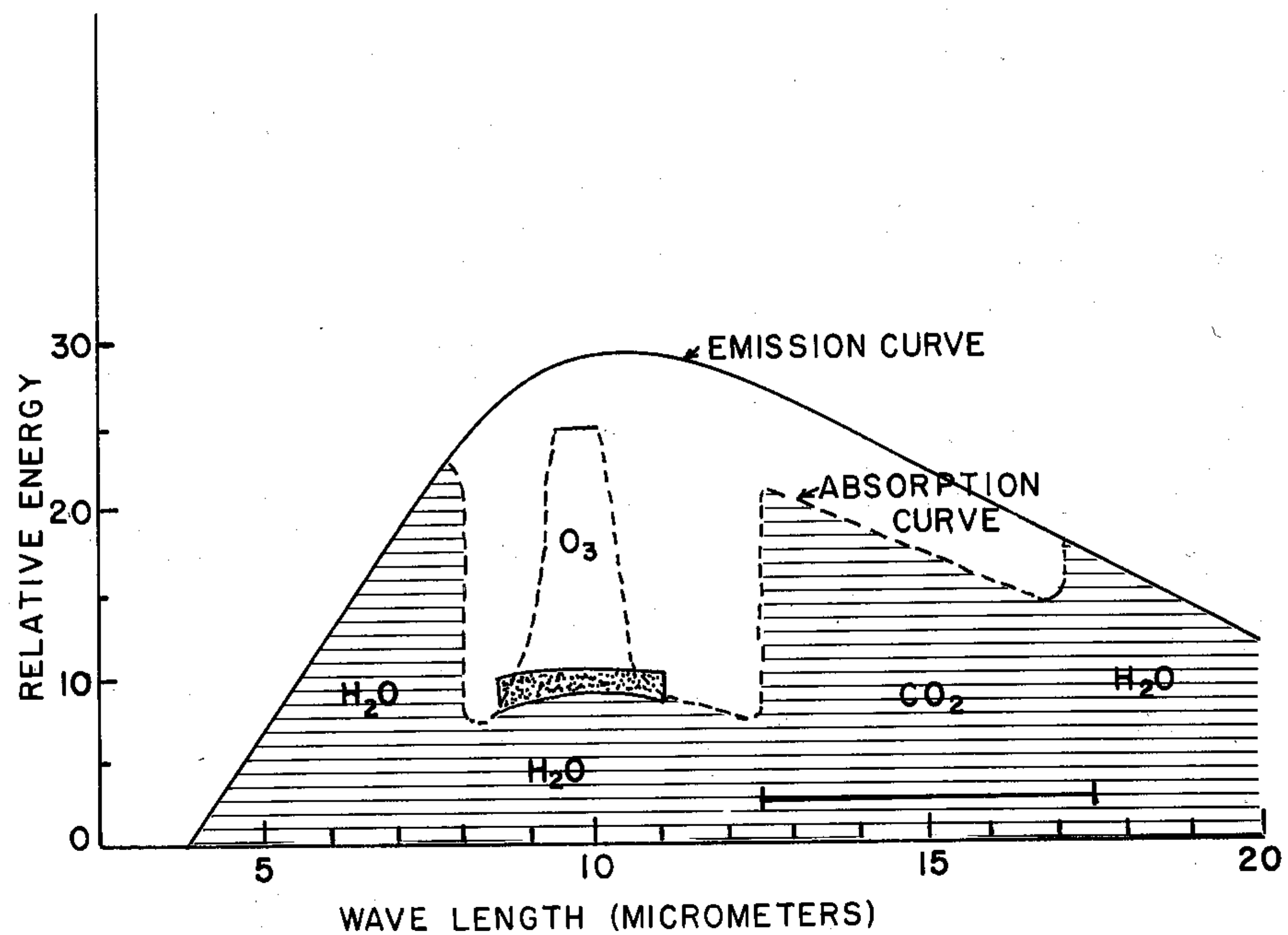

Figure 2. The spectral distribution of emitted and absorbed radiation in the atmosphere. The region of strong absorption by water vapor and CO_2 is horizontally lined. The main CO_2 absorption band is shown by the bracket centered on 15 micrometers. Weak CO_2 absorption is shown by the stippled region.

and O_3, which are sketched from computations based on data in Kondratyev [7] correspond well with a similar figure in Ref. [2]. The horizontally striped region indicates roughly: the main absorption regions of water vapor between 4 μm and 8 μm and above 17 μm; and of CO_2 between 12.5 μm and 17 μm. The principal infrared window to space is between 8 μm and 12 μm. Within the window are an ozone (O_3) absorption band and a relatively unimportant (for present climate) set of CO_2 bands (stippled). If CO_2 were to increase in the atmosphere the principal effect would be a filling in of the presently weak absorption band in the window to space as well as a filling in to the left of the strong absorption band that begins at 12.5 μm. If the CO_2 is more absorbing, it will reradiate more both upward and downward. If all of the other physics remains the same, the effect of this increased downward radiation would be to further increase the temperature of the surface. If the water vapor content were to increase there would be a similar filling in of the window region with more absorbing gases. The other greenhouse gases with absorption bands within the window include NO_x, methane (CH_4), ammonia (NH_3), the halomethanes (freons), carbon monoxide (CO) and hydrocarbons. Moreover, increased emission of NO_x and CO can increase CH_4 and O_3 in the troposphere [8, 9] via chemical reactions that compete with reactions that would otherwise remove them.

Most attention has been directed to the roles of H_2O and CO_2 principally because the data base on them is far more extensive and because the steady increase of CO_2 has been well established while the future increase seems a rational projection.

According to the Jason group [2] the freons have absorbing bands in the middle of the atmospheric window so that if they were to increase by a factor of about one hundred they could contribute strongly to the greenhouse effect.

N_2O, CH_4 and NH_3 appear to be marginally important at present. These gases would fill in the window from the left as CO_2 does from the right if they were to increase. Most recently Lacis et al. [9] calculated that the warming from the increase in trace gases, CH_4, N_2O and chlorofluorocarbons during 1970-1980 amounts to 50% to 100% of that due to CO_2 in the same period. Apparently then, all increases in greenhouse gases plus aerosols should be considered in the total anthropogenic effect.

IV. DESCRIPTION OF THE MODELS

A. Radiation Balance Model

The description and results given here for this most primitive of models follows the standard derivations and results of others, eg Chamberlain [10].

Picture the earth as a uniformly rotating ball with a homogeneous atmosphere in radiative balance with the mean solar heat flux at the top of the atmosphere of S_0 = 1367 watts/meter^2. Moreover, suppose that in equilibrium the earth radiates as a black body at the effective temperature T_e. The sun's radiative flux is plane parallel with a certain fraction, the albedo α, being reflected into space. The amount πR^2 $(1 - \alpha)$ S_0 is absorbed; πR^2 is the effective area for plane parallel rays striking a spherical earth with radius R. The absorbed energy is reradiated according to the radiation balance equation:

$$\frac{dQ}{dt} = -\epsilon A \sigma (T^4 - T_1^4)$$

$$(4\pi R^2)\ \sigma T_e^4 = (\pi R^2)\ (1 - \alpha) S_0, \qquad (1)$$

where the Stefan-Boltzmann constant $\sigma = 0.56687 \times 10^{-7}$ watts/m^2/°K^4. For the value $\alpha = 0.3$, the effective radiation temperature of the earth T_e = 254.4°K.

A simple relation between surface temperature, T_s and T_e can be derived from the following conditions: the thermal radiation is in local thermodynamic equilibrium with the atmospheric gases; the absorption coefficient is independent of frequency (the grey gas approximation); the atmosphere can be treated in a plane parallel geometry; and the thermal radiation flux goes either vertically up or vertically down. From this it is simple to derive [10] the relation

$$T_s^4 = T_e^4\ (1 + 0.75\ \tau_g), \qquad (2)$$

where τ_g is the effective optical depth of the atmosphere - a non dimensional measure of the opacity or absorbing capacity of the atmosphere. So far the theory does not give a value for τ_g.

From Eqs. (1) and (2) we get

$$\frac{\sigma T_s^4}{A_s} = \sigma T_e^4 = \frac{(1 - \alpha) S_0}{4} \qquad (3)$$

where $A_s = 1 + 0.75\ \tau_g$.

If, as is the present practice, one assumes that α remains constant if CO_2 is doubled, then T_e remains unchanged. However, τ_g is a measure of absorbing material in the infrared so that τ_g must increase with the CO_2 increase and with it, A_s. The ratio T_s^4/A_s must remain constant by assumption so that T_s^4 will increase just enough to compensate for the increase in A_s.

A more sophisticated calculation is required to get τ_g. The Jason group [2], in a calculation that summed up the contributions of the absorption coefficients of the major atmospheric constituents found a mean τ_g of 0.748 for the present CO_2 and 0.828 for double CO_2. Substitution of these values gives

$$T_s \text{ (present } CO_2) = 284.9°K$$

and

$$T_s \text{ (double } CO_2) = 287.6°K.$$

The actual values of T_s are not important but any change in T_s <u>is</u> important. The warming is $\Delta T_s = +2.7°C$. In a more complete calculation involving nine absorption bands, the Jason group [2] obtained a 3°C change. The result for a model like this can be only suggestive.

The model producing these results gives the wrong temperature lapse rate for the lower troposphere. The lapse rate is the rate at which temperature falls with altitude. For the case of purely radiative equilibrium, the lapse rate in the lower troposphere will be steep enough for the upper air to be colder and denser than the lower air. Because this is mechanically unstable (a convective instability) the upper air will tend to sink and mix with lower air until the lapse rate reaches a stable value, that is; equal to or less than the adiabatic curves shown in Fig. 3. Because a solution with a stable lapse rate is required for a meaningful result it is necessary to modify the procedure. The simple procedure followed is the replacement of the lower portion of the initially-derived lapse rate curve with one of the adiabatic curves, i.e. the dashed curve of Number 3. The use of such an atmospheric structure would supply enough thermal radiation from the lower troposphere to maintain the radiative profile above the point of intersection C [10]. This

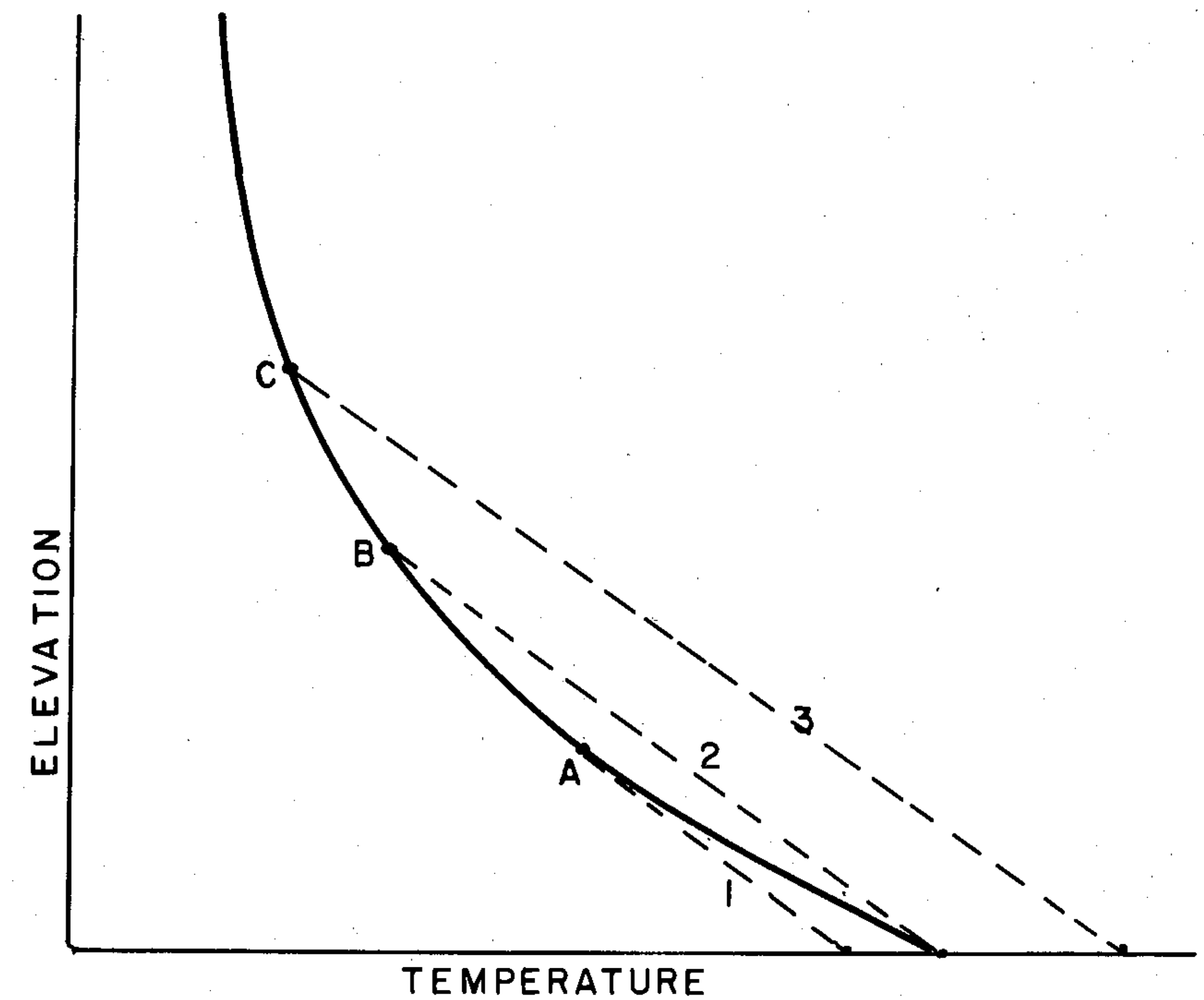

Figure 3. The vertical temperature lapse rate curve resulting from radiation balance solutions (solid curve). Dry adiabatic (constant) lapse rate curves are shown by broken lines 1,2 and 3. Below A the lapse rate curve is unstable. Adiabatic curve 3 is substituted for the lower portion of the lapse rate curve below the point of intersection at C to achieve convective stability and the maintenance of the radiation profile above C.

converts the radiation balance model into the crudest of the radiative-convective models (to be given more attention in Section C).

B. Energy Balance Models

Energy balance models are the next in complexity. They add a latitude dependence and therefore the capacity to treat snow-ice feedback. Moreover, they are capable of analytical solutions limited to highly idealized situations. For these models [11] the globe is divided into latitude strips or zones over which a balance equation states that the solar heat energy flux entering each latitude belt is exactly balanced by the loss rate. In the steady state, the equation for latitude belt i is

$$(\text{net transport out})_i + (\text{infrared out})_i = (\text{solar energy in})_i. \quad (4)$$

Each term would be in units of energy/second/area after the common area of the latitude belt has been divided out. Recall that Eq. (3), the corresponding equation for the radiation balance model has the form

$$(\text{infrared out}) = (\text{solar energy in}).$$

The extra term in (4) represents horizontal transport of heat carried by fluid motions. The properties for each latitude belt are average quantities. The only spatial variable is the quantity $x = \sin\theta$ where θ is the latitude.

In (3) the quantity $\sigma T_s{}^4/(1 + 0.75\tau_g)$ represents the total infrared radiation back to space. One could use such a formula for each strip. However, it is more convenient to convert $T_s = T_s(x)$ to Celsius degrees by $T_s(x) = 273 + T(x)$ where $T(x)$ is in °C and replace the infrared radiation term on the left side of Eq. (3) with the linear version on the left hand side of (5):

$$A(x) + B(x)T(x) = S_0(x)[1 - \alpha(x)]/4 \quad (5)$$

where A and B, in the linearization, absorb the constants of $\sigma T^4/A_s$ but are given experimentally derived values below. $S_0(x)$ is the average value of the solar flux and $\alpha(x)$ the average albedo at altitude x. The variable x is convenient for this work because the differential dx is proportional to the area of the latitude circle. If (5) is multiplied by dx and integrated over latitude the result would be equivalent to (3). Present cloud cover, variation of water vapor content over the globe and the presence of greenhouse gases are accounted for in (5) by writing

$$\begin{aligned} A(x) &= a(x)/(1 + 0.75\tau_g) \\ B(x) &= b(x)/(1 + 0.75\tau_g) \end{aligned} \quad (6)$$

where A(x) and B(x) are deduced from measurements. The Jason group [2] computes τ_g by using the U.S. Standard Atmosphere for 1976 and allowing the assumed structure to radiate to space. They break the thermal region into nine frequency bands, compute the flux for each band separately and then sum them for the total. Thus τ_g accounts for the presence of the greenhouse gases. Then a(x) and b(x) account for variations in cloud cover and water vapor via the measured quantities A(x) and B(x) in (6).

If one assumes that a(x) and b(x) do not change up to a doubling of CO_2 then a computation of τ_g for the case of CO_2 doubled (all other quantities remaining the same) will give a new set of A(x) and B(x) through Eqs. (6).

This approach is not based on solving the equations of radiative transfer hence, again, an estimate for the greenhouse effect rather than a precise number results.

The energy balance equations deal only with the energy content in the total column of atmosphere above the complete latitude strip. These are represented by an average heat capacity multiplied by the surface temperature T(x). Since there are no horizontal velocities in this picture we have to parameterize "net transport out" in terms of T(x) and its derivatives. The parameterization uses the form of molecular diffusion but here the diffusion term has to account for turbulent and eddy transport of heat. For energy balance models the parameterization takes the form of Eq. (7) (or alternate but similar forms)

$$[\text{net transport out}] = -\frac{d}{dx}\left[D(1-x^2)\frac{d}{dx}T(x)\right], \qquad (7)$$

where D, the diffusion coefficient, is at our disposal. It can be a global constant or vary with x or be prescribed in any way that tunes solutions to present climate. At present, whatever method is taken for fixing D, it is kept the same for estimates of doubled CO_2.

In steady state, the full equation has the form

$$-\frac{d}{dx}\left[D(1-x^2)\frac{dT(x)}{dx}\right] + A(x) + B(x)\cdot T(x) = S_0(x)\left[\frac{1-\alpha(x)}{4}\right] \qquad (8)$$

In (8) the surface albedo can be prescribed or it can be written $\alpha(x) = \alpha[x,T(x)]$ in order to account for variations in the ice line if one perturbs the climate. The Jason group [2] uses this parameterization in slightly different notation

$$[1-\alpha(x)] = Z(x)\cdot\begin{cases}0.7 \text{ if } T(x) > -10^\circ C\\ 0.4 \text{ if } T(x) < -10^\circ C\end{cases} \qquad (9)$$

where Z(x) is a correction for variation of zenith angle with x.

Eq. (8) and its time varying counterpart are useful for numerical experimentation. In their most realistic experiment the Jason group finds that by doubling CO_2 an increase of 2.4°C resulted when water vapor increased (constant relative humidity) from the effect of temperature feedback and sea ice was allowed to shrink to zero. High latitudes increased by 7.5°C. The corresponding results from the original Budyko version of this type of model [12] was 3.1°C for the global change and 9°C at high latitudes.

C. Radiative-Convective Models

Manabe and his collaborators [13, 14, 15] developed these models as a prelude to the incorporation of radiative transfer into general circulation models. All of the physical parameters in these models are taken as global averages and all of the computations are in one spatial dimension with variation only in the vertical (z-axis) measured upward from the surface. The equations of radiative transfer can be considered as bookkeeping relations that keep track of the change in radiation intensity I(f) (in watts/meter^2/unit solid angle/unit frequency interval about the frequency f) in some distance dz. They have the form: the change in intensity in distance dz = - the amount absorbed - the amount scattered out of the beam + the amount scattered into the beam + the amount emitted by matter into the beam. In principle the equations are first solved for each narrow frequency interval df with boundary conditions specified at the top and bottom of the atmosphere: at the top the net upward flux of thermal radiation must equal the net downward flux of solar radiation; at the surface the net upward thermal flux equals the net downward solar flux. To reduce the computational burden [14, 16] the solar and long wave fluxes are given different emphasis. That is, the solar radiation may be absorbed, scattered or reflected but emission is neglected, while the long wavelength thermal radiation may be absorbed or may be emitted but scattering is neglected. Molecular absorption is a process in which the molecules absorb radiation and go into excited energy states; they then reradiate energy in all directions. Quantum mechanics locates the energy levels and thermodynamics shows how the absorption coefficient is broadened by pressure and temperature variations. Further simplifications involve breaking the frequency spectrum into representative bands and computing mean absorption coefficients over each band. This reduces considerably the number of intervals for which the radiative transfer equations need solution.

In radiative-convective models the atmosphere is divided into uniform layers for numerical solution of the radiative transfer equations. Carbon dioxide is treated as uniformly mixed but water vapor and ozone are given vertical distributions appropriate to present mean climate. Clouds strongly influence both solar and thermal fluxes. The distribution of clouds as high, medium and low is generally prescribed according to present climate statistics. Hansen et al. [17], for example, take climatological cloud cover to be 50% with distributions in the fraction: 0.1 for high, 0.1 for medium and 0.3 for low clouds. (Low clouds cool the surface while high clouds warm it.)

Wavelength dependences of cloud and aerosol properties are included in some of the later R-C models [17].

The essential point is that the radiative transport equations are treated with considerable detail in R-C models. At any level they give the net heating or cooling after summing over all frequencies.

In Section IV A we saw that the atmosphere is unstable under purely radiative balance for the very simple model described. To avoid this problem in R-C models another set of conditions is required for stability. There must be some mechanism to transport heat upward from the surface (a convective adjustment) so that a stable temperature lapse rate will exist. One of the several alternative methods for performing these adjustments is via the time-stepping procedure of Refs. [14, 17]. (In this and the more complex models that follow, artificial time steps can be used to go from an initial state to the desired equilibrium state without changing the external conditions or solar forcing.) One begins with a standard atmosphere having a given composition and temperature structure subject to the given incoming solar flux and suitable boundary conditions at the surface. Then the equations of radiative transfer are solved to compute the radiative heating terms at each atmospheric level. Given these, the density of the air, the width of the level, and a suitable time step Δt one can compute ΔT_i the temperature adjustment within the i^{th} level. If the lapse rate exceeds 6.5°C/km -- a standard normal for mid-latitudes used in most R-C models -- the atmosphere is unstable and enough heat (or equivalently a convective adjustment to ΔT) must be added to ensure that the lapse rate will be 6.5°C/km or less. With the new temperature structure the radiative transport equations are solved again subject to the same boundary conditions to get new heating rates. The procedure is iterated until the atmosphere is in radiative and convective balance.

Hansen et al. [17] performed different experiments for doubled CO_2 -- the differences are with cloud parameterization, relative humidity, snow and ice and vegetation albedo feedback. With relative humidity and cloud temperatures fixed at present values and with the 6.5°C/km limiting lapse rate they find that the mean surface warming is $\Delta T_s = 2.8$°C with an uncertainty of a factor of 2. In contrast, Augustsson and Ramanathan [18] give $\Delta T_s = 2$°C for a different cloud parameterization. The quoted numbers are those preferred by the authors of [17] and [18] out of sets of runs with a variety of parameterizations. However, similar assumptions lead to similar results (see table 1 of Ref. [17] and table 2 of Ref. [18] -- a clear indication of the sensitivity of the results to assumptions about the cloud physics.

Hummel and Reck [39] improved on previous radiative-convective models by adding water vapor transport to their version of the early Manabe-Wetherald model thus permitting calculation of cloud location and thickness. Prior models used a constant relative humidity profile and cloud distribution. For a doubled CO_2 content and a standard cloud cover input their modification gives an increase of surface temperature of 2.05° compared with 1.71° for the Manabe-Wetherald model. This difference is due to a larger, more realistic water content.

References [14, 16, 17] give a balanced and clear picture of the techniques of radiative-convective modeling.

D. The Thermodynamic (Adem) Model

The basic assumption of this model is that for periods of a month or longer the mean state of the atmosphere depends primarily on the thermodynamics of the atmosphere and seems to be but weakly dependent on the dynamical

$\frac{dQ}{dt} = -hA(T-T_0)$

motions -- those governed by the fluid dynamics version of Newton's laws. The model follows the time evolution of the thermodynamic state of an atmospheric layer about 10 km high that includes a cloud layer, an ocean layer of 50 to 100 meters in depth and a continental layer of negligible depth and heat storage. It also includes a layer of snow and ice over the continents and oceans. The basic prognostic equations used in this system are those of conservation of thermal energy applied to variables that are time averaged over a prescribed interval. It is assumed that the equations of hydrostatic equilibrium, the perfect gas law, and the continuity equation are valid for the time averaged variables.

The thermal energy equations for atmosphere and oceans are integrated over their respective vertical heights -- about 10 km in the atmosphere and 50 to 100 m in the oceans. The resulting equations follow the mean energy of the atmosphere chosen proportional to the absolute temperature T_m at an altitude equal to one half of the mean height of the atmosphere, and the mean energy of the oceans chosen proportional to their surface temperature T_s.

Three basic equations are used to describe the atmosphere, oceans and continents respectively. For the atmosphere and oceans, the equations (which have the same form and are coupled in a full solution) have terms on the left side for local rate of change of thermal energy, heat transport by eddy diffusion, heat transport by mean winds (currents) and vertical heat transport (below the ocean mixed layer). These are balanced on the right side by the heat sources and sinks: radiation, latent heat and sensible heat. For the continents, which have insignificant storage depth and mobility, the left side terms are zero and only the balance among the heat sources and sinks is considered.

Albedo feedback for snow and ice is obtained by adjusting the snow-ice margin to a selected isotherm (currently 0°C) by iterative solutions until convergence is obtained. All of the terms of the atmosphere-earth radiation balance are also computed internally in the model solutions. Changes in cloud amount are computed as a function of latent heat changes.

Solutions of the linearized differential equations are carried out at 512 grid points over the hemisphere. Output is in the form of hemispheric maps for surface (land and water) and mid-tropospheric temperatures. In addition, all of the diagnostic terms involved are also printed out in separate charts. These include evaporation at the surface, latent heat of condensation in the atmosphere, computed meridional and zonal winds and associated heat transports, absorbed surface radiation, long wave and net radiation and cloud cover.

The model has been applied with success to the calculation of absolute and anomalous values of all of the above terms. It has also been applied with good results to the computation of known long-range climate changes during geologic time.

Although this model was developed primarily for prediction of current climate, it can be modified to be applied to predict the anthropogenic changes in climate for increased combustion gases.

The current model has been used to get a provisional prediction of a doubled CO_2 effect by using published values of the changes that would occur in black-body emission. A mean increase of 0.6°C is predicted in the experiment with a high-latitude change of 2° and a low to mid-latitude change of about 0.5°. These values may be revised when the model is optimized for the experiment.

The mathematical version of the model is given below.

In the present form of the model the equations for T_m (the mid-tropospheric temperature) and T_s (the surface temperature) both have the general form

$$\frac{\partial T}{\partial t} + \vec{V}\cdot\nabla T - K\nabla^2 T = \text{heat sources and sinks} \qquad (11)$$

The first term is proportional to the local time rate of change of the energy. The second term represents the transport of heat by mean motions: for the atmosphere $\vec{V}$ is determined by thermodynamic relations -- the geostrophic wind relations -- and for the oceans is determined from the surface wind speeds [19]. The third term represents horizontal diffusion of heat by eddy and turbulent motions. The right hand sides, the heat sources and sinks (HSS) are:

$$\text{HSS for the atmosphere} = E_t + G_5 + G_2, \qquad (12)$$

and

$$\text{HSS for the oceans} = E_s - G_3 - G_2. \qquad (13)$$

In addition, with neglect of heat storage in the continents the third equation reads:

$$0 = E_s - G_3 - G_2 \qquad (14)$$

for the continental surfaces.

In (12) E_t is the heat energy added to the atmosphere by radiation, G_5 is the heat added by condensation of water vapor in the clouds and G_2 is the heat added by vertical turbulent transport from the surface - a parameterization of the convective transport that is dealt with by the convective adjustments in radiative-convective models. In (13) and (14) E_s is the rate at which energy is added to the surface by radiation, and G_3 is the rate at which heat is lost by evaporation.

The parameterization of E_t and E_s is based on assumptions that the cloud layers and the earth radiate as black bodies and that the clear sky atmosphere has a window for wavelengths between 8 μm and 13 μm. They are given in terms of T_s, T_m, the insolation I at the given latitude, the cloud cover, the total radiation received at the surface (for E_s) under clear sky conditions and the surface albedo α. Over the oceans the quantities G_2 and G_3 are parameterized in terms of measured normals, departures of $(T_s - T_m)$ from their normal values and normal surface wind speeds. Over the land G_2 has the same parameterization while G_3 simply depends on empirical normals, and a known function of map coordinates. Similarly, the heat gained by condensation of water vapor in the clouds G_5 is given in terms of its normal seasonal values G_{5N} and $(T_m - T_{mN})$ and its first order derivatives with respect to map coordinates. (The subscript N indicates normal values.)

The cloud cover E is a variable given by:

$$\varepsilon = \varepsilon_N + D_2 (G_5 - G_{5N}) \qquad (15)$$

where ε_N is the normal cloud cover and D_2 is a constant. Details of the parameterizations are given in Refs. [20, 21, 22, 23].

E. General Circulation Models (GCM)

The design of general circulation models begins with the basic equations governing large scale atmospheric motions and follows by transforming them into some kind of finite differences scheme suitable for solution on digital computers. In this process, the original equations and boundary conditions (or the finite differences scheme itself) would be altered to remove the physical mechanisms responsible for wave motions that would otherwise be generated by errors in initial data. These waves would be spuriously amplified by computational rather than actual physical instabilities and ultimately swamp the motions under study [24].

The first of the basic equations is the equation of conservation of mass. It states that if you follow an individual parcel of gas in time the total mass of the parcel remains constant. This becomes:

The fractional change in density of the parcel with time = the negative of the fractional rate of change of its volume with time... (16)

(Thus a fractional increase in volume of 1% would be accompanied by a fractional decrease in density of 1%.)

The next equation describes the evolution of the internal energy per unit mass e of the parcel in time. In terms of the absolute temperature T and C_v the specific heat at constant volume:

$$e = C_v T \qquad (17)$$

The energy equation (the First Law of Thermodynamics) reads:

The time rate of change of internal energy + the rate of working by the fluid system = the rate at which heat is added to the system. (18)

Equation (8) of the energy balance models is derived as an approximation to Eq. (18). For Adem's model, Eqs. (16) and (18) together with a parameterization of the mean motion reduce to equations (11) and (12) for the atmosphere and (11) and (13) for the oceans.

The new equations for GCM are the fluid dynamical versions of Newton's Second Law F = ma. In cartesian coordinates, for the horizontal west to east coordinate x and velocity u and the south to north coordinate y and velocity v the equations read:

$$\rho \left(\frac{du}{dt} - f\ v\right) = - \frac{\partial p}{\partial x}, \qquad (19)$$

and

$$\rho \left(\frac{dv}{dt} + f\ u\right) = - \frac{\partial p}{\partial y}, \qquad (20)$$

where the symbol $\frac{d}{dt}$ stands for the time rate of change as we follow the given parcel of fluid, p is the pressure, $\frac{\partial p}{\partial x}$ and $\frac{\partial p}{\partial y}$ are components of the pressure gradient (the force terms), ρ is the density of the parcel, f the Coriolis parameter is equal to $2\Omega \sin\phi$ where Ω is the angular rotation of the earth (2π radians/day) and ϕ is the latitude. Eqs. (19) and (20) when multiplied by the volume of the parcel are in the form of Newton's Law

$$ma = F \qquad (21)$$

in a rotating frame.

Vertical accelerations (which would be perturbations on the fundamental hydrostatic pressure balance equation of the atmopshere) are important on smaller space scales than the motions followed in meteorology and must be parameterized in order to include an adequate treatment of convective heat transport from the surface to the atmosphere.

Adem's model uses a thermodynamic parameterization of (19) and (20) by setting the d/dt terms equal to zero and computing u and v from

$$u = - (\rho f)^{-1}\ \partial p/\partial y,\ v = (\rho f)^{-1}\ \partial p/\partial x. \qquad (22)$$

These are the geostrophic winds and are used wherever advection terms are used. For large scale motions of the kind used in climate studies this is a reasonable approximation since the geostrophic wind approximates the true horizontal velocity to within about 15% in midlatitudes.

For GCM the full set of equations must be transformed into some version of a finite differences scheme suitable for solution by a digital computer. Typical horizontal grid spacings might range from a $4° \times 5°$ net to an $8° \times 10°$ net. For the vertical structure, 2, 7, 9 or more levels are used. With each choice of net there are wavelengths of motions smaller than the grid spacings that cannot be resolved. Because these subgrid motions are important transport mechanisms for energy and momentum their effects must be parameterized in terms of the grid scale variables and their derivatives.

At present the GCM use oceans without surface currents as sources and sinks of heat. In addition to the convection of moisture and sensible heat (described above for the thermodynamic model) the GCM must also provide for convection of momentum.

In a survey of this size it is difficult to describe in detail the computational complexities of the major models or the various schemes for parameterization of physical processes that can not be treated directly or simply. It is relevant to note that all of these are active areas of present research and that year by year models undergo modification to accomodate changes in knowledge. Reference [1] contains a summary of predictions of the outcome of CO_2 warmings from two of the principal GCM modeling groups: the group led by Hansen at the Goddard Institute for Space Studies in New York and the group led by Manabe at the Geophysical Fluid Dynamics Laboratory at Princeton, N.J. The global mean warming for the most complete of the two sets of models is 2°C for Manabe et al. and 3.5°C for Hansen et al., quoted in [1]. As might be expected different parameterizations and different feedback mechanisms produce different results within the above range.

In the latest published GCM experiment, Gates et al. [27] used a two layer atmospheric model which included an ocean constrained with prescribed climatological temperature and obtained a global surface air temperature warming of only 0.2°C and a surface warming of only 0.1°C. This low result is primarily a function of the use of a prescribed sea surface temperature.

The magnitudes of the warmings by GCM, as with all models are higher at high latitudes. The maximum value, according to Ref. [1], is between 4°C and 8°C in polar and adjacent regions for the annual mean surface ΔT. All models also indicate increased warming in summer and over land, but the magnitudes differ.

V. ASSESSMENT OF THE MODELS

A. Common Assumptions

In climate modeling certain physical processes must be parameterized in order to make computations tractable on current generation computers. This includes eddy diffusion of heat and momentum, convective transport of heat, moisture and momentum, and the radiative properties of the atmosphere. In many of these parameterizations a particular constant (the parameter) is given a value that tunes the final result to present climate. This is a perfectly respectable procedure and enables one to perform experiments involving small changes in solar constant or some physical input with a reasonable expectation that the constants will remain valid for the altered climate state.

Common practice involves the assumption that present parameterizations will be valid for a doubling of CO_2. Some of these parameterizations have a very strong influence on the outcome of the doubling. One such assumption is that the mean planetary albedo α and consequently T_e, the effective radiation temperature of the earth, remain unchanged. An example of this in the simplest case is seen with equation (3):

$$\sigma T_s{}^4/A_s = \sigma T_e{}^4 = (1 - \alpha)S_0/4, \qquad (3)$$

where $A_s = 1 + 0.75\ \tau_g$. It is clear that depending on whether α goes up or down T_e can be colder or warmer.

Another assumption is that the present mean distribution of relative humidity remains fixed for a CO_2 doubling. Since a CO_2 warming will increase the water vapor content of the atmosphere, if relative humidity remains constant, the greenhouse effect of water vapor in the atmospheric window will result in a strong positive feedback. Thus, the Jason group model [2] predicts an additional warming of about 50% of the bare $2 \times CO_2$ warming. However, in the complex feedback mechanism, increased CO_2 leads to increased temperature with a consequent increase in evaporation and increased moisture content of the atmosphere. Although this effect leads to a further warming, the probable increase in cloud cover would increase albedo and offset the warming effect [38]. The true effects of all of these sensitive relationships are not yet known.

Wherever the models agree on these two assumptions it is likely that the predicted global warmings will be close simply because the final results are very sensitive to the planetary albedo and the relative humidity. The assumptions serve as constraints and as modeling efforts evolve these constraints will be relaxed.

B. Energy Balance Models

Energy balance models are extremely tractable for both analytical and numerical treatment [11, 2]. With them one can follow the lowest order effects of climate change on the ice line and the latitudinal distribution of a warming. The ice line separates the region of snow and ice where the albedo is high from the region of bare earth where it is low. In these models, the ice line can be made a function of surface temperature and will shift latitudinally with the surface temperature.

The principal difficulties with this class of models are:

i. they define all physical variables over a complete latitude strip so that there is no proper separation of oceans and continents;

ii. they have absolutely no advection parameterization -- an important transport mechanism for mid-latitudes;

iii. they have no hydrological cycle and

iv. any interaction between oceans and air would be too crude to offer any reliable time estimates for a warming.

In summary, the models are extremely useful for preliminary experiments since they are fast and simple but they can give no definitive answer about a climate warming.

C. Radiative-Convective Models

Radiative-convective models are one dimensional representations of the earth's atmosphere with variation possible only in the vertical and in time. They were designed originally as precursors for the incorporation of radiative transfer into GCM but have served for a considerable amount of interesting experimentation.

The principal weakness of these models are:

1. they treat a mean earth;
2. they have no horizontal heat transport and
3. the convective adjustments are very crude mechanisms introduced to maintain mechanical stability of the lower troposphere.

Treatments with horizontal transport and realistic oceans and continents could modify any conclusions drawn from radiative-convective models. Nonetheless, these models can be powerful tools for exploring radiative properties of the atmosphere especially parameterizations of cloud cover and dynamics and the effect of industrial pollutants. The fact of a predicted change will be important rather than the magnitude. For accurate magnitudes the radiative computation package must be appended to models with two dimensional horizontal variation and a realistic geography.

Reck and collaborators have studied the effects of a wide range of industrial pollutants on climate with a version of the Manabe-Wetherald radiative-convective model. These include the effect of aerosols on climate [28, 29, 30] and the effects of the freons on atmospheric surface temperature [31]. These and related numerical experiments and others on CO_2 warmings [16, 32] are suggestive rather than definitive at this time.

D. The Thermodynamic (Adem) Model

The thermodynamic model of Adem is the only operating climate model that gives reasonable forecasts of current temperature anomalies. It has also been used on a quasi-operational basis to predict monthly climate with very good performance and has been successful in simulating past climates related to ice ages and different continental locations [33, 34]. Since early in 1980 it has been generating monthly forecasts with good skill for the northern Hemisphere [35, 36]. Other strong points of the model are:

i. it is fast -- a one month forecast takes about 1 minute on an IBM 360/95;

ii. it is the only existing model with a realistic mean ocean having wind driven currents parameterized in a useful way and

iii. it generates cloud cover, the radiation balance, snow-ice feedback and sea surface temperatures internally.

The weak point of the model is that many of its parameterizations, while adequate for present climate predictions, require adjustment for optimum application of the model to the CO_2 warming problem. As with all models, parameterization of physical processes require better and more fundamental understanding of the role of cloud physics, the distribution of moisture in the atmosphere, and the way subgrid scale motions contribute to time mean motions followed by the equations of motion. Further work is necessary on this model to optimize it for application to the CO_2 problem.

E. General Circulation Models

Despite the fact that General Circulation Models include simultaneously details of those processes that control climate, they may not be, at least at this time, the appropriate vehicles for predicting long term climate change for the following reasons (paraphrased from Refs. [2] and [3]:

i. the computing time for current GCM could take from a half of a year to a full year to calculate a century of climate for a single combination of initial conditions or prescribed external parameters;

ii. in order to be useful for climate studies it may require calculation of statistics from an ensemble of numerical integrations and

iii. it is difficult to track down cause and effect relationships with the many degrees of freedom involved in GCM.

No GCM (as of this writing) can predict present climate or give even a two-week forecast. There is a phenomenon of "intrinsic stochasticity" referred to in Ref. [2] which refers to a kind of internal chaotic motion (not driven by external noise) that occurs even in simple dynamical systems that are deterministic. For certain values of the constants in the equation these systems become extremely sensitive to initial conditions so that closely neighboring initial physical states can evolve into quite different final states. Since GCM have so many constants and adjustable parameters the authors of Ref. [2] expect a good amount of such chaotic behavior.

In addition to these difficulties, it is much more difficult to assess the effects of any input assumptions, including errors, on results of the complex GCM than it is for simpler models. Example of effects already detected in which large changes occur are evident in the change from a swamp ocean (no heat storage) to a mixed-layer (heat storage) ocean in the GCM models of Manabe and Wetherald [37] and Manabe and Stouffer [26]. The warming of 3° in the former case falls to 2° in the latter. And in the case of Gates et al. [27] who used effectively an ocean of infinite heat storage a warming of only 0.1° resulted. These are gross effects. Changes due to the many more subtle aspects are much more difficult to trace.

Both Ref. [2] and [3] suggest that simpler models would be more tractable and useful for probing long term variations in climate.

F. Future Directions

Most models prescribe the data for the radiation balance at the top of the atmosphere. Involved with this is the tuning to present conditions of cloud cover, relative humidity and planetary albedo. These terms have a profound influence on the warming due to a change in combustion gas input. It is essential that these terms evolve in some parameterized way, with changing climate. In this connection we note that Ohring and Clapp [38] deduced from observations that the net albedo cooling effect of clouds is slightly greater than the greenhouse warming effect.

In addition to the problems connected with the meteorological parameters, a basic problem appears to exist in the computation of heating rates. This computation requires the solution of the equations of radiative transfer, a process which currently uses in part, analytical expressions devised prior to the advent of present high-speed computers. The magnitude of potential errors in the above procedure should be evaluated and computational strategies devised to determine transmission in sufficiently small frequency bands over the spectrum of interest.

In addition to the above fundamental areas, necessary improvement must still be carried out for many of the parameterizations of both atmospheric and ocean terms.

Despite all of the uncertainties in the classes of models described, their very errors serve to give outside limits of global warming of 0.1°C to 3.5°C from a doubling of CO_2. Effects of trace gases, referred to earlier, might lead to a near doubling of these numbers.

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November 12, 1982

CO_2 "Greenhouse" Effect

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SUMMARY

Atmospheric monitoring programs show the level of carbon dioxide in the atmosphere has increased about 8% over the last twenty-five years and now stands at about 340 ppm. This observed increase is believed to be the continuation of a trend which began in the middle of the last century with the start of the Industrial Revolution. Fossil fuel combustion and the clearing of virgin forests (deforestation) are believed to be the primary anthropogenic contributors although the relative contribution of each is uncertain.

The carbon dioxide content of the atmosphere is of concern since it can affect global climate. Carbon dioxide and other trace gases contained in the atmosphere such as water vapor, ozone, methane, carbon monoxide, oxides of nitrogen, etc. absorb part of the infrared rays reradiated by the earth. This increase in absorbed energy warms the atmosphere inducing warming at the earth's surface. This phenomenon is referred to as the "greenhouse effect".

Predictions of the climatological impact of a carbon dioxide induced "greenhouse effect" draw upon various mathematical models to gauge the temperature increase. The scientific community generally discusses the impact in terms of doubling of the current carbon dioxide content in order to get beyond the noise level of the data. We estimate doubling could occur around the year 2090 based upon fossil fuel requirements projected in Exxon's long range energy outlook. The question of which predictions and which models best simulate a carbon dioxide induced climate change is still being debated by the scientific community. Our best estimate is that doubling of the current concentration could increase average global temperature by about 1.3° to 3.1°C. The increase would not be uniform over the earth's surface with the polar caps likely to see temperature increases on the order of 10°C and the equator little, if any, increase.

Considerable uncertainty also surrounds the possible impact on society of such a warming trend, should it occur. At the low end of the predicted temperature range there could be some impact on agricultural growth and rainfall patterns which could be beneficial in some regions and detrimental in others. At the high end, some scientists suggest there could be considerable adverse impact including the flooding of some coastal land masses as a result of a rise in sea level due to melting of the Antarctic ice sheet. Such an effect would not take place until centuries after a 3°C global average temperature increase actually occurred.

There is currently no unambiguous scientific evidence that the earth is warming. If the earth is on a warming trend, we're not likely to detect it before 1995. This is about the earliest projection of when the temperature

might rise the 0.5° needed to get beyond the range of normal temperature fluctuations. On the other hand, if climate modeling uncertainties have exaggerated the temperature rise, it is possible that a carbon dioxide induced "greenhouse effect" may not be detected until 2020 at the earliest.

The "greenhouse effect" is not likely to cause substantial climatic changes until the average global temperature rises at least 1°C above today's levels. This could occur in the second to third quarter of the next century. However, there is concern among some scientific groups that once the effects are measurable, they might not be reversible and little could be done to correct the situation in the short term. Therefore, a number of environmental groups are calling for action now to prevent an undesirable future situation from developing.

Mitigation of the "greenhouse effect" would require major reductions in fossil fuel combustion. Shifting between fossil fuels is not a feasible alternative because of limited long-term supply availability for certain fuels although oil does produce about 18% less carbon dioxide per Btu of heat released than coal, and gas about 32% less than oil. The energy outlook suggests synthetic fuels will have a negligible impact at least through the mid 21st century contributing less than 10% of the total carbon dioxide released from fossil fuel combustion by the year 2050. This low level includes the expected contribution from carbonate decomposition which occurs during shale oil recovery and assumes essentially no efficiency improvements in synthetic fuels processes above those currently achievable.

Overall, the current outlook suggests potentially serious climate problems are not likely to occur until the late 21st century or perhaps beyond at projected energy demand rates. This should provide time to resolve uncertainties regarding the overall carbon cycle and the contribution of fossil fuel combustion as well as the role of the oceans as a reservoir for both heat and carbon dioxide. It should also allow time to better define the effect of carbon dioxide and other infrared absorbing gases on surface climate. Making significant changes in energy consumption patterns now to deal with this potential problem amid all the scientific uncertainties would be premature in view of the severe impact such moves could have on the world's economies and societies.

PROPRIETARY INFORMATION

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CO_2 GREENHOUSE EFFECT

A TECHNICAL REVIEW

PREPARED BY THE

COORDINATION AND PLANNING DIVISION

EXXON RESEARCH AND ENGINEERING COMPANY

APRIL 1, 1982

EC-11-5/A2

CO_2 GREENHOUSE EFFECT

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CO_2 GREENHOUSE EFFECT

Background

The buildup of CO_2 in the atmosphere has been monitored continuously at the National Oceanic and Atmospheric Administration's (NOAA) Observatory at Mauna Loa, Hawaii, and periodically in other places since 1957. In addition to observing a trend between 1957-1979 that showed atmospheric CO_2 increasing from 315 to 337 ppm, Keeling and others also observed a seasonal variability ranging from 6 to 10 ppm between a low at the end of the summer growing season (due to photosynthesis) and a high at the end of winter (due to fossil fuel burning for heat, and biomass decay). There is little doubt that these observations indicate a growth of atmospheric CO_2 (see Figure 1). It is also believed that the growth of atmospheric CO_2 has been occurring since the middle of the past century, i.e., coincident with the start of the Industrial Revolution. There is, however, great uncertainty as to whether the atmospheric CO_2 concentration prior to the Industrial Revolution (ca., 1850) was 290-300 ppm which one would arrive at by assuming atmospheric CO_2 growth is due to fossil fuel burning and cement manufacturing, or 260-270 ppm based on carbon isotope measurements in tree rings. The information on CO_2 concentration prior to 1850 is important because it would help establish the validity of climatic predictions with respect to the inception of a CO_2 induced "greenhouse effect".

The "greenhouse effect" refers to the absorbtion by CO_2 and other trace gases contained in the atmosphere (such as water vapor, ozone, carbon monoxide, oxides of nitrogen, freons, and methane) of part of the infrared radiation which is reradiated by the earth. An increase in absorbed energy via this route would warm the earth's surface causing changes in climate affecting atmospheric and ocean temperatures, rainfall patterns, soil moisture, and over centuries potentially melting the polar ice caps.

Sources and Disposition of Atmospheric Carbon Dioxide - The Carbon Cycle

The relative contributions of biomass oxidation (mainly due to deforestation) and fossil fuel combustion to the observed atmospheric CO_2 increase are not known. There are fairly good indications that the annual growth of atmospheric CO_2 is on the order of 2.5 to 3.0 Gt/a* of carbon and the net quantity of carbon absorbed by the ocean is similarly 2.5 to 3 Gt/a. Thus, these two sinks (atmosphere and ocean) can account for the total fossil carbon burned (including 0.3 GtC/a** from cement manufacturing) which is on the order of 5-6 Gt/a and does not allow much room for a net contribution of biomass

* Gt/a = gigatons per annum = 10^9 metric tons per year.
** GtC/a = gigatons carbon per annum = 10^9 metric tons of carbon per year.

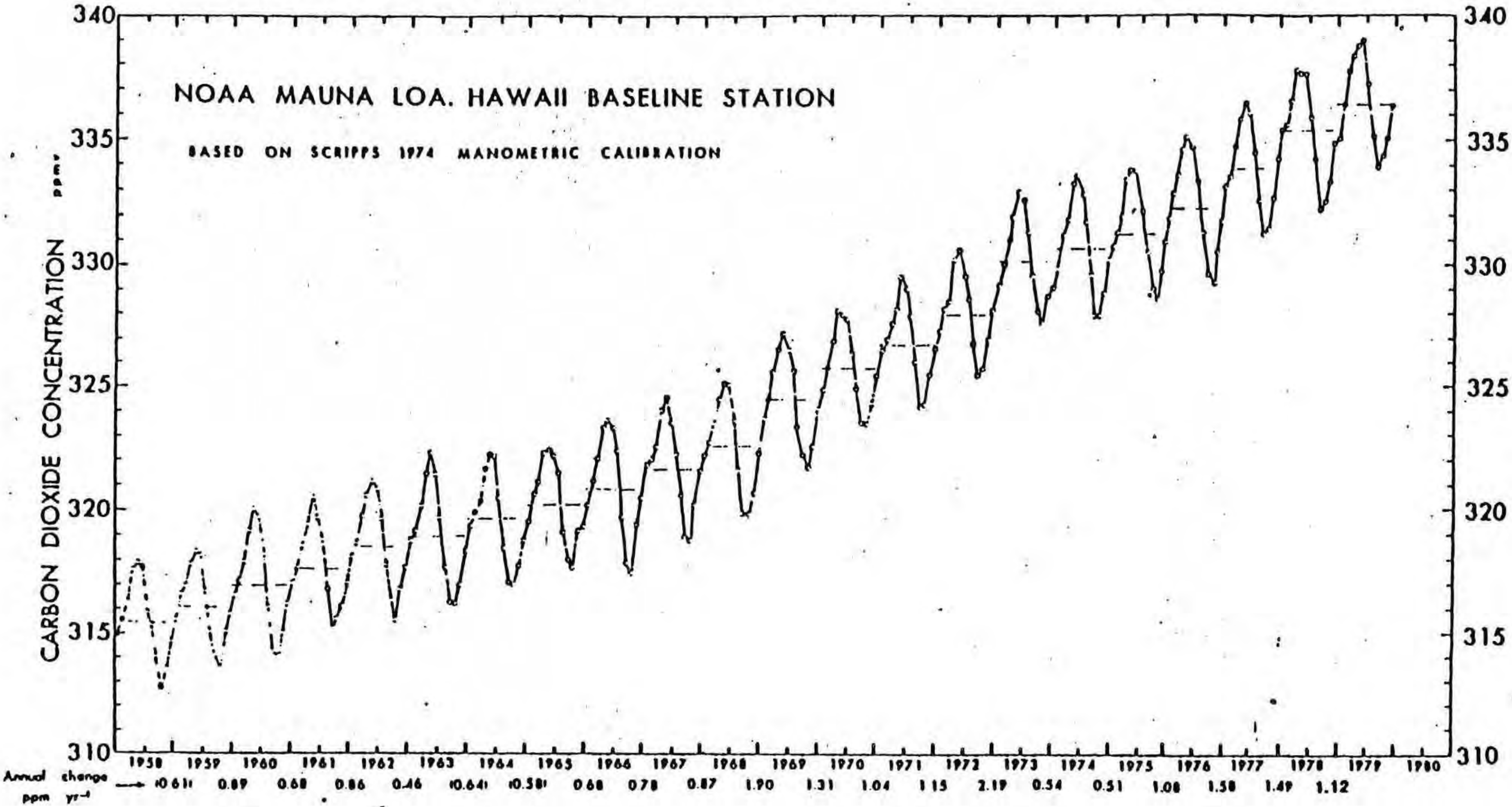


Figure 1 Modern record of atmospheric CO_2 concentrations. Mean monthly concentration measurements at Mauna Loa, Hawaii. Annual changes in parentheses are based on incomplete records; the solid dots are interpolated values (source: NOAA).

carbon. Yet, highly respected scientists such as Woodwell, Bolin and others have postulated a net biomass contribution to atmospheric CO_2 that ranges from 1 to perhaps 8 Gt/a of carbon. During 1980, a number of different groups produced new estimates of the contribution of organic terrestial fluxes to atmospheric CO_2. A consensus has not been reached, but estimates of the net annual terrestial biosphere emissions to the atmosphere now range between a 4 GtC/a source and a 2 GtC/a sink. Figure 2 summarizes the fluxes and reservoirs for the carbon cycle. It should be noted that the net biosphere contribution was assumed to be 0-2 GtC/a.

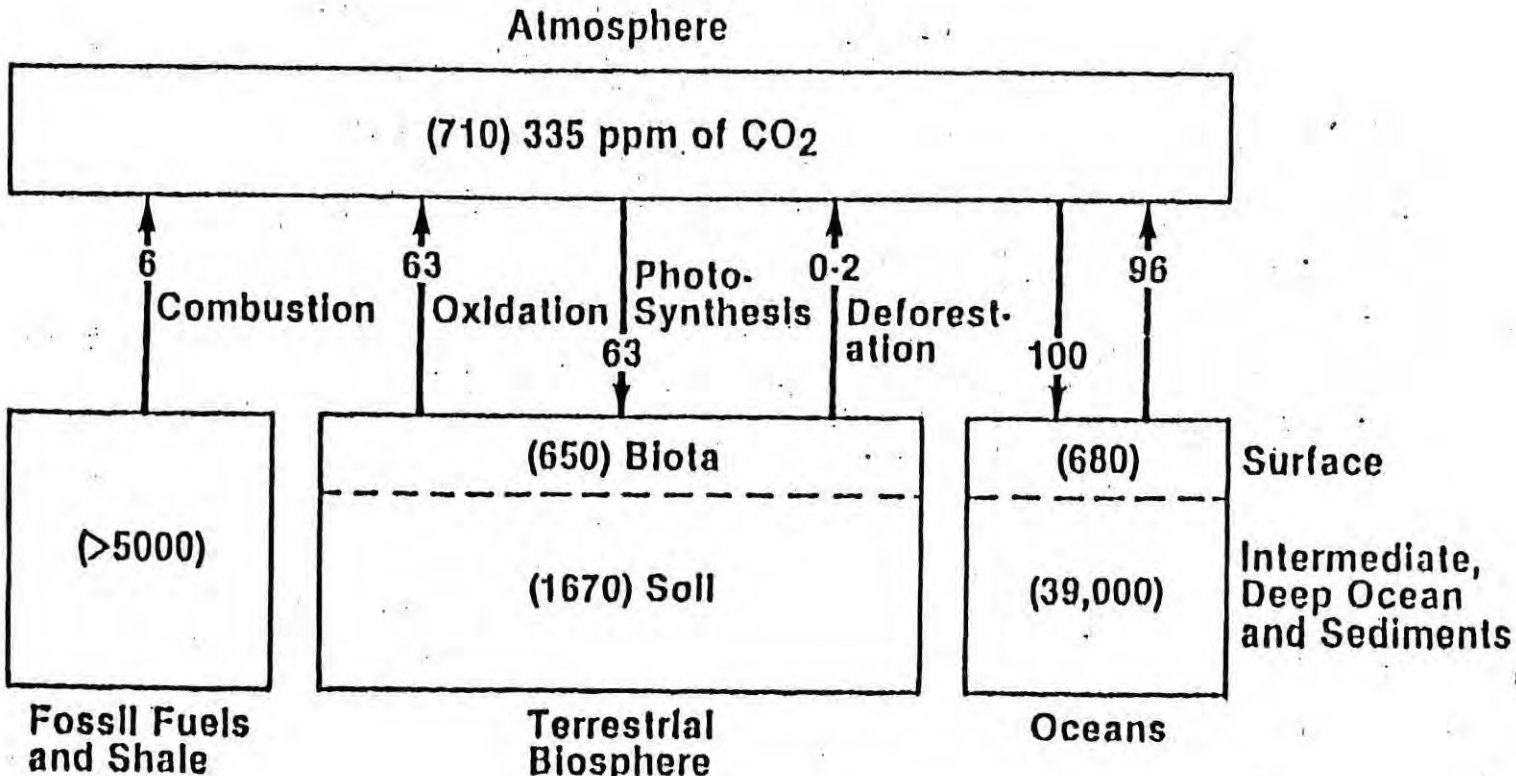
The rate of forest clearing has been estimated at 0.5% to 1.5% per year of the existing area. Forests occupy about 50 x $10^6 km^2$ out of about 150 x $10^6 km^2$ of continental land, and store about 650 Gt of carbon. One can easily see that if 0.5% of the world's forests are cleared per year, this could contribute about 3.0 Gt/a of carbon to the atmosphere. Even if reforestation were contributing significantly to balancing the CO_2 from deforestation, the total carbon stored in new trees tends to be only a small fraction of the net carbon emitted. It should be noted, however, that the rate of forest clearing and reforestation are not known accurately at this time. If deforestation is indeed contributing to atmospheric CO_2, then another sink for carbon must be found, and the impact of fossil fuel must be considered in the context of such a sink.

The magnitude of the carbon fluxes shown in Figure 2 between the atmosphere and the terrestial biosphere, and the atmosphere and the oceans are not precisely known. The flow of carbon between these reservoir pairs is generally assumed to have been in equilibrium prior to the Industrial Revolution. However, the errors in the estimated magnitude of these major fluxes are probably larger than the magnitude of the estimated man-made carbon fluxes, i.e., fossil fuels and deforestation. The man-made fluxes are assumed to be the only ones that have disturbed the equilibrium that is believed to have existed before the Industrial Revolution, and they can be estimated independently of the major fluxes. The man-made carbon fluxes are balanced in Figure 2 between the known growth rate of atmospheric carbon and the oceans. The carbon flux to the atmosphere is 6Gt/a from fossil fuels and cement manufacturing (cement manufacturing contributes about 4% of non-biosphere anthropogenic carbon) and 2Gt/a from deforestation, while 4Gt/a return to the ocean, resulting in a 50% carbon retention rate in the atmosphere. One cannot rule out, in view of the inherent uncertainty of the major fluxes, that the biosphere may be a net sink and the oceans may absorb much less of the man-made CO_2.

Projections of scientists active in the area indicate that the contribution of deforestation, which may have been substantial in the past, will diminish in comparison to the expected rate of fossil fuel combustion in the future. A few years ago a number of scientists hypothesized that a doubling of the amount of carbon dioxide in the atmosphere could occur as early as 2035. This hypothesis is generally not acceptable anymore because of the global curtailment of fossil fuel usage. Calculations recently completed at Exxon Research

FIGURE 2

Exchangeable Carbon Reservoirs and Fluxes



( ) = Size of Carbon Reservoirs in Billions of Metric Tons of Carbon

Fluxes (arrows) = Exchange of Carbon Between Reservoirs in Billions of Metric Tons of Carbon per Year and Engineering Company using the energy projections from the Corporate Planning Department's 21st Century Study*, indicate that a doubling of the 1979 atmospheric CO_2 concentration could occur at about 2090. If synthetic fuels are not developed and fossil fuel needs are met by new gas and petroleum discoveries, then the atmospheric CO_2 doubling time would be delayed by about 5 years to the late 2090's. Figure 3 summarizes the projected growth of atmospheric CO_2 concentration based on the Exxon 21st Century Study-High Growth scenario, as well as an estimate of the average global temperature increase which might then occur above the current temperature. It is now clear that the doubling time will occur much later in the future than previously postulated because of the decreasing rate of fossil fuel usage due to lower demand.

Description of Potential Impact on Weather, Climate, and Land Availability

The most widely accepted calculations carried on thus far on the potential impact on climate of doubling the carbon dioxide content of the atmosphere use general circulation models (GCM). These models indicate that an increase in global average temperature of $3^{\circ} \pm 1.5^{\circ}C$ is most likely. Such changes in temperature are expected to occur with uneven geographic distribution with greater warming occurring at the higher latitudes, i.e., the polar regions. This is due to increased absorption of solar radiation energy on the darker polar surfaces that would become exposed when ice and snow cover melt due to increasing temperature (see Figure 4). There have been other calculations using radiative convective models and energy balance models which project average temperature increases on the order of $0.75^{\circ}C$ for a doubling of CO_2. These calculations are compared in Figure 5. Figure 6 summarizes possible temperature increases due to various changes in atmospheric CO_2 concentration.

If the atmospheric CO_2 content had been 295 ppm prior to the Industrial Revolution, and an average global temperature increase above climate noise is detectable at the present time, this would add credibility to the general circulation models. However, if the CO_2 concentration and been 265 ppm prior to the Industrial Revolution, then detecting a temperature effect of $0.5^{\circ}C$ now would imply that the temperature for a doubling of CO_2 would be $1.9^{\circ}C$. The projected temperatures for both alternatives fall within the $3^{\circ} \pm 1.5^{\circ}C$ range. Temperature projections for alternate scenarios will be discussed later.

Climate modeling was studied by a committee of the National Research Council, chaired by Jules G. Charney of MIT, and the conclusions are summarized in

* The "21st Century Study" referred to here and in other places in this report has been superseded by a new energy study called the "2030 Study". The new study projects energy demands that are lower than the earlier figures, but not sufficiently different to change any of the conclusions of this report.

Figure 3

GROWTH OF ATMOSPHERIC CO_2 AND AVERAGE GLOBAL TEMPERATURE INCREASE AS A FUNCTION OF TIME

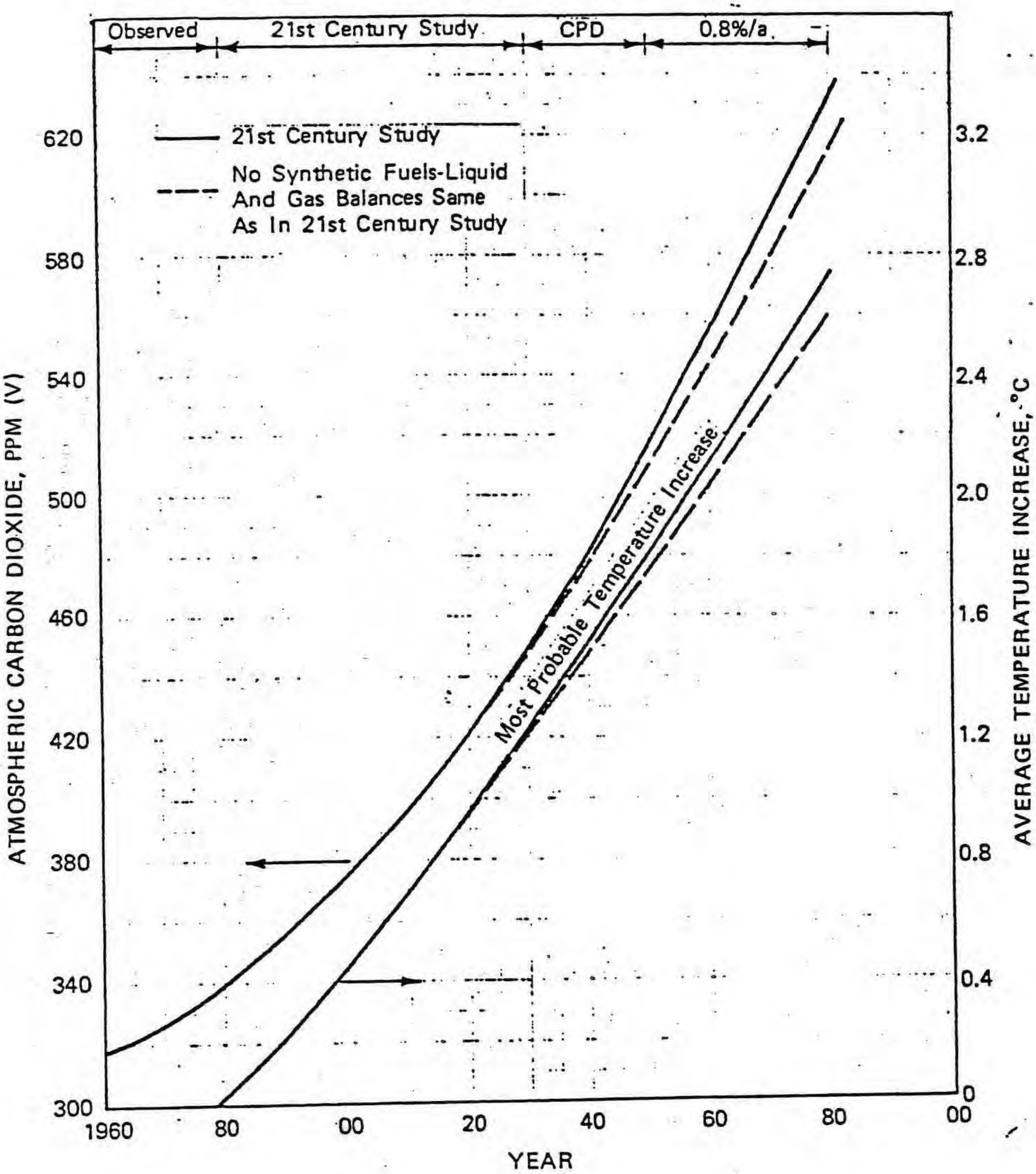


Figure 4

Temperature Change (^oC) Due to Doubling CO_2 Concentrations

Basis: Computed by the U.S. National Oceanic and Atmospheric Administration using their general circulation model.

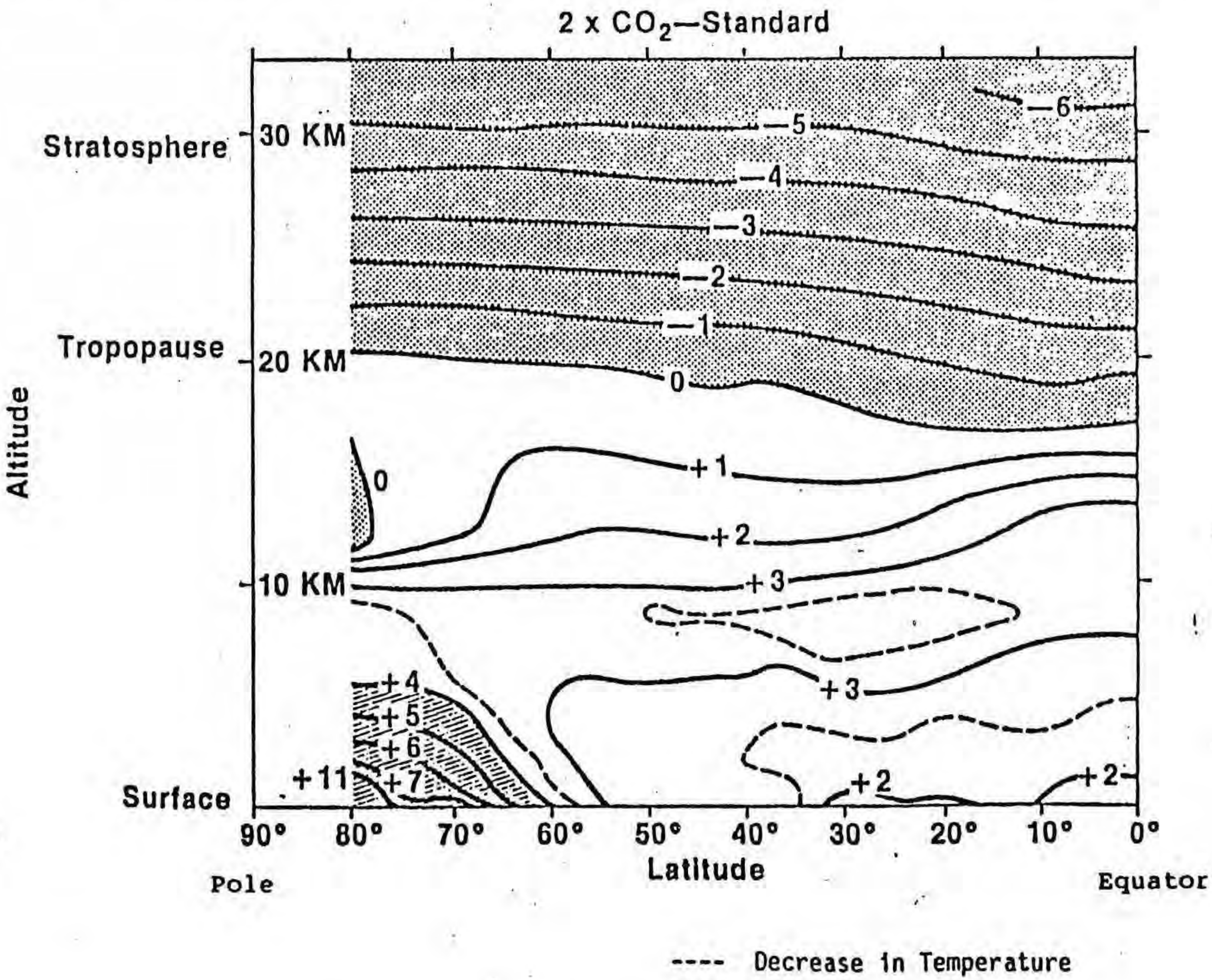
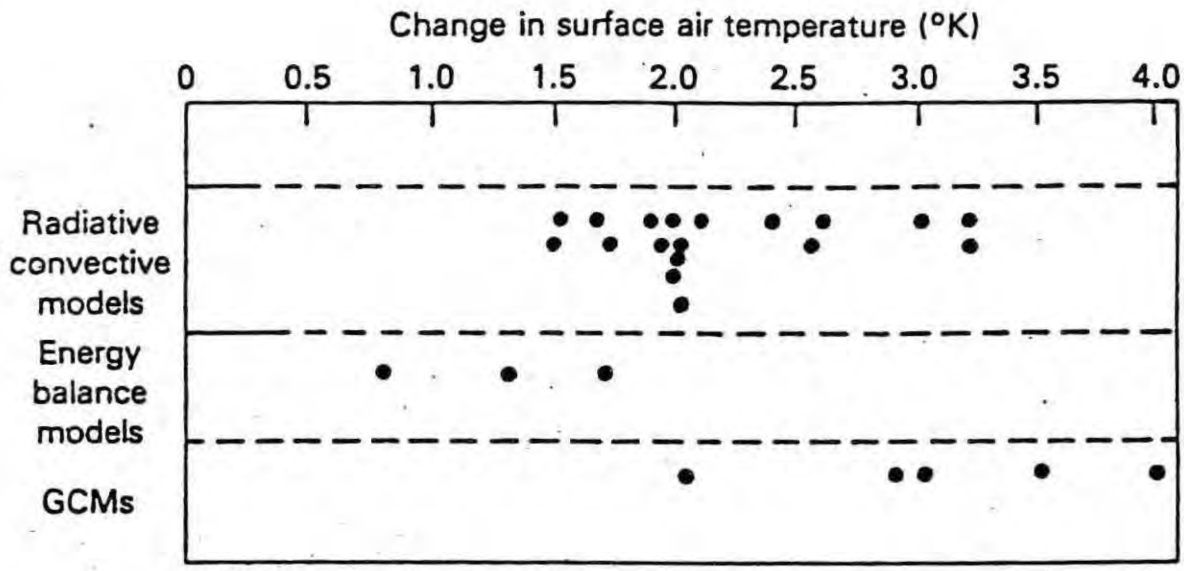


Figure 5



The change in globally averaged surface air temperature resulting from a doubling of atmospheric CO_2 as given by a variety of radiative-convective, energy balance, and global circulation (GCM) models. (From W. L. Gates, Oregon State University Technical Report no. 4.)

Figure 6

Estimates of the Change in Global Average Surface Temperature Due to Various Changes in CO_2 Concentration. Shading Shows Present Range of Natural Fluctuations.

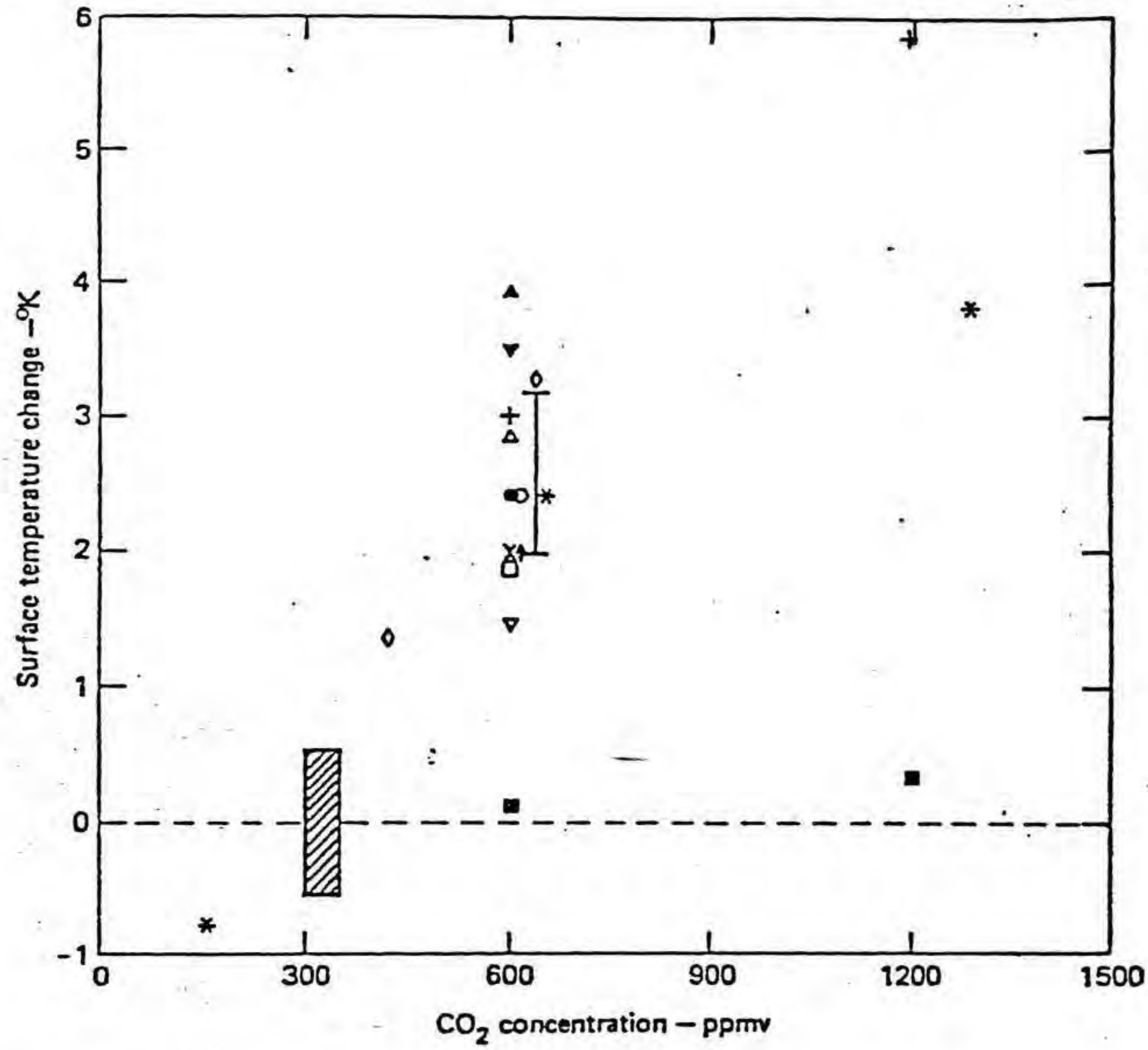
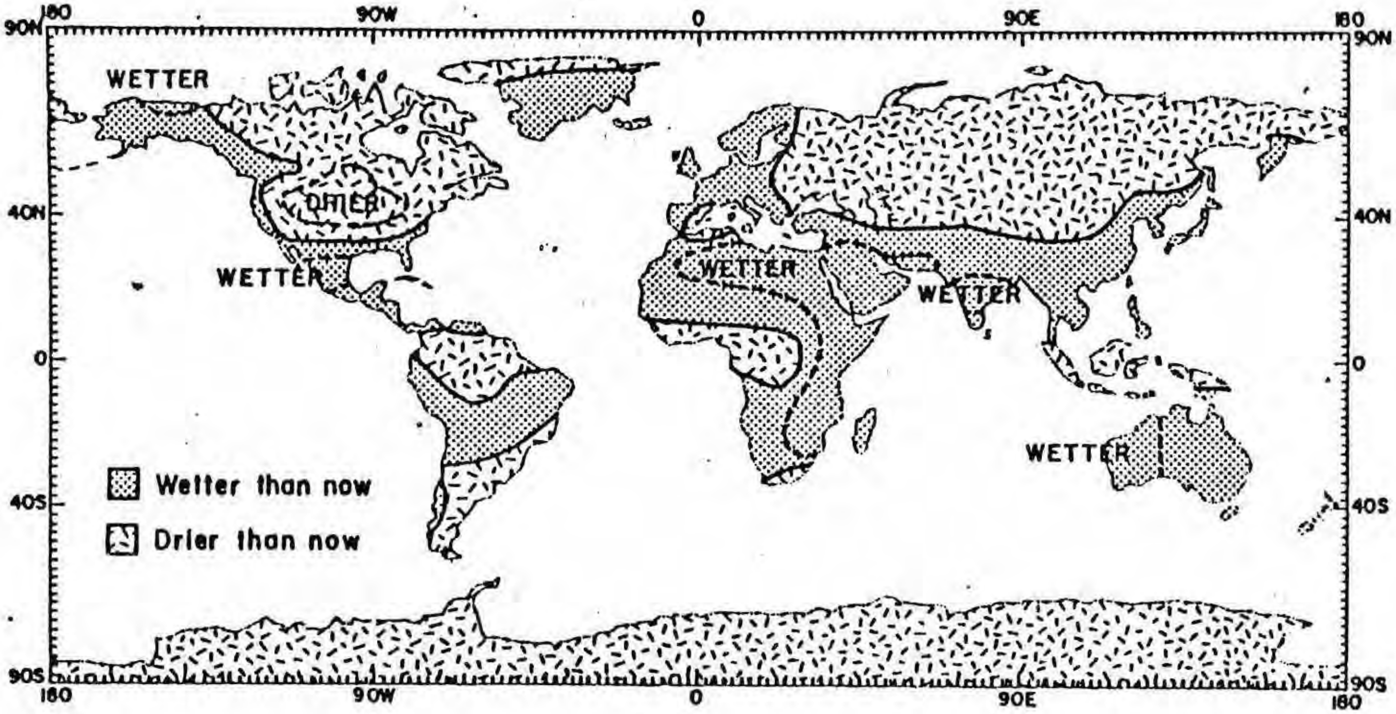


Figure 7



Example of a scenario of possible soil moisture patterns on a warmer Earth. It is based on paleoclimatic reconstructions of the Altithermal Period (4500 to 8000 years ago), comparisons of recent warm and cold years in the Northern Hemisphere, and a climate model experiment. (For a discussion of these sources of information see Appendix C.) Where two or more of these sources agree on the direction of the change we have indicated the area of agreement with a dashed line and a label.

their report titled, "Carbon Dioxide and Climate: A Scientific Assessment." This National Research Council study concluded that there are major uncertainties in these models in terms of the timing for a doubling of CO_2 and the resulting temperature increase. These uncertainties center around the thermal capacity of the oceans. The oceans have been assumed to consist of a relatively thin, well mixed surface layer averaging about 70 meters in depth in most of the general circulation models, and the transfer of heat into the deep ocean is essentially infinitely slow. The Charney panel felt, however, that the amount of heat carried by the deep ocean has been under estimated and the oceans will slow the temperature increase due to doubling of atmospheric CO_2. The Charney group estimated that the delay in heating resulting from the effect of the oceans could delay the expected temperature increase due to a doubling of CO_2 by a few decades. Accordingly, the time when the temperature increases discussed above are reached must be assumed to have occurred at an instantaneous equilibrium.

Along with a temperature increase, other climatological changes are expected to occur including an uneven global distribution of increased rainfall and increased evaporation. These disturbances in the existing global water distribution balance would have dramatic impact on soil moisture, and in turn, on agriculture. Recently, Manabe et al., using GCM's calculated that the zonal mean value of soil moisture in summer declines significantly in two separate zones of middle and high latitudes in response to an increase in the CO_2 concentration of air. This CO_2 induced summer dryness results not only from the earlier ending of the snowmelt season, but also from the earlier occurrence of the spring to summer reduction in rainfall rate. The former effect is particularly important in high latitudes, whereas the latter effect becomes important in middle latitudes. Other statistically significant changes include large increases in both soil moisture and runoff rates at high latitudes during most of the annual cycle with the exception of the summer season. The penetration of moisture rich, warm air into high latitudes is responsible for these increases.

The state-of-the-art in climate modeling allows only gross global zoning while some of the expected results from temperature increases of the magnitude indicated are quite dramatic. For example, areas that were deserts 4,000 to 8,000 years ago in the Altithermal period (when the global average temperature was some $2^{\circ}C$ higher than present), may in due time return to deserts. Conversely, some areas which are deserts now were formerly agricultural regions. It is postulated that part of the Sahara Desert in Africa was quite wet 2,000 to 8,000 years ago. The American Midwest, on the other hand, was much drier, and it is projected that the Midwest would again become drier should there be a temperature increase of the magnitude postulated for a doubling of atmospheric CO_2 (see Figure 7).

In addition to the effects of climate on global agriculture, there are some potentially catastrophic events that must be considered. For example, if the Antarctic ice sheet which is anchored on land should melt, then this could cause a rise in sea level on the order of 5 meters. Such a rise would cause flooding on much of the U.S. East Coast, including the State of Florida and Washington, D.C. The melting rate of polar ice is being studied by a number of glacialogists. Estimates for the melting of the West Anarctica ice sheet range from hundreds of years to a thousand years. Etkins and Epstein observed a 45 mm raise in mean sea level. They account for the rise by assuming that the top 70 m of the oceans has warmed by 0.3°C from 1890 to 1940 (as has the atmosphere) causing a 24 mm rise in sea level due to thermal expansion. They attribute the rest of the sea level rise to melting of polar ice. However, melting 51 Tt (10^{12} metric tonnes) of ice would reduce ocean temperature by 0.2°C, and explain why the global mean surface temperature has not increased as predicted by CO_2 greenhouse theories.

In an American Association for the Advancement of Science (AAAS) and Department of Energy (DOE) sponsored workshop on the environmental and societal consequences of a possible CO_2 induced climate change, other factors such as the environmental effects of CO_2 concentration on weeds and pests were considered. The general consensus was that these unmanaged species would tend to thrive with increasing average global temperature. The managed biosphere, such as agriculture, would also tend to benefit from atmospheric CO_2 growth. This is a consequence of CO_2 benefiting agriculture, provided the other key nutrients, phosphorous and nitrogen, are present in the right proportions. Agricultural water needs can be met by new irrigation techniques that require less water. In addition, with higher CO_2 and higher temperature conditions, the amount of water needed by agricultural plants may be reduced. It is expected that bioscience contributions could point the way for dealing with climatological disruptions of the magnitude indicated above. As a result of the workshop, research in 11 areas was recommended:

1. CO_2 fertilization could have broad beneficial effects on agriculture. These effects need to be studied in detail and for a variety of plant, soil and climatic conditions.

2. There is a need for a fuller understanding of the dynamics of currents and water masses in the Arctic Ocean.

3. It is necessary to determine whether there was deglaciation of the West Antarctic ice sheet about 120,000 years ago and whether this caused a rise in global sea levels at that time. If this occurred, then the information could serve as an analog of future deglaciation.

4. It is necessary to develop and use scenarios which integrate (a) information about population, resources, energy consumption and fuel mixes; (b) buildup of atmospheric CO_2; (c) response of the climate system; (d) effects on various biological systems, especially agricultural, economic and social consequences, international and interregional conflicts; and (e) possible feedback among these forces.

5. CO_2 induced warming is predicted to be much greater at the polar regions. There could also be positive feedback mechanisms as deposits of peat, containing large reservoirs of organic carbon, are exposed to oxidation. Similarly, thawing might also release large quantities of carbon currently sequestered as methane hydrates. Quantitative estimates of these possible effects are needed.

6. Although all biological systems are likely to be affected, the most severe economic effects could be on agriculture. There is a need to examine methods for alleviating environmental stress on renewable resource production — food, fiber, animal, agriculture, tree crops, etc.

7. Information exists on the relationship of cultivated and non-cultivated biomes to climatic fluctuations. Similarly, there is considerable information on the response of various nations and economic sectors to climatic variations over the past few hundred years. This information, which is currently scattered and not uniformly presented or calibrated, is thus of limited usefulness.

8. Studies of climate effects are recommended for the semi-arid tropics because of the relatively large populations in these countries and because of special sensitivity to climate.

9. There are situations (soil erosion, salinization, or the collapse of irrigation systems) which are recommended for study as indicators of how societies respond, and how they might learn to cope and adapt more effectively to a shift in global climate.

10. Research is recommended on the flow of information on risk perception and decision making to and from both laymen and experts, the physiological aspects of understanding and perception, and the factors that influence decision making.

11. There is a need to be sure that "lifetime" exposure to elevated CO_2 poses no risks to the health of humans or animals. Health effects associated with changes in the climate sensitive parameters, or stress associated with climate related famine or migration could be significant, and deserve study.

In terms of the societal and institutional responses to an increase in CO_2, the AAAS-DOE workshop participants felt that society can adapt to the increase in CO_2 and that this problem is not as significant to mankind as a nuclear holocaust or world famine. Finally, in an analysis of the issues associated with economic and geopolitical consequences, it was felt that society can adapt to a CO_2 increase within economic constraints that will be existing at the time. Some adaptive measures that were tested would not consume more than a few percent of the gross national product estimated in the middle of the next century.

Major Research Programs Underway

The Department of Energy (DOE) which is acting as a focal point for the U.S. government in this area is planning to issue two reports to the scientific community and to policy makers. The first one, summarizing five years of study is due in 1984, and the second one in 1989. The current plan is to invest approximately 10 years of research and assessment prior to recommending policy decisions in this area which impact greatly on the energy needs and scenarios for the U.S. and the world. The strategic elements of the United States national total CO_2 program are summarized in Figure 8.

Much of the government sponsored effort to date has focused on delineating the research needed to enhance our understanding of the potential problems. Accordingly, a number of workshops and symposia were held to this end. The consensus of the key research needs is summarized in Figure 8 under the heading "Research Program Results." To date, most of the research effort has been concentrated on the first two research categories. It should be noted, however, that this research started in 1979 and there are few results to report. The most ambitious project being conducted at this time is called "Transient Tracer in the Ocean (TTO)." This research, jointly funded by the DOE and the National Science Foundation (NSF), is a 4M$ project to investigate ocean mixing processes in order to enhance the understanding of how surface water CO_2 is mixed into the deep ocean. Tracers normally found in the ocean, such as ^{14}C, ^{3}H, ^{3}He, ^{85}Kr and ^{39}Ar, are monitored in the North Atlantic Ocean from oceanographic vessels.

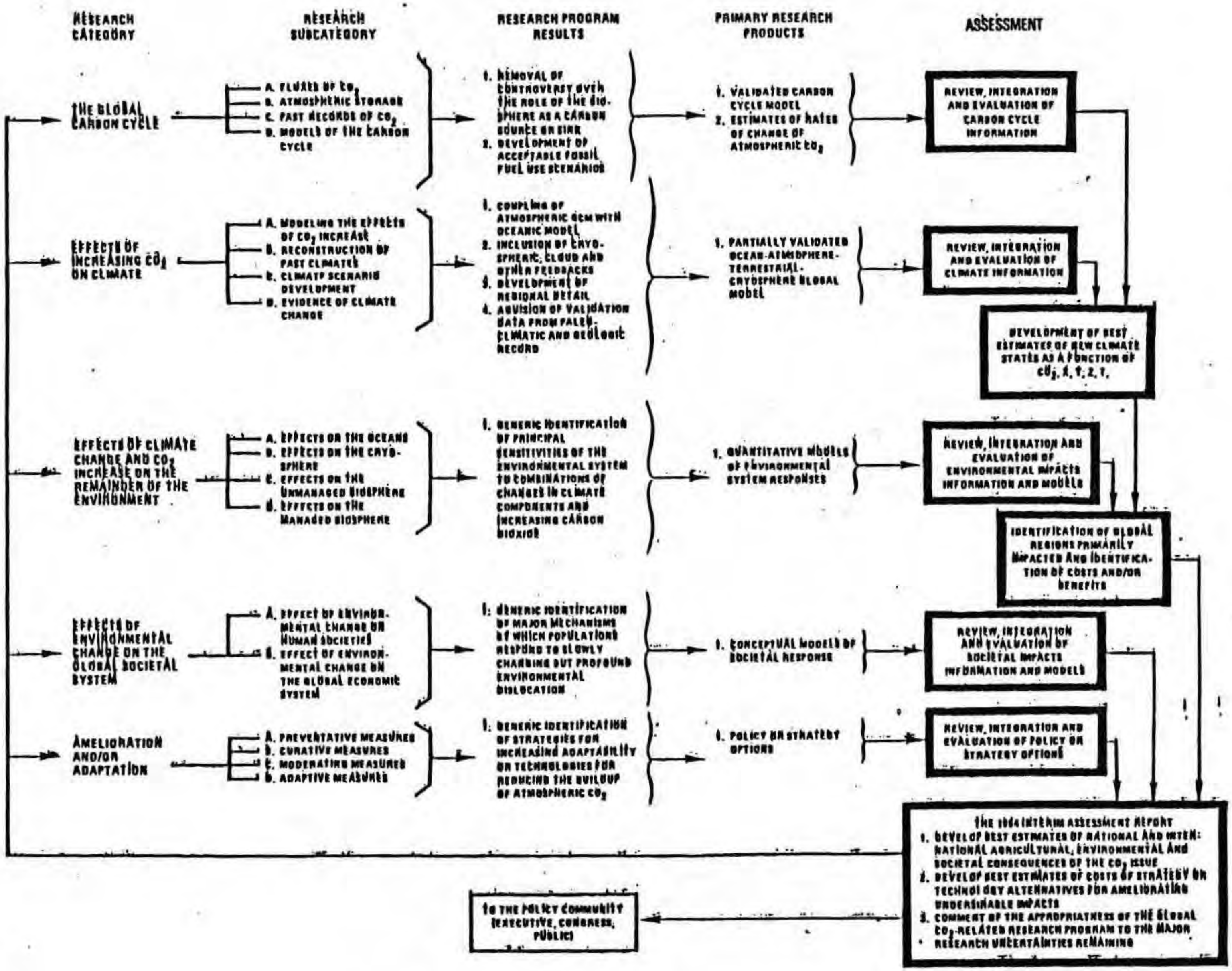
In addition to the mixing of surface waters into the bottom layers, carbon can be added to deep waters by the oxidation of organic matter and the dissolution of calcium carbonate. In order to separate these three processes and determine their relative significance, precise total carbon dioxide, alkalinity, and calcium concentration data are needed to construct and test mathematical models. Preliminary analysis of the limited data indicates that (1) lateral processes dominate the distribution of calcium and inorganic carbon in the deep oceans away from the polar regions, (2) the amount of calcium carbonate dissociated in the deep oceans is only a fraction of the previously estimated value, and (3) the excess CO_2 may have penetrated farther into the deep oceans than the currently available models predict.

Ultimately, CO_2 in the air should find its way into the deep ocean sediments. As currently understood, the deeper sediments have thus far been little affected by the fossil fuel era because of the slow mixing of the ocean. A group of scientists examined the contention that some shallow water sediments could now be dissolving and thus providing a sink for atmospheric CO_2, and concluded that the extent of dissolution is not great enough to have a large effect on the global carbon cycle.

It would be helpful if reliable estimates of the CO_2 concentration in the air could be obtained for the years prior to 1957, when the modern measurements

Figure 8

A NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY



began. Old Smithsonian Astrophysical Observatory plates of the solar spectrum taken in the early twentieth century might provide such an opportunity if they could be properly interpreted. A method for reducing the data has been developed and estimates of the CO_2 concentration should be available next year. As mentioned previously, determination of the CO_2 concentrations prior to the Industrial Revolution would help ascertain the validity of climate models, and thus the likely temperature due to a doubling of atmospheric CO_2.

Groups in Europe have used Antarctic and Greenland ice cores to independently estimate the CO_2 concentrations in the more distant past. While it is difficult to measure the CO_2 content of the dated ice cores, the results suggest that the atmospheric CO_2 concentration during the height of the last ice age (about 18,000 years ago) may have been about half its present value. This is consistent with recently published speculations derived from examination of the composition of ocean sediment cores.

There are currently approximately 40 carbon cycle and climate research projects in about 25 different institutions. Many of these projects are either supported jointly by the DOE and other agencies or exclusively by other agencies. The 1982 Federal budget request for CO_2 research was 23.9M$. The DOE, as the lead agency, would be allocated 14.0M$, NSF 6.4M$, NOAA 2.5M$, and the Department of Agriculture 1.0M$.

Future Energy Scenarios and Their Potential Impact on Atmospheric Carbon Dioxide

A number of future energy scenarios have been studied in relation to the CO_2 problem. These include such unlikely scenarios as stopping all fossil fuel combustion at the 1980 rate, looking at the delay in doubling time, and maintaining the pre-1973 fuel growth rate. Other studies have investigated the market penetration of non-fossil fuel technologies, such as nuclear, and its impact on CO_2. It should be noted, however, that fuel technology would need about 50 years to penetrate and achieve roughly half of the total market. Thus, even if solar or nuclear technologies were to be considered viable alternatives, they would not really displace fossil fuel energy for the next 40 to 50 years, and CO_2 growth would have to be estimated based on realistic market displacement of the fossil fuel technologies.

A draft report from Massachusetts Institute of Technology (MIT) and Oak Ridge (ORNL) authored by D. Rose and others considered the societal and technological inertia vis a vis decision making on the CO_2 issue. The CO_2 problem was considered as the major potential constraint on fossil fuel use. It was estimated in the study that the CO_2 problem may curtail fossil fuel use before physical depletion occurs. Considerable effort was devoted in the study to "option space," i.e., what are the potential energy alternatives, how long would it take to introduce them, and what type of material resources would be needed for effective market penetration. On reviewing the report we addressed only the technical questions relating to CO_2, and did not evaluate the plausibility of the scenarios relating to energy use in the future.

The study considered the implications of limiting atmospheric CO_2 at two different levels:

1. Rate of CO_2 addition to the atmosphere be limited to 450-500 ppm in 50 years.

2. The concentration ceiling for atmospheric CO_2 be in the range of 500-1000 ppm.

The rationale for choosing these limits is economic. If the rate of CO_2 increase is too rapid, then society may not be able to economically adapt to the resulting climate change. The second limit is based on a level where the harm due to CO_2 would greatly exceed the societal benefits that produced the CO_2. The second limit can be illustrated as an assumed threshold for inducing great irreversible harm to our planet, such as causing a large ocean level rise due to melting polar ice. In addition to improving the use of energy sources as a means of gaining time to understand the problem, it was concluded that vigorous development of non-fossil energy sources be initiated as soon as possible.

The study appears to be based on reasonable assumptions but has an inherent bias towards the accelerated development of non-fossil energy sources which, based on the present state-of-the-art, implies nuclear energy.

In his analysis, Rose introduced the concept of AIT (action initiation time), defined as the time when policies to modify or restrain fossil fuel use actually start to be effective. Based on this concept, Rose projects non-fossil growth rates of 6 to 9%/a over 40 to 50 years in order to limit atmospheric CO_2 to 500 to 700 ppm. These rates can be put in perspective by noting that such growth rates were achieved for natural gas introduction. However, nuclear or solar sources would have severe restrictions because such technologies are not as economically and politically attractive, technologically straightforward, and are encountering social and environmental opposition. In addition, Rose points out that the rate of growth of manufacturing facilities required to achieve a 6-9%/a growth rate in non-fossil fuel power generation is so large that it would be equivalent to increasing each year the U.S. power equipment manufacturing capability by an amount equivalent to the current capacity.

The study also indicated that other <u>energy-use-related</u> greenhouse gases (viz. carbon monoxide, methane, and oxides of nitrogen) may significantly contribute to a global warming. We believe the contribution of these gases to a global warming is highly speculative. Furthermore, N_2O, the only oxide of nitrogen that could contribute to a global warming is produced primarily by the microbial oxidation of ammonia from fertilizer use, and to a lesser extent from the combustion of fossil fuels. Additionally, N_2O is more reactive than CO_2 and is expected to have a relatively shorter atmospheric residence time. In a similar vein, methane is primarily emitted to the atmosphere via the anaerobic fermentation of organic material. The contribution of anthropogenic activities (mining, industrial processes, and combustion) are 1% to 10% of the total atmospheric methane sources. The atmospheric destruction of methane is more rapid than that of CO_2, and tends to yield CO, water vapor and formaldehyde. Also, methane is believed to contribute to tropospheric ozone formation by oxidizing to CO_2. The CO in the atmosphere can be traced to anthopogenic sources (50 to 60%) and to the atmospheric oxidation of methane (30%). The major CO sink is oxidation (70 to 90%) to CO_2. One can therefore consider CO and methane as precursors to CO_2. Accordingly, CO and methane ultimately contribute to climatological effects as part of atmospheric CO_2. The N_2O, on the other hand, may not be directly related to fossil fuel combustion. One should question whether the other "greenhouse" gases should be considered part of the CO_2 problem in view of the uncertainties regarding their connection to energy use. It is not clear, at this time, whether their effect would be additive to CO_2.

Forecast Based on Fossil Fuel Projected in Exxon's Long Range Energy Outlook

As part of the Exxon 21st Century Study, the rate of fossil fuel CO_2 emissions was estimated in late 1981. Specifically, the "High Case" volumetric data provided by the Corporate Planning Department was used to estimate the potential growth of atmospheric CO_2. The volumetric data was converted to an energy basis (Quads/a = 10^{15} Btu/year) using 5.55 MBtu/B for U.S., 5.64 MBtu/B for Canada and 5.85 MBtu/B for all other countries. In addition, a shale processing loss was added using a constant rate of 27.5% of the primary energy consumption from shale. This was based on the assumption that above ground retorting of relatively high quality oil shale (>30 gallons/ton) would be recovered with a thermal efficiency of 80%, and in-situ recovery of relatively poor oil shale (>15 gallons/ton) would be accomplished with a thermal efficiency of 65%. These efficiencies were averaged over the U.S. resource base to arrive at 72.5%. Table 1 summarizes the primary energy consumption of fossil fuels.

The total carbon dioxide that can be emitted from primary fossil fuels was estimated using the following factors:

Oil = 170 lb CO_2/MBtu = 21.0 MtC*/Quad.

Gas = 115 lb CO_2/MBtu = 14.2 MtC/Quad.

Coal = 207 lb CO_2/MBtu = 25.6 MtC/Quad.

In addition, the quantity of carbon dioxide that could be emitted from the decomposition of carbonate minerals in processing U.S. oil shale was estimated by averaging this potentially large CO_2 source over the Green River formation resource base. It should be noted that poorer shale resources tend to

* MtC = million metric tons of carbon.

PRIMARY ENERGY CONSUMPTION OF FOSSIL FUELS
21st CENTURY STUDY--HIGH CASE

Quads/a

Year	1979	1990	2000	2015	2030	2050
Oil						
U.S.	37.09	33.32	32.01	35.35	36.35	36.80
Canada	4.06	4.30	4.71	5.62	6.09	5.97
Others	96.62	111.93	128.16	139.63	148.57	132.75
Total	137.77	149.55	164.88	180.60	191.01	175.52
Gas						
U.S.	20.95	17.83	17.24	15.98	16.87	17.42
Canada	1.83	2.51	2.88	3.48	4.38	4.73
Others	30.88	55.54	74.95	86.24	99.65	108.68
Total	53.66	75.88	95.07	105.70	120.90	130.83
Coal						
U.S.	14.69	20.14	28.66	37.19	43.17	55.10
Canada	0.80	1.37	1.98	2.72	3.62	5.35
Others	60.17	81.44	103.90	125.55	175.55	261.14
Total	75.66	102.95	134.54	165.41	222.54	321.59
Fossil Fuels						
World Total	267.09	328.38	394.49	451.71	534.45	627.94
Rate %/a		1.90	1.85	0.91	1.13	0.81

emit much more CO_2 from carbonate minerals than the more desirable high quality resources for the same quantity of shale oil produced. It was further assumed that 65% of the carbonate minerals decompose during processing. This very conservative assumption is based on the average of 100% decomposition that may occur in "hot spots" during in-situ recovery and 30% decomposition that is generally observed in above ground retorting. Table 2 summarizes the total CO_2 produced in GtC/a. Please note that CO_2 emissions resulting from CO_2 mixed with natural gas in producing wells can be substantial, but due to the unavailability of quantitative data this factor was assumed to contribute about 5% additional CO_2 currently rising to 15% in the year 2050. This trend of CO_2 contamination of natural gas is consistent with recent Exxon experience.

The contributions of shale oil to primary fossil fuel energy and primary fossil fuel carbon are summarized in Table 3. This table shows that the fraction of shale oil CO_2 emissions to total CO_2 is greater than the corresponding contribution of shale oil energy to total energy. Table 3 also indicates the breakdown between CO_2 generated in producing and consuming shale oil, and that due to carbonate mineral decomposition.

Table 4 presents the estimated total quantities of CO_2 emitted to the environment as GtC, the growth of CO_2 in the atmosphere in ppm (v), and average global temperature increase in $^{\circ}C$ over 1979 as the base year. In order to estimate the buildup of atmospheric CO_2, it was assumed that the average atmospheric CO_2 concentration was 337 ppm in 1979. The fraction of CO_2 accumulated in the atmosphere was assumed to be 0.535 of the total fossil fuel CO_2. This number is derived from the observed historic ratio of total atmospheric CO_2 to total fossil fuel CO_2. Inherent in this number is the assumption that biomass and cement production did not contribute to atmospheric CO_2. It should be noted, however, that this method of calculation would tend to predict total anthropogenic CO_2 as long as the ratio of biomass and cement manufacture to fossil fuel consumption remains constant. The average temperature increase since 1979 was estimated, assuming that a doubling of CO_2 would cause an average global temperature increase of $3.0^{\circ} \pm 1.5^{\circ}C$. It was also assumed that fossil fuel carbon would grow at a rate of 0.8%/a between 2050 and 2080, which is a reasonable decrease from the 0.97%/a rate projected between 2030 and 2050. The following section analyzes the implications of the temperature rise due to CO_2 doubling with respect to initial detection of a greenhouse effect.

One variation of the High Case scenario was considered. It was assumed that adequate quantities of oil and gas would be discovered to exactly match those estimated to be produced from synthetic fuels in the High Case scenario, and thus balance the primary energy needs of the 21st Century Study. The net quantity of carbon that would be saved is summarized in Table 5. The implications of the synfuel losses are compared with the High Case in Figure 3. The overall impact is relatively minor.

TABLE 2

PRIMARY CARBON DIOXIDE (AS CARBON) FORMATION FROM FOSSIL FUELS
21st CENTURY STUDY--HIGH CASE

GtC/a

Year	1979	1990	2000	2015	2030	2050
Oil	2.90	3.15	3.47	3.79	4.01	3.69
Inorganic Carbon	-	0.01	0.05	0.19	0.27	0.40
Total Oil	2.90	3.16	3.52	3.98	4.28	4.09
Gas	0.76	1.08	1.35	1.50	1.72	1.86
CO_2 in Gas	0.04	0.11	0.15	0.18	0.22	0.28
Total Gas	0.80	1.19	1.50	1.68	1.94	2.14
Total Coal	1.93	2.64	3.45	4.24	5.70	8.24
World Total	5.63	7.00	8.47	9.90	11.92	14.47
Rate %/a	2.00	1.92	1.05	1.25	0.97	0.80

TABLE 3

OIL SHALE LIQUID FUELS
PRIMARY ENERGY CONSUMPTION AND
CARBON DIOXIDE (AS CARBON) PRODUCTION
21st CENTURY STUDY--HIGH CASE

Year	1979	1990	2000	2015	2030	2050
U.S. Shale, Quads/a	--	1.01	3.65	14.38	20.66	30.79
Other Shale	--	0.21	1.49	2.56	5.55	11.10
Total	--	1.21	5.14	16.94	26.21	41.89
% Primary Shale Energy/Primary Fossil Fuels Energy	--	0.35	1.30	3.75	4.90	6.67
Shale Carbon, GtC/A	--	0.03	0.11	0.36	0.55	0.88
Carbonate Carbon	--	0.01	0.05	0.19	0.27	0.40
Total	--	0.04	0.16	0.55	0.82	1.28
% Primary Shale Carbon/Primary Fossil Fuel Carbon	--	0.55	1.89	5.55	6.87	8.85

TABLE 4

ESTIMATED ATMOSPHERIC CO_2 CONCENTRATION AND
AVERAGE TEMPERATURE INCREASE
21st CENTURY STUDY--HIGH CASE

Year	Emitted, GtC		Stored in Atmosphere, GtC		Atmospheric Concentration, ppm		Average Temperature Increase, °C
	Incremental	Cummulative	Incremental	Cummulative	Incremental	Cummulative	
1979	--	--	--	715	--	337	0
1990	69.3	69.3	37.1	752	17.5	355	0.22
2000	77.2	146.5	41.3	793	19.5	374	0.45
2015	137.5	284.0	73.6	867	34.7	409	0.84
2030	163.3	447.3	87.4	954	41.2	450	1.25
2050	263.5	710.8	141.0	1095	66.5	516	1.84
2080	490.6	1201.4	262.5	1358	123.7	640	2.78
2090	191.3	1392.7	102.3	1160	48.2	688	3.09

TABLE 5

ESTIMATED INCREMENTAL CO_2 CONTRIBUTION FROM SYNTHETIC FUELS TO ATMOSPHERIC CO_2 CONCENTRATION AND AVERAGE GLOBAL TEMPERATURE INCREASE

GtC/a

Year	1990	2000	2015	2030	2050	2080
Shale Loss	0.004	0.025	0.069	0.114	0.181	
Carbonate Decomposition	0.013	0.047	0.186	0.267	0.398	
Total Shale	0.017	0.072	0.255	0.381	0.579	
Coal Loss	0.018	0.067	0.136	0.276	0.535	
Total Synfuels Loss	0.035	0.139	0.391	0.657	1.114	
Rate %/a		14.8	7.1	3.5	2.7	2.0
Incremental CO_2, GtC	-	0.80	3.73	7.73	17.38	45.79
Cummulative CO_2, GtC	-	0.80	4.53	12.26	29.64	75.43
Incremental Atmospheric CO_2, ppm	-	0.2	0.9	1.9	4.4	11.5
Cummulative Atmospheric CO_2, ppm	-	0.2	1.1	3.1	7.5	19
Net Atmospheric CO_2, ppm	355	374	407	446	506	616
Average Temperature Increase, °C	0.22	0.45	0.82	1.21	1.76	2.61

Detection of a CO_2 Greenhouse Effect

It is anticipated by most scientists that a general consensus regarding the likelihood and implications of a CO_2 induced greenhouse effect will not be reached until such time as a significant temperature increase can be detected above the natural random temperature fluctuations in average global climate. These fluctuations are assumed to be $\pm 0.5^{\circ}C$. The earliest that such discreet signals will be able to be measured is one of the major uncertainties of the CO_2 issue.

A number of climatologists claim that they are currently measuring a temperature signal (above climate noise) due to a CO_2 induced greenhouse effect, while the majority do not expect such a signal to be detectable before the year 2000. In order to quantify the implications of detecting a greenhouse effect now, as opposed to the year 2000, estimates were made on temperature projections as a function of the CO_2 concentration that existed prior to the Industrial Revolution. Available data on CO_2 concentration prior to the Industrial Revolution tend to fall into two groups: 260 to 270 ppm or 290 to 300 ppm. In Table 6, possible temperature increases were estimated as a function of initial CO_2 concentrations of 265 and 295 ppm. Temperatures were projected for three cases, viz., (1) a temperature increase of $3^{\circ}C$ occurs if current CO_2 concentration doubles, (2) the greenhouse effect is detectable now (1979), and (3) the greenhouse affect is detected in the year 2000.

One can see in Table 6 that if a doubling of atmospheric CO_2 will cause a $3^{\circ}C$ rise in temperature, then we should have seen a temperature increase above climate noise if initial CO_2 concentration was 265 ppm, or be on the threshold of detecting such an effect now, if the initial concentration was 295 ppm. If we assume that we are on the threshold of detecting a greenhouse effect, then the average temperature due to a doubling of CO_2 will be $1.9^{\circ}C$ for an initial CO_2 concentration of 265, or $3.1^{\circ}C$ for an initial concentration of 295 ppm. Finally, if the greenhouse effect is detected in the year 2000, then the doubling temperature for initial CO_2 concentrations of 265 and 295 ppm will be 1.3° and $1.7^{\circ}C$, respectively. Based on these estimates, one concludes that a doubling of current concentrations of CO_2 will probably not cause an average global temperature rise much in excess of $3^{\circ}C$, or the effect should be detectable at the present time. Alternatively, if the greenhouse effect is not detected until 2000, then the temperature due to a CO_2 doubling will probably be under $2^{\circ}C$. Using the Exxon 21st Century Study as a basis for fossil fuel growth patterns, the average global temperature increases due to CO_2 would range between 0.8 and $1.6^{\circ}C$ by 2030. A doubling of atmospheric CO_2 would be extropolated from the fossil fuel consumption rates of the 21st Century Study to occur at about the year 2090 with the temperature increase ranging between 1.3° and $3.1^{\circ}C$. The projected range presented above is considerably lower than the generally accepted range of 1.5° to $4.5^{\circ}C$. Figure 9 illustrates

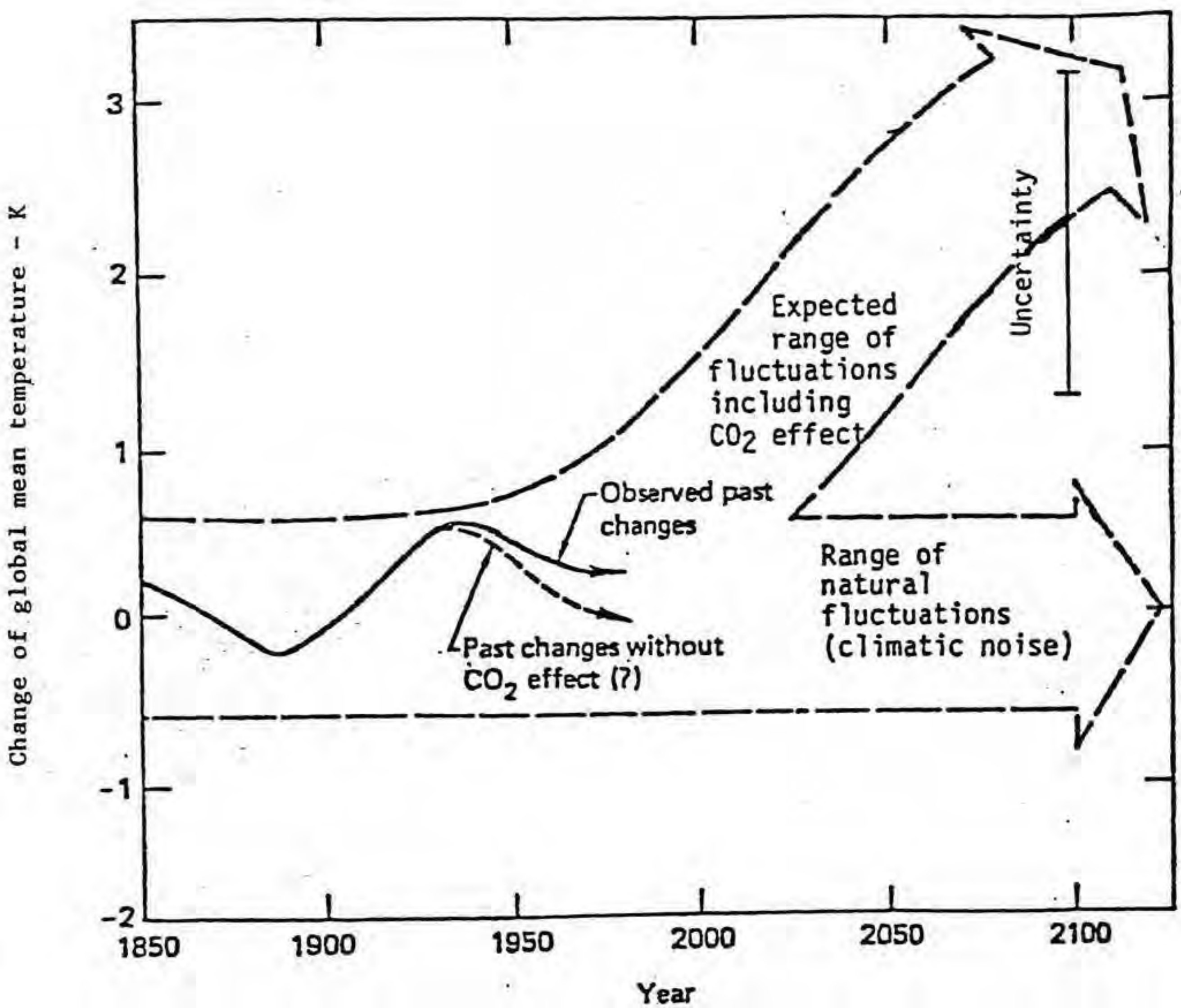
TABLE 6

EFFECT OF PRE-INDUSTRIAL ATMOSPHERIC CO_2 CONCENTRATION ON GLOBAL AVERAGE TEMPERATURE INCREASE

Atmospheric CO2 Concentration, ppm	Time (Instantaneous Equilibrium)	Temperature, °C Doubling ~2090 265	295	Detected 1979 265	295	Detected 2000 265	295
1,000	~2140	4.3	4.4	2.8	4.6	1.9	2.5
800	~2110	3.6	3.6	2.3	3.7	1.4	2.1
674 (Doubling)	~2090	3.0	3.0	1.9	3.1	1.3	1.7
451	2030	1.7	1.5	1.1	1.6	0.8	0.9
375	2000	1.1	0.9	0.7	0.9	0.5	0.5
337 (Current)	1979	0.8	0.5	0.5	0.5	0.3	0.3
295	~1850	0.3	0	0.2	0	0.2	0
265	~1850	0	–	0	–	0	–

Figure 9

Range of Global Mean Temperature From 1850 to the Present with the Projected Instantaneous Climatic Response to Increasing CO_2 Concentrations.



the behavior of the mean global temperature from 1850 to the present, contained within an envelop scaled to include the random temperature fluctuations, and projected into the future to include the 1.3° to 3.1°C range of uncertainty noted above for the CO_2 effect.

Depending on the actual global energy demand and supply, it is possible that some of the concerns about CO_2 growth due to fossil fuel combustion may be reduced if fossil fuel use is decreased due to high price, scarcity, and unavailability.

The above discussion assumes that an instantaneous climatic response results from an increase in atmospheric CO_2 concentration. In actuality, the temperature effect would likely lag the CO_2 change by about 20 years because the oceans would tend to damp out temperature changes.

Given the long term nature of the potential problem and the uncertainties involved, it would appear that there is time for further study and monitoring before specific actions need be taken. At the present time, that action would likely be curtailment of fossil fuel consumption which would undoubtedly seriously impact the world's economies and societies. Key points needing better definition include the impact of fossil fuel combusion and the role of the oceans in the carbon cycle and the interactive effect of carbon dioxide and other trace atmospheric gases on climate.

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