Case No. 18-36082

IN THE UNITED STATES COURT OF APPEALS FOR THE NINTH CIRCUIT

KELSEY CASCADIA ROSE JULIANA, *et al.*,
Plaintiffs-Appellees,
v.
UNITED STATES OF AMERICA, *et al.*,
Defendants-Appellants.

On Interlocutory Appeal Pursuant to 28 U.S.C. § 1292(b)

DECLARATION OF JULIA A. OLSON IN SUPPORT OF PLAINTIFFS' URGENT MOTION UNDER CIRCUIT RULE 27-3(b) FOR PRELIMINARY INJUNCTION

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I, Julia A. Olson, hereby declare and if called upon would testify as follows:

1. I am an attorney of record on behalf of Plaintiffs-Appellees in the above-entitled action. I make this Declaration in support of Plaintiffs' Urgent Motion Under Circuit Rule 27-3(b) for Preliminary Injunction. I have personal knowledge of the facts stated herein, except as to those stated upon information and belief and, if called to testify, I would and could testify competently thereto.
2. Plaintiffs are aware that further expansion of the U.S. fossil fuel-based energy system could happen during the pendency of this interlocutory appeal. Dates of upcoming Defendant Department of Interior offshore lease sales are identifiable at the following website: https://www.boem.gov/2017-2022-Lease-Sale-Schedule/. Based on a review of that website, the next Oil and Gas Region-Wide Lease Sale of federal public offshore lands is in the Gulf of Mexico and scheduled for March 20, 2019. 83 Fed. Reg. 48,863 (Sept. 27, 2018). Other actions by Defendants that would be subject to Plaintiff's requested Preliminary Injunction are not readily-identifiable by date, but may occur before a decision by this Court on Plaintiffs' Urgent Motion, as explained in the Declaration of Pete Erickson.
3. Attached hereto as **Exhibit 1** is a true and correct copy of the Expert Report of Frank Ackerman, Ph.D, which was filed in support of Plaintiffs' Opposition

to Defendants' Motion for Summary Judgment in the district court at Doc. 257-1.

4. Attached hereto as **Exhibit 2** is a true and correct copy of the Expert Report of Dr. Howard Frumkin, which was filed in support of Plaintiffs' Opposition to Defendants' Motion for Summary Judgment in the district court at Doc. 259-1.
5. Attached hereto as **Exhibit 3** is a true and correct copy of the Expert Report of G. Philip Robertson, Ph.D, which was filed in support of Plaintiffs' Opposition to Defendants' Motion for Summary Judgment in the district court at Doc. 263-1.
6. Attached hereto as **Exhibit 4** is a true and correct copy of the Corrected Expert Report of James Gustave Speth, J.D., which was served on Defendants' counsel on September 28, 2018. The Corrected Expert Report of Mr. Speth was not filed with the district court.
7. Attached hereto as **Exhibit 5** is a true and correct copy of the Supplemental Expert Report of Dr. Harold R. Wanless, which was served on Defendants' counsel on September 11, 2018. The Supplemental Expert Report of Dr. Wanless was not filed with the district court.
8. Pursuant to Circuit Rule 27-3, counsel for Plaintiffs contacted counsel for Defendants via email on February 6, 2019 to determine the position of

Defendants. Counsel for Defendants communicated in response that "Defendants oppose Plaintiffs' motion for a preliminary injunction."

I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct. Executed on February 7, 2019.

s/ Julia A. Olson
JULIA A. OLSON

Exhibit 1

EXPERT REPORT
OF
FRANK ACKERMAN

Principal Economist, Synapse Energy Economics

Kelsey Cascadia Rose Juliana; Xiuhtezcatl Tonatiuh M.,
through his Guardian Tamara Roske-Martinez; et al.,
Plaintiffs,

v.

The United States of America; Donald Trump,
in his official capacity as President of the United States; et al.,
Federal Defendants.

IN THE UNITED STATES DISTRICT COURT
DISTRICT OF OREGON

(Case No.: 6:15-cv-01517-TC)

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TABLE OF ACRONYMS AND ABBREVIATIONS

CO_2:	carbon dioxide
CBA:	cost-benefit analysis
DICE:	Dynamic Integrated Climate-Economy
FUND:	Climate Framework for Uncertainty, Negotiation and Distribution
IAM:	integrated assessment model
IWG:	U.S. Federal Government Interagency Working Group
kwh:	kilowatt hour
MWh:	megawatt hour
NAS:	National Academy of Sciences
OMB:	Office of Management and Budget
PAGE:	Policy Analysis of the Greenhouse Effect
PPA:	purchased power agreements
SCC:	social cost of carbon
VSL:	value of a statistical life
WTA:	willingness to accept
WTP:	willingness to pay

INTRODUCTION

I, Frank Ackerman, have been retained by Plaintiffs in the above-captioned matter to provide expert testimony regarding the economic consequences of human-caused climate change and the economic feasibility of a swift transition off of fossil fuels for energy. In this report, I examine multiple reasons why conventional economic analyses, such as those relied on by the Defendants, knowingly undervalue or dismiss the serious risks of climate damages that Defendants are in the process of imposing on the Youth Plaintiffs here and on future generations. These reasons include the standard approaches to discounting, the treatment of extreme risks and irreversible losses, reliance on flawed techniques of cost-benefit analysis, use of limited and often biased damage estimates, and specific choices made in calculating the "social cost of carbon" (SCC, i.e. the cumulative value of damages caused by a ton of CO_2 emissions). I also briefly discuss the surprisingly low, and declining, costs of emission reduction, which make active, large-scale climate protection policies more feasible.

As evidenced by my CV, I have written extensively about the economics of climate change, energy, and other environmental problems. I have particular expertise on the limitations of traditional cost-benefit analyses. I have written several books that address these issues, including *Worst-Case Economics: Extreme Events in Climate and Finance* (2017); *Climate Economics: The State of the Art* (2013); *Can We Afford the Future? The Economics of a Warming World* (2008); and *Priceless: On Knowing the Price of Everything and the Value of Nothing* (2004). I received my PhD in economics from Harvard University and have taught economics at the Massachusetts Institute of Technology, Tufts University, and the University of Massachusetts. I am a founder and member of the Steering Committee of Economics for Equity and Environment and a member scholar of the Center for Progressive Reform.

I also have significant professional experience in the private and nonprofit sectors, including work as: Principal Economist for Synapse Energy Economics, Inc. (2012 - present); Senior Economist and Director of Climate Economics Group for the Stockholm Environment Institute's U.S. Center (2007 - 2012); and Senior Economist for the Tellus Institute (1985 - 1995). My clients have included the European Parliament, the U.S. Environmental Protection Agency, and the Environment, Economics and Society Institute. I have testified on the economic implications of global climate change to the United States Congress House Committees on Energy and Commerce and Ways and Means, and I have testified on energy and environmental concerns at a variety of state agency hearings.

This expert report contains my opinions, conclusions, and the reasons therefore. My CV, which includes a list of publications I have authored in the last ten years, is contained in **Exhibit A** to this expert report. In preparing my expert report and testifying at trial, I am deferring my expert witness fees to be charged Plaintiffs given the financial circumstances of these young Plaintiffs. If a party seeks discovery under Federal Rule 26(b), I will charge my reasonable fee of $280 per hour for the time spent in addressing that party's discovery. I have not provided previous testimony within the preceding four years as an expert at trial or by deposition. I have, however, provided expert witness testimony in several utility regulatory proceedings. My report contains citations to all documents that I have used or considered in forming my opinions, listed in **Exhibit B** to this expert report.

The opinions expressed in this expert report are my own and are based on the data and facts available to me at the time of writing, as well as based upon my own professional experience and expertise. All opinions expressed herein are to a reasonable degree of scientific certainty, unless otherwise specifically stated. Should additional relevant or pertinent information become available, I reserve the right to supplement the discussion and findings in this expert report in this action.

EXECUTIVE SUMMARY

There are multiple grounds for believing that the economic analyses relied on by Defendants to inform climate and energy policy in the United States, knowingly underrepresent costs of climate disruption, thus undervalue the damage that Defendants are imposing on Youth Plaintiffs and future generations, and exaggerate the cost of reducing that damage today. One result of these biases is that the Obama Administration's estimate of the social cost of carbon ("SCC"), a measure of the severity of climate damages and the urgency of policy responses, was much too low, an affirmative step that placed these Youth Plaintiffs at significant risk. Defendants' underrepresentation and undervaluation of climate damages affirmatively placed these Youth Plaintiffs in a worse position than that in which they would have been had Defendants based their actions on recognition of the true costs, thereby predictably exposing these Youth Plaintiffs to the actual, particularized, and obvious dangers of climate disruption.

The treatment of discounting by Defendants frames their economic analysis of long-term problems such as climate change and has resulted in a policy or practice by Defendants that deliberately devalues the climate harms that Defendants know these Youth Plaintiffs will experience over the long term. Discount rates have immense influence on the results of economic analyses, particularly in an intergenerational context. How much less are future costs and benefits worth today, solely because they will occur in the future? If a high discount rate is used, the costs and benefits that will be experienced 100 years from now are worth almost nothing today, suggesting that climate mitigation (or other policies that benefit future generations) are not worth spending much on today. At a low discount rate, such as the 1.4% annual rate adopted by the Stern Review (Stern 2007), the present value of future impacts is much more substantial, endorsing policy-making as if the future mattered. Within the economic debates over discount rates, there are many strong rationales for very low, and even zero, discount rates. This is important because a very low discount rate is required in order to recognize the importance of climate impacts on future generations and their wellbeing in Defendants' climate and energy policy.

Cost-benefit analysis ("CBA") is a flawed economic framework for informing climate and energy policy, all too frequently biased against protecting the earth's climate and the needs of future generations. Some of the most ominous and important risks of climate change involve future risks and potential catastrophic and irreversible tipping points that may not be the most likely outcome but are nonetheless too likely to ignore. The framework of CBA, often applied to public policy evaluation today, relies on most likely, average, or expected (weighted-average) values for future risks and benefits. The CBA approach dismisses or devalues risks of extreme events and cannot accommodate climate impacts that become irreversible or unstoppable. An insurance framework provides a better way of thinking about catastrophic risks. Individuals who buy fire insurance or life insurance are typically insuring against events with annual probabilities of just a few tenths of a percent. Public policy modeled on insurance might focus on extreme risks which are about as likely as, or even more likely than, a residential fire or the death of a young parent (not impossible, but far from the most likely outcome), leading to a much more precautionary approach to climate and energy policy.

In addition to the issues of discounting and treatment of extreme risks, there are at least three fundamental problems with Defendants' application of CBA to climate and energy policy, all of which stem from the fundamental principle of CBA that requires a monetary value for every cost and every benefit – even those that are difficult or impossible to quantify.

- CBA is only meaningful if the estimates of costs and benefits are comparably complete – but this is almost never true in Defendants' evaluation of environmental policy. Costs of climate and environmental protection are generally matters of hardware and engineering estimates, which are easy to establish and meaningfully described in monetary terms. Benefits, in contrast, involve protection of life, health, nature, biodiversity, and other unmonetized, often unquantified, crucial values. Attempts at monetization of benefits are necessarily incomplete and approximate, to a much greater extent than on the cost side.
- Defendants' CBA analyses use the wrong information to measure the harm CO_2 emissions and unchecked climate change impose on individuals, families, and communities. When economists survey people to determine the value that the public places on environmental assets, they consider two perspectives. Willingness to pay ("WTP") asks what people would pay to avoid degradation of the asset, while willingness to accept ("WTA") asks what compensation people would accept for degradation. WTA would be appropriate if there is a right at issue – e.g., a property right or right to be free from harm – and polluters have to pay us to pollute; WTP would be appropriate if there is no such right, and we have to pay polluters to stop polluting. Both theory and experiment show that WTA is routinely higher than WTP, yet WTP has become the standard in CBA and climate economics, despite the fact that WTA would be more appropriate in the climate context.
- Since CBA demands prices for everything that matters, economists have invented prices for priceless values such as human life. These numbers do not play the same role as normal prices, however. Estimates such as $9 million per life saved do not imply that you can buy a life, or the right to kill someone, for $10 million. In the words of Immanuel Kant, some things we care about have a price, while others have a dignity. When evaluating policies and actions that encourage or discourage the development and use of fossil fuels, Defendants have not recognized that the benefits of climate protection include many things that have a dignity, which are literally priceless.

The conventional economic analyses relied upon by Defendants underrepresent costs of climate disruption. Within the existing methodology of cost-benefit-based federal government policy and the Obama Administration's SCC[1] calculations, there are specific data and analytical choices, which create additional biases against taking future climate risks seriously. In practice, economic assessment of climate policy has relied heavily on a handful of integrated assessment models ("IAMs"), namely DICE, FUND, and PAGE.[2] Inside each of these models, there is an assessment of the climate damages that are likely to occur as temperatures rise – the so-called "damage function". Calibration of the models' damage functions requires estimating the monetary value of damages at varying temperatures far above human historical experience.

[1] The social cost of carbon ("SCC") refers to the present value of the cumulative damages caused by an additional ton of carbon dioxide ("CO_2") emissions.

[2] FUND (Climate Framework for Uncertainty, Negotiation and Distribution), DICE (Dynamic Integrated Climate-Economy), and PAGE (Policy Analysis of the Greenhouse Effect) are the three IAMs relied upon by the federal government in estimating the SCC.

These damage functions are misleading, in part, because they have often been based on very dated sources and imply very small aggregate damages from the first few degrees of warming. A National Academy of Sciences review (NAS 2017) has called for the use of newer sources, and proposed a number of such sources. Moreover, these damage functions exclude significant and severe climate impacts, such as ocean acidification and species and wildlife loss, and some of the biggest potential risks of climate change, such as climate-induced migration and conflict, because these impacts and risks are extremely difficult to quantify.

The result of all these biases is that Defendants' estimate of the SCC under the Obama Administration, a measure of the severity of climate damages and the urgency of policy responses, is much too low. The Obama Administration's final estimate (the August 2016 technical revision of their 2013 estimate), converted to 2017 dollars, was $49 per ton of CO_2 in 2020, rising to $81 in 2050. These government estimates of the SCC seriously understate the harm that continued CO_2 emissions will impose on these Youth Plaintiffs and future generations. Many other sources exploring small changes in assumptions, or addressing uncertainties in the calculation, have come up with much higher numbers: frequently above $100 today, and in some cases above $1,000 by 2050.

The costs of solving the climate crisis are falling rapidly. In contrast to the risks of catastrophic changes in the earth's climate system and the ever-increasing damages and costs from the present inaction of government that perpetuates climate pollution, the costs of renewable energy technologies to reduce emissions have been plunging downward in recent years. It is now much cheaper than anyone expected just a decade ago to substitute carbon-free energy for fossil fuels. Wind power is fully competitive with other power sources in suitably windy areas, such as the Plains states, and solar power and battery storage are moving rapidly in the same direction.

In my expert opinion, Defendants have made deliberate decisions with respect to the economic analyses underlying climate and energy policy decisions, placing these Youth Plaintiffs at substantial risk of suffering serious harm, without taking readily available measures to abate that risk, even though a reasonable government official in the circumstances would have appreciated the high degree of risk involved—making the consequences of Defendants' conduct obvious. By not taking such measures, Defendants engaged in conduct that caused and continues to cause injury to these Youth Plaintiffs and future generations. Defendants have dismissed or devalued the serious harm from climate change that young people and future generations will experience, resulting in a policy and practice that discriminates against Youth Plaintiffs and future generations. In other words, Defendants' longstanding climate and energy policy in the United States knowingly underrepresented costs of climate disruption and was deliberately indifferent to a substantial risk of serious harm to these Youth Plaintiffs and future generations, and therefore caused harm (and is causing harm) to these Youth Plaintiffs and future generations.

EXPERT OPINION

My purpose in this expert report is to identify biases in Defendants' conventional economic treatment of the costs and benefits of climate and energy policies. I find that there are multiple reasons why the costs of enabling and maintaining the fossil fuel energy system are often understated, while the costs of rapid emission reduction and climate recovery have often been exaggerated. As a result, conventional economic analysis conducted by Defendants has incorrectly suggested that the benefits of rapid emission reduction are not large enough to justify its costs. This biased conclusion and the policies based on it discriminate against young people and put the welfare of future generations at risk, by allowing climate change to proceed with too little effort to reduce emissions and impacts.

I. Discounting devalues future climate harm

Under Executive Order 12866 (1993), federal agencies are required to conduct a cost-benefit analysis of all economically significant policies and regulatory alternatives, comparing actions that could be taken to the alternative of no change in the status quo. This clearly applies to climate and energy policies. Defendants' attempts to perform cost-benefit analysis of climate and energy policies lead immediately to the dilemmas of discounting future costs and benefits – and in practice, have led to a devaluation of future climate harms, and discrimination against Youth Plaintiffs and future generations.

Conventional economic analyses, underlying Defendants' climate and energy policies, provide an inappropriate framework for analyzing such policies, when the costs and benefits occur across multiple generations. Any evaluation of climate and energy policy costs and benefits must weigh the costs of emission reduction incurred today and in the near term against benefits (i.e., avoided climate damages) that stretch much farther into the future. Conversely, such an evaluation involves weighing the short-term economic benefits of not reducing emissions against the long-term damages and costs of climate harm. Climate change is a very long-term problem, spanning multiple generations and lifetimes. A significant fraction of carbon dioxide ("CO_2") emissions remain in the atmosphere for more than a century, continuing to heat up the earth. Even if emissions were to stop tomorrow, the CO_2 already in the atmosphere would continue to heat up the oceans for decades to come, causing an ongoing rise in sea levels as well as other impacts. (Hansen et al. 2013, 2015)

In this context, Defendants' use of the common economic practice of discounting devalues the serious harm from climate change that young people and future generations will experience in their lifetimes. In particular, Defendants' use of improperly high discount rates allows the short-term economic benefits of maintaining a fossil fuel-based energy system, combined with inaction (or insufficient action) on emission reduction, to outweigh the very severe long-term impacts in its cost-benefit analysis.

The standard practice in climate economics, as in many other areas of economic analysis, is to convert – or "discount" – future costs and benefits into their present values in today's dollars. The present value of a future amount is the amount that would need to be placed in a savings account today, at a specified interest rate, in order to end up with the target amount in the future year. Note that the result is crucially dependent on the discount rate, as the interest rate is called in present value calculations. The larger the discount rate, the smaller the present value of any future amount. And the longer the time period, the greater the effect of changes in the discount rate.

These effects can be seen in **Table 1** below. At a discount rate of 1.5%, the present value of $1,000 a century from now is $226; at 3% it is $52, and at 6%, it is merely $3. Run the clock forward another century, and the present value of $1,000 two centuries from now is $51 at 1.5%, $3 at 3%, or just $0.01 at 6%.

In other words, at a low discount rate such as 1.5%, the present value of a cost or benefit 100 years from now is almost one-fourth of the future value. Even after 200 years, it retains some visibility, with a present value of $51. On the other hand, at a 6% discount rate, costs and benefits 100 or 200 years barely matter today: the present value of $1,000 drops to $3 in one century, and to just a penny in two centuries. At 6% it is hard to "see" the future; it shrinks by five orders of magnitude in 200 years. A 3% rate, intermediate between these extremes, still belittles the far future, reducing $1,000 to a present value of $3 in 200 years. Even at a rate of 3% – the rate used in Defendants' SCC under the Obama Administration – long-term climate consequences are largely hidden by discounting.[3]

Table 1. Present value of $1,000 payment in future years

Years from now	*Discount rate* 1.5%	3%	6%
100	$226	$52	$3
200	$51	$3	$0.01

Source: Author's calculations. Amounts, except $0.01, rounded to nearest dollar.

Discounting does have appropriate applications. Using a market interest rate, discounting is appropriate for private financial decisions within a single lifetime. The present value of the entire stream of payments due on a mortgage, car loan, or student loan, discounted at the rate at which one borrowed the money, is simply the amount that one borrowed. If one has the option of making an investment with a known payoff at a fixed future date, one would be well-advised to compare the present value of the payoff to the cost of the investment today, discounting the payoff at the interest rate available on savings accounts or other risk-free investments. If the present value of the payoff is less than the cost of the investment today, one would be better off leaving the money in the bank.

However, the same logic does not apply to intergenerational decisions about public goods. There is no one person who will experience and compare both costs of climate and energy policy incurred today and benefits of that policy experienced a century or more from now. And in any

[3] Defendant EPA recognizes the serious equity considerations of discounting in an intergenerational context in its Guidelines for Preparing Economic Analyses: "compounding interest over very long time horizons can have profound impacts on the intergenerational distribution of welfare. An extremely large benefit or cost realized far into the future has essentially a present value of zero, even when discounted at a low rate." (EPA 2010)

case, the benefits accrue to everyone worldwide, not solely to the descendants or fellow citizens of those who pay the costs today. Thus, as many economists would agree, the discount rate for climate analysis is at least in part an ethical decision, expressing our beliefs today about the value of the lives and wellbeing of young people and future generations, and the environment that we are leaving to them. If our impacts on future generations matter, then the appropriate discount rate for climate costs and benefits needs to be very low, probably near zero, an argument made effectively in the Stern Review (Stern 2007), and other sources.

There are two major approaches to calculating the discount rate for climate analysis, known as the descriptive and prescriptive approaches (for the classic presentation of these approaches, see Arrow, Cline *et al.* 1996). The descriptive approach asserts that the discount rate should be based on the rate of return on assets in financial markets; the prescriptive approach develops a discount rate from principles of economic theory, ultimately including normative judgments about the weight that should be given to the utility and welfare of future generations. Arguments can be made within either framework for adopting a near-zero discount rate.

The descriptive approach argues that rates of return in financial markets must be the relevant standard, even for long-term climate analyses, since we have a choice between investing in climate mitigation or investing the same amount in financial assets held in trust for future generations. The idea is that discounting future impacts at the market rate of return will tell us which choice is worth more for our descendants.

However, there are multiple rates of return on financial assets varying, among other characteristics, in their level of risk. Stock markets, with relatively high rates of risk, have high rates of return, often estimated at 6% or more in the long run. Use of such a high discount rate would amount to ignoring the far future, as suggested by Table 1 above. On the other hand, virtually risk-free assets such as government bonds have much lower rates of return, and risk-reducing assets such as insurance policies have negative rates of return (in every year when you do not file a claim for payment under the policy).

Investing in climate mitigation most closely resembles investing in risk-neutral or risk-reducing financial assets, in the face of uncertain but extreme climate risks. If expenditure on climate mitigation is virtually risk-free, or perhaps even risk-reducing, the descriptive approach might imply that its costs and benefits should be discounted at a risk-free or risk-reducing rate – perhaps 1.5% or less. As Table 1 demonstrates, a rate of 1.5% implies that far-future impacts remain significant in present value, and hence, should influence policymaking today.

The prescriptive approach, in contrast, separates the question of the appropriate discount rate into two parts. The first part is based on the assumption of rising income levels, and the second would apply if every generation had equal resources.[4] Regarding the first part: if we assume future generations will be richer than we are today, each additional dollar will be worth less to them than it is to us. One part of the prescriptive discount rate is therefore based on the projected

[4] Theoretical analysis identifies a third part based on the year-to-year variation (in technical terms, the variance) of growth rates. This is frequently omitted in applied analyses, since it is difficult to forecast the variance of growth rates, and numerical simulations suggest that this third term may be small.

growth rate of per capita consumption.[5] This part is generally less controversial among economists; however, it is important to note that by the same logic, if future generations are poorer than we are, due to climate-induced losses or any other cause, then the same amount of money is worth more to them than to us, so this part of the discount rate should become negative. This is an important but often overlooked argument for very low discount rates when evaluating the worst potential climate outcomes.

The second part of the discount rate under the prescriptive approach is the rate that would be appropriate if we knew that every generation would have the same per capita resources. This is often referred to as the rate of pure time preference. Its value is a matter of ethical judgment – and of unresolved controversy. A positive rate of pure time preference implies that we judge the contribution of future generations to social welfare to be less than ours. In effect, it represents discrimination by date of birth. Concern about the ethics of this judgment is not new in economics, as acknowledged by the Federal Government's Interagency Working Group ("IWG") on the Social Cost of Carbon: "Ramsey (1928), for example, has argued that it is 'ethically indefensible' to apply a positive pure rate of time preference to discount values across generations, and many agree with this view." (IWG 2010) The Stern Review argued that intergenerational equity – i.e. taking future generations seriously – requires a near-zero rate of pure time preference.[6] Combined with a low estimate of future growth rates, this led Stern to use a discount rate of 1.4%, close to the lowest rate shown in Table 1.

In summary, while debate continues on the merits of descriptive versus prescriptive approaches to discounting, and on the numerical values to be used, strong arguments have been made for a very low discount rate under either approach, if a cost-benefit analysis is performed at all. This is important because a very low discount rate is required in order to recognize the importance of climate impacts on future generations and their wellbeing, as suggested by Table 1.

Low values such as the Stern Review discount rate of 1.4% have been endorsed by many economists. For example, Nicholas Stern (2007), Geoffrey Heal (2009), Chris Hope (Johnson and Hope 2012), Martin Weitzman (1998), William Cline (2004), John Broome (1992), Paul Kelleher (2012), and myself (Ackerman and Finlayson 2006), among others, have all expressed opinions that the discount rate applied to long-term climate change damages should be lower than the 3% rate assumed by the IWG.

The Trump Administration's March 28, 2017 Executive Order rescinding the social cost of carbon ("SCC") continues the government practice of using high discount rates, which knowingly results in policies that are dismissive of future impacts. The Executive Order states: "when monetizing the value of changes in greenhouse gas emissions resulting from regulations, including with respect to the consideration of domestic versus international impacts and the

[5] In a discount rate based on the prescriptive approach, the growth rate of consumption is multiplied by a parameter expressing how fast a fixed sum of money loses value to us as we become richer; in practice, that parameter is often assumed to be in the range of 1 to 3.

[6] A value of exactly zero leads to mathematical problems in formal modeling, and perhaps to implausibly strong implicit bias against the needs of the current generation. Stern (2007) proposed a rate of pure time preference of 0.1%, based on the assumption that we have an annual probability of 0.1% of destroying the human species. For Stern, all generations are of equal ethical importance if they exist, but next year's population is only 99.9% as important as this year's, due to its slightly lower probability of existence, and so on.

consideration of appropriate discount rates, agencies shall ensure, to the extent permitted by law, that any such estimates are consistent with the guidance contained in OMB Circular A-4 of September 17, 2003 (Regulatory Analysis)."[7] Circular A-4 describes the longstanding practice and policy in government regulatory analyses of assessing policies using both a 3% and a 7% discount rate. Whatever the historical merits of these rates, or the impacts in other arenas, in my opinion, they are far too high for sensible analysis of climate and energy policy. Even the use of a 3% discount rate – the rate used in Defendants' SCC under the Obama Administration – amounts to a dismissal of the impacts on future generations caused by present CO_2 emissions, compared to the lower rates used in the Stern Review and elsewhere. The discount rates mandated by the March 28, 2017 Executive Order continue to effectuate discrimination against future generations and children who will live into the second half of the century. By utilizing these inappropriately high discount rates, Defendants made a deliberate decision to be indifferent to the impacts on future generations caused by present CO_2 emissions, objectively knowing such impacts are substantially certain to result in continued and increased harm to the wellbeing and personal security of these Youth Plaintiffs and future generations.

II. Extreme risks and worst cases

Cost-benefit analysis requires a monetary value for every cost and every benefit – even those that are difficult or impossible to quantify. In the face of uncertainty, CBA requires an average, expected value, or most likely outcome. But the most worrisome consequences of climate change are the risks of catastrophic, irreversible changes for the worse, at times in the future that cannot be precisely predicted. Faced with catastrophic risks, most people do not think in terms of cost-benefit analysis; instead, they often buy insurance, even though they hope they will never need to use it. (This section of my report is based on the extended discussion of uncertainty and worst-case risks in Ackerman 2017.)

Consider the purchase of fire insurance. Public fire departments across the United States responded to 370,000 residential fires in 2013, while there were 133 million housing units in the country.[8] At that rate, the average housing unit has a fire large enough to report to the fire department once every 360 years. The annual number of fires is less than 0.3% of the number of housing units, so you have better than 99.7% confidence that you will not use your fire insurance next year. The most likely number of fires anyone will experience in a lifetime is zero.[9]

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[7] Presidential Executive Order on Promoting Energy Independence and Economic Growth, Sec. 5, March 28, 2017, https://www.whitehouse.gov/the-press-office/2017/03/28/presidential-executive-order-promoting-energy-independence-and-economi-1

[8] Fire data from National Fire Protection Association, "Fire Loss in the United States During 2013," http://www.nfpa.org/~/media/files/news-and-research/fire-statistics/overall-fire-statistics/fireloss2014.pdf?la=en. Housing unit data from the Census Bureau's American Housing Survey 2013, http://www.census.gov/programs-surveys/ahs/data/2013/national-summary-report-and-tables---ahs-2013.html.

[9] The National Fire Protection Agency similarly concluded that a household has a one in four chance of a fire reported to a fire department during an average lifetime. http://www.nfpa.org/research/reports-and-statistics/fires-by-property-type/residential/a-few-facts-at-the-household-level. If the annual probability of a fire is 0.3%, there is a one in four chance of a household having a fire every 95 years.

Much the same applies to life insurance, which is frequently purchased by young parents. The chance of dying next year is under 0.2% for the average American until age 40, and under 1% until age 60.[10] When homeowners buy fire insurance and young parents buy life insurance, they are expressing concern about potential personal disasters with probabilities of a few tenths of a percent per year.

Despite the fact that an insurance policy will lose money for the average policyholder, the worst-case outcome is bad enough to make it seem worthwhile. Even without knowing the exact probabilities of the ominous risks associated with climate change, future catastrophic outcomes are becoming more likely with every day we continue on a business-as-usual emissions trajectory, and delay serious emission reductions. Considering this, it makes sense to take catastrophic climate risks much more seriously, and to seek forms of collective self-insurance or protection against those risks (since there is no galactic insurance company that can write a policy covering damage to the only planetary climate we own).

In fact, the problem is more difficult than a decision to buy insurance, since we do not know the probabilities of worst-case outcomes. This leads to several unexpected results. For example, the Harvard economist Martin Weitzman (2009) proved what he called the "Dismal Theorem" of climate economics: the expected value of the benefits from emission reductions is literally infinite, essentially because worst-case scenarios could approach or include human extinction, and uncertainties regarding the probability of worst-case scenarios make it impossible to rule out those worst cases with sufficient confidence.[11]

Another strand of economic theory analyzes choices under deep uncertainty, where the range of possibilities is known, but nothing is known about their exact probabilities. Kenneth Arrow and Leonid Hurwicz, two well-known theorists who each won the Nobel Prize in economics, proved that if the possibilities are known but the probabilities are unknown, the ideal policy decision is based only on the best and worst possible outcomes (Arrow and Hurwicz 1972). Later work based on their result has shown if society is risk-averse or wants to keep its options open, only the worst case matters for choosing the best policy (Kelsey 1993, Gilboa and Scheidler 1989).

There is a secondary problem of determining whose forecasts of risks are credible, which may be particularly important in the age of Internet rumors and fake news. But the message of the Arrow-Hurwicz result and related later work is crucial for climate and energy policy: in the presence of inescapable uncertainties, policy should be based on the credible worst-case outcome. This, of course, entails rapid reduction in emissions to minimize the all-too-credible risks of abrupt, irreversible tipping points and catastrophic changes in the earth's climate. (Hansen et al. 2013, 2015) However, Defendants have not integrated these concerns about worst-case outcomes into their climate and energy policies and actions. The result is a theoretically unsound and dangerous bias favoring policies and actions that will increase the disproportionate climate damages and financial burden borne by these Youth Plaintiffs and future generations.

[10] Based on all-cause mortality rates for 5-year age brackets, calculated from Arias (2014), Table B.
[11] See also discussion of Weitzman's Dismal Theorem in Ackerman (2017), pp. 127-129.

III. Why not cost-benefit analysis?

Since the beginning of the Reagan Administration, the Federal Government has been required to conduct a cost-benefit analysis ("CBA") for any significant regulatory action, to ensure that the action is worth doing.[12] In addition to the problems related to discounting and responding to extreme but uncertain risks, there are multiple, fundamental flaws in CBA as it has been practiced in Defendants' recent policy analysis. Here I will discuss three factors that make CBA inappropriate for climate analysis[13], and for many other environmental analyses as well:

- Asymmetry and incomplete monetization of benefits vs. costs;
- Use of willingness to pay (WTP) rather than willingness to accept (WTA) for valuations of environmental benefits and fundamental human rights; and
- "Pricing the priceless" – the morally ambiguous improvisations at the heart of the CBA process for human rights and environmental concerns.

A. Asymmetry and incompleteness

A hidden assumption of the cost-benefit comparison is that the calculations of costs and benefits are comparably complete. The calculation explicitly mimics the decision-making of a business comparing its costs and revenues; a product is profitable if and only if revenues exceed costs. Note that this calculation is biased and unreliable if either the costs or the revenues are incomplete. A business that compared complete costs to a partial accounting of revenues could miss profitable opportunities for investment. The opposite mistake, comparing partial costs to complete revenues, could lead to missing the signals that the company is losing money.

CBA of climate, energy, or other environmental policies is typically imbalanced and biased, providing a relatively complete accounting of costs, versus an incomplete and problematical accounting of benefits. On the cost side, environmental protection usually requires spending money on technologies and activities with well-defined, easily discovered market prices. For example, it may be possible to document the costs of emission reduction for the electric power system, transportation, and other sectors.

In contrast, the CBA process for climate and energy policy is very likely to have only a partial accounting and valuation of benefits.[14] Analysts may not recognize or include all the benefits of,

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[12] This requirement first appeared on February 17, 1981, in President Reagan's Executive Order 12291 and has been updated and continued by subsequent Executive Orders under more recent administrations.

[13] Defendant EPA has confirmed this conclusion in a 2008 report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, "Analyses of the effects of global change on human health and welfare and human systems." The report stated: "the economic approach [to human welfare], when interpreted as requiring a strict cost-benefit test, is not appropriate in all circumstances, and is viewed by some as controversial in the context of climate change [due to considerations of intergenerational equity and 'potential irreversible consequences']. Benefit cost analysis is one tool available to decision makers; in the context of climate change; other decision rules and tools, or other definitions of welfare, may be equally, or more relevant." (Sussman et al. 2008)

[14] The Office of Management and Budget in its 2003 guidance on Regulatory Analyses explains how this can be misleading: "When important benefits and costs cannot be expressed in monetary units, [CBA] is less useful, and it can even be misleading, because the calculation of

for example, the immense health benefits from the cleaner air that results from reduction of greenhouse gas emissions[15], or the multiple ecological services that forest protection can provide. The benefits of climate policy include protection of human life, health, many dimensions of the natural environment, biodiversity, ecosystem services, and other non-market values, such as aesthetic, cultural, and spiritual values. Prices can be deduced for some of these values, but not all; construction of artificial prices for human life and nature is a controversial process requiring significant time and expense. (This differs from market prices, which are available to all with little or no cost of acquiring information.) Additional problems with the construction of prices for priceless values are discussed in subsection C below.

Moreover, if the value of benefits cannot be estimated, Defendants' default value is zero. The adversarial context of CBA for government policy insists that if a monetized value for a non-market benefit cannot meet very high standards of rigor and certainty, it must be treated as if it were zero.[16] Analysts often try to describe in qualitative terms the benefits that they could not monetize, surrounding the numbers with extensive verbal accounts and multiple caveats. This prose can vanish in the policymaking process, which often acts as a "caveat-stripper": lose the words, keep the numbers. When this occurs, all information is lost about important benefits that the analysts identified but could not monetize. The result is an impoverished discourse about climate impacts, and an underestimate of the costs of climate harm and the benefits of emission reduction – contributing to the bias Defendants have shown toward policy decisions that perpetuate the harm to these Youth Plaintiffs and future generations.

Due to the problem of asymmetry and incompleteness in any CBA of climate and energy policy, we are left with a comparison of relatively complete costs and much more incomplete monetized benefits – and therefore a meaningless bottom line.

B. Who pays whom?

In the attempt to monetize non-market values, economists often end up surveying people about what those values are worth to them. It is worth noting at the outset that this method cannot measure the value to children of health and environmental protection.[17] For adults, economic value can be expressed in either of two ways: the most a person is willing to pay ("WTP") to obtain a benefit or item that they do not now have, or the minimum amount a person is willing to

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net benefits in such cases does not provide a full evaluation of all relevant benefits and costs." (OMB 2003).

[15] For a review of the rapidly expanding literature on health co-benefits of greenhouse gas emission reduction, see Gao et al. (2018).

[16] This is the effect, though not the stated intent, of the 1993 Supreme Court decision in *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993), setting extremely high standards for admissible evidence in regulatory analyses. As a result of *Daubert* and related standards, "pressures for ever-increasing documentation, review, and 'sound science' have been used to create unreasonable standards of evidence, interfering with the government's task of protecting the public." (Neff and Goldman 2005)

[17] The Office of Management and Budget in its 2003 guidance on regulatory analyses points out that the valuation of health and safety risks to children and infants "poses special challenges" stating that "[i]t is rarely feasible to measure a child's willingness to pay for health improvement." (OMB 2003).

accept ("WTA") for giving up a benefit or item that they currently have. Some simple economic theories have suggested that at the margin, the two should be the same.

However, both theory and experiment now confirm that there can be a wide gap between WTP and WTA measures, with WTA routinely larger than WTP. In theory, the gap between the two depends, in part, on whether there are any close substitutes available for the benefit in question, with very wide gaps possible for irreplaceable benefits (Hanemann 1991). In practice, one of the classic experiments of behavioral economics shows that even for ordinary, easily replaced items, WTA can be greater than, and often twice as large as, WTP.[18]

For CBA, economists have standardized on WTP measures of non-market values, perhaps because they are easier to calculate, or avoid problems of very high, even infinite valuations (Arrow, Solow *et al.* 1993). In any carefully framed and conducted study, no one's WTP can meaningfully exceed their income or assets, whereas people could logically demand much more than their own resources to accept environmental degradation. In fact, a refusal to accept environmental loss or loss of fundamental rights like personal security at any price, a legitimate, perhaps common, preference, could show up as an infinite WTA.

Climate mitigation benefits, or conversely losses from unchecked climate change, frequently involve irreplaceable gains or losses, where WTP and WTA would be expected to differ most widely. The choice between these two methods, in effect, is a question of rights and ownership: is the public buying natural assets or pollution abatement from polluters, at the WTP rate? This assumes that polluters own the environment and have the right to pollute. Or are polluters buying the opportunity to pollute from the public, at the WTA rate? The latter option assumes that the public owns the environment, and has the right to refuse pollution and be free from harm. Whatever the historical origins of the practice, standardization on WTP valuations in CBA amounts to asserting that the public has to buy nature from the polluters – a choice that lowers the value assigned to climate protection.

To make this more concrete, consider the plight of Levi, the youngest of the Youth Plaintiffs in this case, a child who lives on a barrier island off the coast of Florida. His WTP to avoid sea-level rise that would destroy his home and the surrounding beach is presumably limited to some fraction of his limited assets. His WTA value for destruction of his home and community could be very large, even infinite. Use of WTP reinforces inequality, since wealthier communities are willing to pay more, "justifying" greater protection for them. Moreover, the WTP approach implicitly asserts that Levi and his neighbors may have to buy the right to continue living where they do, from polluters who would profit by contributing to their community's destruction.

C. Pricing the priceless

Many of the benefits of climate and environmental protection are difficult to value because they consist of saving human lives, preventing extinction of species, and other non-marketable goals.

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[18] A group of college students were randomly given either a mass-produced coffee mug decorated with their college insignia, or an amount of money equal to the market price of the mug, and then invited to trade with each other. WTA, i.e. the price at which those who were given mugs were willing to sell them, averaged about twice as much as WTP, the amount that those who received cash would pay for a mug. This general pattern has reportedly been found in a number of other settings (Kahneman 2011).

Since air pollution kills many people, the value of each life saved is crucial to valuation of the benefits of pollution reduction. For CBA purposes, it has become common to assume values around $9 million per life saved (often called the "value of a statistical life", or VSL) in the United States. Regulations that save lives at less than $9 million apiece pass a cost benefit test; those that cost more than $9 million per saved life fail the test.

This monetization of a human life at $9 million does not mean, however, that you can buy the right to kill someone for $10 million. Even stranger is the alternative, favored by some analysts, of individually valuing each year of life saved; since everyone will eventually die, the argument goes, all we are doing is saving life-years. But assigning a fixed dollar value per saved life-year suggests that, contrary to all major ethical and religious beliefs, it is a lesser crime to kill an older person.

The urge to monetization has mis-framed the question of the value of life. Figures such as $9 million per life saved are built up from small risks, such as $9 WTP to avoid a one-in-a-million risk of death. But imagine one million people, all facing a one-in-a-million risk of death. On average, all but one of them will survive, although experiencing that $9 risk. Those risks to the 999,999 survivors total almost $9 million in value, amounting, in round numbers to the value of one "statistical life." One of the million people, on average, will not survive; that person's much worse experience is not meaningfully addressed by the $9 WTP value nor the $9 million VSL.

WTP to avoid small fractional risks of premature death can, arguably, place a value on risks experienced by those who survive. It cannot, however, value life itself, which has no meaningful monetary price. As the philosopher Immanuel Kant said long ago, some things have a price, while other things have a dignity (Kant 2005 [1785]).

The same is true of the natural world and the valuation of non-human species. A study, some years ago, found that U.S. households were willing to pay a total of $18 billion to prevent the extinction of humpback whales.[19] This does not mean that anyone would have welcomed an offer of $20 billion for the opportunity to hunt humpback whales to extinction. Rather, the $18 billion WTP value was an inarticulate statement of the fact that people value the survival of whales very highly; the number itself has no real meaning. Whales, too, as sentient beings and thus proper objects of our moral concern, have a dignity, and not a price.

A final, jarring example of an attempt to monetize the priceless came in a Department of Justice study, which chose to conduct a CBA of the Prison Rape Elimination Act. The study, which was clearly not required by law, has been praised by prominent CBA advocates (Sunstein 2014). A centerpiece of the study was the value of an avoided rape, reportedly $310,000. Resembling the problems with the value of a statistical life, the number apparently came from a survey asking people how much they would pay to live in a neighborhood with fewer rapes. Once again, it is a value of avoiding small risks experienced by those who do not suffer the horrific event being evaluated. The assigned price again illustrates the poverty of thinking underlying traditional CBA. Freedom from violence also has a dignity, and that too should not be ignored simply because it is not susceptible to accurate pricing.

Climate mitigation is full of parallel cases: policies that will protect human lives, species at risk, public trust resources, and other priceless values such as these Youth Plaintiffs' fundamental

[19] See the account in Ackerman and Heinzerling (2004).

constitutional rights. However, these priceless benefits from climate mitigation are deliberately not reflected in Defendants' climate and energy policies or actions. The invented imperative of cost-benefit analysis neither justifies nor renders rational the assignment of prices to human lives and other matters of intrinsic concern. They are worth protecting because of their dignity, not their invented prices. But if all you have is a calculator, everything looks like a number.

IV. The social cost of carbon: Getting the numbers wrong

Economic analysis of climate damages is often summarized in estimates of the social cost of carbon ("SCC"), defined as the present value of the present and future damages caused by emission of one additional ton of CO_2. The previous sections of this expert report identified many reasons why such numerical estimates are likely to be incomplete and understate the true extent of climate damages. This section explores recent calculations of the SCC in greater detail, focusing on the models used in the federal Interagency Working Group ("IWG") calculations in 2010 and 2013 (IWG 2010, 2016).

Economic theory describes environmental damages as negative externalities, or costs that market transactions impose on uninvolved third parties. For example, the Plaintiffs in this case, and others of their generation and their descendants, were neither the buyers nor the sellers of fossil fuels that caused most of the harm to the climate. The theoretical remedy, known since the work of Arthur Pigou (1920), is that the costs of externalities should be internalized, or included in the price of activities that cause emissions. This would force buyers and sellers to recognize the true costs of emissions, and would decrease demand.

If the SCC were an accurate measure of climate damages, then it could be incorporated into prices of fossil fuels (and other sources of CO_2), sending a strong price signal about the need to cut back on these fuels and their associated emissions. In practice, this has never been done for the economy as a whole, although many Obama Administration regulatory analyses included the IWG's SCC estimate for the value of carbon emissions. For example, this added to the calculated benefits of vehicle fuel economy standards, since those standards (modestly) reduced fuel use and vehicle emissions. (Conversely, the Trump Administration's abandonment of the SCC means that there is a complete lack of internalization of climate externalities; continuing the same example, the calculated benefits of vehicle fuel economy standards would now be lower, with the cost of carbon emissions effectively valued at zero.)

The IWG's analyses averaged the results from slightly modified versions of three integrated assessment models ("IAMs"), known as DICE, PAGE, and FUND. IAMs offer "integrated" calculations of the future evolution of the global economy and climate, at a very simplified level. The three chosen models are perhaps the best-known IAMs, but not necessarily the most accurate, and certainly not the most detailed. A 2017 review by the National Academy of Sciences (NAS 2017) identifies numerous weaknesses in these three models, and makes many suggestions for improvement.

A. Damage functions and dated research

IAMs rely on a "damage function" – a mathematical representation of the damages expected as temperatures and sea levels rise. The creation and validation of a damage function is difficult, as it describes climate-related losses expected under conditions that are outside our historical experience. Nonetheless, there is a certain amount of research bearing on this subject. As the

National Academy of Sciences review (NAS 2017) points out, the three IAMs used by the IWG, namely DICE, PAGE, and FUND, rely on dated research.

FUND, the one of the three models with the most disaggregated damage calculations, relies heavily on estimates of climate damage from the 1990s. According to NAS (2017), FUND version 3.8, used in the 2013 IWG calculation, relied on 27 sources for its damage estimates – 18 of them published in the 1990s.[20] This is potentially important because FUND consistently produces the lowest estimate of climate damages among the three models relied on by the IWG, reducing the SCC (which is calculated as a three-model average). FUND's agricultural estimates, drawing on 1990s research, project net global benefits from the first few degrees of warming, offsetting damages in other sectors (Ackerman and Munitz 2012, 2016). Newer research is available, often projecting a more ominous picture of damages in agriculture from near-term climate changes. Indeed, the NAS review offers a list of 30 sources, published from 2007 to 2016, which could be used to update climate damage estimates relied on by FUND.[21]

DICE and PAGE also understate the cost of climate damages, but offer less detailed development of their damage estimates. The latest version of DICE (newer than the one used by the IWG), DICE-2016R, bases its damage estimates on a recent (apparently unpublished) literature review by William Nordhaus and a coauthor. According to Nordhaus, the economist who developed DICE, the damage function in DICE-2016R implies global climate damages equal to 2.1% of income at 3°C of warming, and 8.5% of income at 6°C (Nordhaus 2017, supplementary information). At recent U.S. growth rates, this means that 3°C of warming would cause damages equal to the loss of less than 18 months of economic growth, equivalent to taking us back to the economy of early 2017, while the damages from 6°C would be equivalent to losing less than 5 years of growth – the same as busting us all the way back to 2013. At China's much faster growth rates, even 6°C would cause losses of less than 18 months of growth, sending the Chinese economy back to early 2017.

Whatever the source of the DICE damage estimates, they appear to trivialize the risks of significant warming. In his recent writing, Nordhaus has emphasized unquantifiable impacts and risks of irreversible extreme events (Nordhaus 2013). But the damage function in his model lags behind his qualitative descriptions of climate risk, helping to perpetuate an understatement of the cost of emissions.

Defendants, through the IWG (in both 2010 and later revisions), recognized the many sources of uncertainty and important limitations of the IAMs relied upon for the SCC. The IWG admitted that the IAMs do not include "all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature" due to a "lack of precise information on the nature of damages and because the science incorporated into these models understandably lags behind the most recent research." (IWG 2010, 2016) Importantly, the IWG recognized its complete inability to monetize, and thus omission, of significant and severe climate impacts: "even in future applications, a number of potentially significant damage categories will remain non-monetized. (Ocean acidification is one example of a potentially large damage from CO_2 emissions not quantified by any of the three models. Species and wildlife loss is another example that is exceedingly difficult to monetize.)" (IWG 2010)

[20] See NAS (2017), Table 5.2. Two of the nine "newer" sources for FUND 3.8 were review articles by one of FUND's developers, published in 2002.
[21] NAS (2017), Table 5.3.

In addition to the complete omission of these severe damages from the SCC estimates, the IWG noted other sources of uncertainty that have not yet been fully quantified in the IAM's, and thus Defendants' SCC estimate under the Obama Administration, including potential catastrophic damages due to "tipping points" in Earth systems with "potentially severe social and economic consequences" and "inter-sectoral and inter-regional interactions, including global security impacts of high-end warming." (IWG 2010, 2016)

The IWG also explained the risks of using conventional economic analysis and assumptions in the context of climate change: "The three IAMs used here assume that it is possible to compensate for the economic consequences of damages to natural systems through increased consumption of non-climate goods, a common assumption in many economic models. In the context of climate change, however, it is possible that the damages to natural systems could become so great that no increase in consumption of non-climate goods would provide complete compensation. . . . For instance, as water supplies become scarcer or ecosystems become more fragile and less bio-diverse, the services they provide may become increasingly more costly to replace." (IWG 2010)

B. Published estimates of the SCC

There is a wide range of published estimates of the SCC, many of them much higher than the estimates the IWG proposed for use in U.S. government cost-benefit analyses. The federal IWG's final revision, in August 2016, put the SCC, in 2017 dollars, at $42 per metric ton of CO_2 in 2015, rising to $49 for emissions in 2020 and $81 in 2050 (IWG 2016).[22] The IWG offered two variants on its own work that implied much higher values: reducing the discount rate from 3% to 2.5% would raise the SCC by about 40%, while using much higher climate sensitivity (implying much greater long-term warming from the same level of greenhouse gases in the atmosphere), at a 3% discount rate, would roughly triple the SCC.[23]

Several SCC calculations have been done with DICE, after making minor modifications to the model. In my own work, coauthored with Elizabeth A. Stanton, we explored combinations of four changes to DICE: lowering the discount rate to 1.5%, adopting much higher climate sensitivity, and making two adjustments to the DICE damage function, one of which was based on Martin Weitzman's suggestion of 50% loss of global income at 6°C and 99% loss at 12°C (Ackerman and Stanton 2012). With four independent changes to the DICE defaults, we produced 16 variants on the SCC. Our estimates for the SCC in 2050, converted to 2017 dollars, ranged from $75 to $1,824 per metric ton of CO_2. The point is not that we know the SCC will be over $1,800 in 2050; rather, we do not know with any reasonable level of confidence that the

[22] The basic modeling was done by the IWG twice, in 2010 and 2013. Several technical updates made minor corrections to the 2013 estimate after publication. The results were published in 2007 dollars, and have been multiplied by 1.177 to convert to 2017 dollars, based on the increase in the Consumer Price Index. The figures here are the so-called "central estimate", based on a 3% discount rate and median climate sensitivity.

[23] Results were not provided for the combination of these two innovations. Another set of IWG calculations raised the discount rate to 5%, resulting in an SCC of about one-third of the "central estimate". For the reasons I have explained above, estimates of the SCC using a discount rate this large are not appropriate for Defendants' climate and energy policies and actions.

SCC will not be that high. The range of uncertainty in the DICE SCC, considering only the four changes we examined, is more than twenty-fold (i.e., $1,824 is more than 20 times $75).

In Nordhaus' latest work (Nordhaus 2017), using a newer version of DICE than used in my research, or in the IWG calculations, he finds that in his most severely climate-constrained scenario, the SCC rises from $207 in 2015 to $1,129 in 2050.[24] For another analysis that finds that revision of the DICE damage function can cause a large increase in the estimated SCC, see Howard and Sterner (2017). Yet another analysis, using an older version of DICE, modified to include the risks of multiple tipping-point catastrophes, found that those risks increased the SCC to $130 in 2017 dollars (Cai et al. 2016).

Chris Hope, the developer of the PAGE model, has also estimated the SCC to be higher than the government's calculation. Hope has published an analysis of the SCC implied by his PAGE09 model (Hope 2011). His preferred estimate, using his default values, is equivalent to $151 in 2017 dollars.[25] PAGE has always been the source of the highest SCC estimates in the IWG process, but the estimate using Hope's preferred values is even higher than the IWG's modified PAGE values.

Surveys of scientists and economists show broad agreement that the IWG's SCC is too low. Robert Pindyck (2016) surveyed several hundred climate experts, both economists and scientists, and concludes that their consensus estimate, for the SCC today, is about $200 for the entire sample, or $80 for the subset who expressed high confidence in their estimates. Estimates from scientists were, on average, much higher than from economists. In another survey of experts on the economics of climate change, over half of the respondents believed that the SCC should be higher than the IWG estimate, and only 8% of respondents believed it should be less (Howard and Sylvan 2015).

A meta-analysis (van den Bergh and Botzen 2014), exploring risks and uncertainties left out of the standard IAM calculations, concluded that the SCC should be at least $125, and perhaps much higher. A modification of DICE, incorporating new research showing that temperature increases lead to slower economic growth, implies a SCC more than six times the standard DICE estimate today, and rising rapidly beyond that over the next few decades (Moore and Diaz 2015).

In short, there is an enormous range of SCC estimates, including values far above the IWG estimates, that have appeared in the recent climate economics literature. The IWG itself recognized the inherent uncertainty about the value of the SCC and concluded in 2016 that due to the many sources of uncertainty and important limitations in the IAMs (discussed above), the SCC "estimates are likely conservative." The IWG quotes from the IPCC Fourth Assessment Report's conclusion that the SCC "estimates 'very likely . . . underestimate the damage costs' due to omitted impacts. Since then, the peer-reviewed literature has continued to support this conclusion, as noted in the IPCC Fifth Assessment report." (IWG 2016) There is nothing

[24] These numbers are for his scenario constrained to stay under 2.5°C of warming. The higher SCC results from the constraint, not from a different damage function. Results in Nordhaus (2017) were published in 2010 dollars, and have been converted to 2017 dollars by multiplying by 1.122.
[25] His published value of $106 for 2010, in 2000 dollars, was multiplied by 1.427 to convert to 2017 dollars.

approaching a consensus about the SCC – which is another way of saying that the exact damages expected from climate change remain uncertain, but potentially very serious.

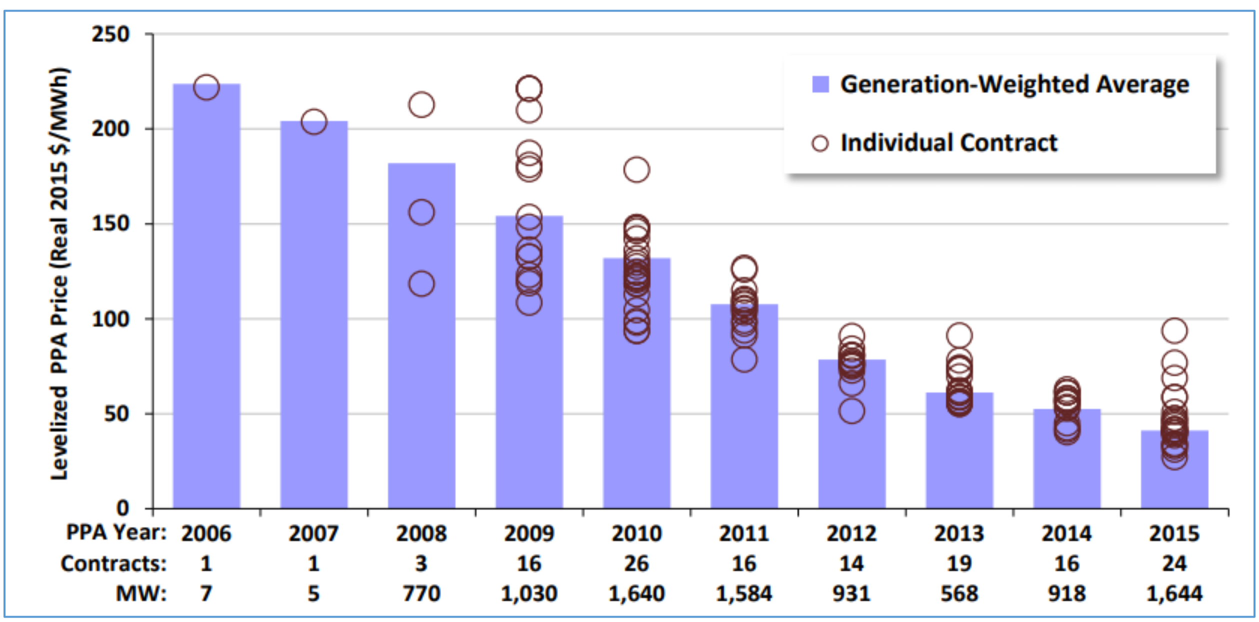
The preceding paragraphs also suggest it would be reasonable to conclude that the actual SCC is several times greater than the Obama Administration's admittedly conservative and incomplete estimates of the SCC. Those estimates therefore provided a knowingly biased basis for Defendants' policies and actions favoring the burning of fossil fuels and imposing the costs on these Youth Plaintiffs and future generations. Actions by the Trump Administration to abandon consideration of the SCC deliberately exacerbate the bias.

V. The low cost of climate protection

The costs of climate impacts are high and increasing, while the costs of climate protection technologies are low and decreasing. The uncertainties surrounding climate damages (and hence the benefits of avoiding those damages) involve risks of disastrously worse-than-expected outcomes, which are difficult to rule out with a comfortable level of confidence. In contrast, the uncertainties surrounding the costs of emissions are often a source of optimism: prices for clean energy, especially solar power, have dropped precipitously in recent years.

The levelized prices in purchased power agreements ("PPAs") for utility-scale photovoltaic installations are falling, as shown in **Figure 1**. These are the prices that independent solar power producers receive when they sign long-term contracts to provide power to local utilities, including the effects of subsidies.[26]

Figure 1. Levelized photovoltaic PPA prices by contract vintage



Source: Mark Bolinger and Joachim Seel, "Utility-Scale Solar 2015" (Lawrence Berkeley National Laboratory, 2016), p.33.

[26] "Levelized" means these are the average present value prices over the lifetime of the contract. They were calculated using a 7% discount rate.

The price of solar electricity generation is falling precipitously. As recently as 2006-07, large-scale solar installations were rare, and the few large-scale solar installations that existed were receiving over $200 per MWh – or $0.20 per kwh. By 2014-15, utility-scale contracts were numerous, with average payments of $50 per MWh ($0.05 per kwh) or less – that is, less than one-fourth of the rate just eight years earlier. (Other measures of costs of solar power yield different numbers, but the downward trend remains unexpectedly strong, and encouraging.) Ten years ago, it would have seemed foolishly optimistic to predict such a rapid decline in renewable energy costs absent government leadership and support. Yet it has happened: wind and solar power are now important resources in state energy planning. Indeed, wind power plays an even larger role than solar power. In two states, Iowa and South Dakota, wind was the source of more than 30% of total electricity generation in 2016, and 12 other states exceeded 10%.[27]

There are now multiple studies – based on costs of renewable energy that are only a few years out of date – showing that 80% reduction in emissions by 2050 can be achieved with moderate, if any, increases in energy costs, without assuming any SCC or other internalization of climate damages (Ackerman et al. 2015, Williams, Haley, *et al.* 2015, White House CEQ 2016). This target requires doing more than switching to clean sources of electricity: emissions from electricity generation were only 29% of total U.S. carbon emissions in 2015.[28] In addition to introducing nearly emission-free electricity, the 80% reduction target requires electrifying other fossil fuel-using sectors such as light-duty vehicles (cars, pickups, and SUVs), residential and commercial heating, and others.

To achieve the even greater reduction in emissions, close to 100% by 2050, which Hansen et al. (2013) found to be necessary to achieve climate stability, even more must be done. Additional sectors such as heavy-duty vehicles (trucks and buses), agriculture, and industry must also be converted to zero-carbon fuels and technologies. Technologies that reduce emissions in these sectors are also progressing rapidly. For example, through the Department of Energy's "SuperTruck" program, major truck manufacturers have already produced tractor-trailer prototypes using half the fuel of conventional models.[29] This and other advances provide grounds for optimism about completing the transition to a carbon-free economy – a goal that is urgent to complete as rapidly as possible. The urgency with which Defendants treat that goal is ultimately a judgment about how to value today's youngest generation and those who will follow them.

CONCLUSION AND RECOMMENDATIONS

My expert report identifies deliberate biases in Defendants' use of the conventional economic treatment of the costs and benefits of climate policies, including the federal government's development of an estimated social cost of carbon as a measure of expected climate damages. I find that there are multiple reasons why Defendants use of standard economic analyses has materially understated the costs of business as usual, while the costs of taking action to mitigate

[27] American Wind Energy Association, "U.S. wind generation reached 5.5% of the grid in 2016", March 6, 2017, http://www.awea.org/MediaCenter/pressrelease.aspx?ItemNumber=9999.
[28] Data on emissions from https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.
[29] Department of Energy, "SuperTruck leading the way in efficiency for heavy duty, long haul vehicles", June 27, 2016, https://energy.gov/eere/articles/supertruck-leading-way-efficiency-heavy-duty-long-haul-vehicles.

climate harm have often been exaggerated. As a result, Defendants' economic analyses underestimate and devalue the serious harm from climate change that young people and future generations will experience, allowing the short-term economic benefits of not regulating (or insufficient regulations) to outweigh extremely severe long-term impacts in its cost-benefit analysis. This biased result does not reflect the reality that continuing to burn fossil fuels and increase CO_2 emissions will be extremely harmful to these Youth Plaintiffs and future generations and that this harm far exceeds the costs of implementing measures that would prevent this harm. Accordingly, Defendants have been on notice for some time that their policies pose a substantial risk of serious harm to these Youth Plaintiffs and future generations, and they continue to be deliberately indifferent to that risk.

Defendants are unreasonably placing the welfare of our nation's youngest and future generations at risk, by allowing climate change to proceed with too little effort to reduce emissions and their potentially catastrophic and irreversible impacts. My grandchildren, and the Plaintiffs in this case, as well as the generations that will follow them, deserve a climate and environment as stable and supportive of human and natural life as the one I grew up in. To that end, Defendants should be directed to rapidly accelerate efforts to reduce greenhouse gas emissions, and to stop supporting and promoting fossil fuel energy, supported by the corrected and updated economic analysis that I have described in this expert report.

Signed this 13th day of April, 2018 in Cambridge, Massachusetts.

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PROFESSIONAL EXPERIENCE

Synapse Energy Economics Inc., Cambridge, MA. *Principal Economist*, 2012 – present.

Consults on issues of energy economics, environmental impacts, climate change policy, and environmental externalities valuation.

Boston University, Global Economic Governance Institute, Boston, MA. *Senior Research Scholar*, 2016 – present.

Assisting in research on trade and environment, and advising graduate student research.

Massachusetts Institute of Technology, Cambridge, MA. *Lecturer, Department of Urban Studies and Planning*, 2014 –2015.

Taught graduate seminars on "Electricity, Economics, and Environment" and "Climate Economics and Policy."

Stockholm Environment Institute – US Center, Somerville, MA. *Senior Economist and Director of Climate Economics Group*, 2007 – 2012.

Wrote extensively for academic, policy, and general audiences, and directed studies for a wide range of government agencies, international organizations, and nonprofit groups.

Tufts University, Global Development and Environment Institute, Medford, MA. *Senior Researcher*, 1995 – 2007.

Editor of GDAE's *Frontier Issues in Economic Thought* book series, a coauthor of GDAE's macroeconomics textbook, and Director of the institute's Research and Policy program. Taught courses in the Tufts Department of Urban and Environmental Policy and Planning.

Tellus Institute, Boston, MA. *Senior Economist*, 1985 – 1995.

Responsible for research and consulting on aspects of economics of energy systems and of solid waste and recycling.

University of Massachusetts, Amherst, and Boston, MA. *Visiting Assistant Professor of Economics*, 1982 – 1984.

Dollars and Sense, Somerville, MA. *Editor and Business Manager*, 1974 – 1982.

EDUCATION

Harvard University, Cambridge, MA
Doctor of Philosophy in Economics, 1975

Swarthmore College, Swarthmore, PA
BA in Mathematics and Economics, 1967

AFILLIATIONS

Economics for Equity and the Environment (E3 Network), Portland, OR
Co-founder and steering committee member, 2007 – present

Center for Progressive Reform, Washington, DC
Member scholar, 2002 – present

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Commonwealth of Kentucky, Kentucky Public Service Commission (Case No. 2013-00199): Direct testimony regarding the Application of Big Rivers Electric Corporation for a General Adjustment in Rates. On behalf of Ben Taylor and the Sierra Club. October 28, 2013.

State of Nevada, Public Utilities Commission of Nevada (Docket No. 13-07021): Direct testimony regarding the proposed merger of NV Energy, Inc. and MidAmerican Energy Holdings Company. On behalf of the Sierra Club. October 24, 2013.

Commonwealth of Kentucky, Kentucky Public Service Commission (Case No. 2012-00535): Direct testimony regarding the Application of Big Rivers Electric Corporation for a General Adjustment in Rates. On behalf of Ben Taylor and the Sierra Club. May 24, 2013.

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Exhibit B: References

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Exhibit 2

EXPERT REPORT
OF
HOWARD FRUMKIN, MD, MPH, DrPH

Professor of Environmental and Occupational Health Sciences
University of Washington School of Public Health

Kelsey Cascadia Rose Juliana; Xiuhtezcatl Tonatiuh M.,
through his Guardian Tamara Roske-Martinez; et al.,
Plaintiffs,

v.

The United States of America; Donald Trump,
in his official capacity as President of the United States; et al.,
Defendants.

IN THE UNITED STATES DISTRICT COURT
DISTRICT OF OREGON

(Case No.: 6:15-cv-01517-TC)

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TABLE OF ACRONYMS AND ABBREVIATIONS

ACE3: *America's Children and the Environment*, Third Edition
CDC: U.S. Centers for Disease Control and Prevention
CO_2: Carbon dioxide
EPA: U.S. Environmental Protection Agency
GHG: Greenhouse gas
HABs: Harmful algal blooms
IPCC: Intergovernmental Panel on Climate Change
OPOH: Our Planet, Our Health
PAM: Primary amebic meningoencephalitis

INTRODUCTION

I, Howard Frumkin, am a physician and epidemiologist specializing in environmental health. I have been retained by the Plaintiffs to give my expert opinion on the health impacts of climate change, with particular emphasis on those impacts affecting children, and on present and future health impacts that will affect today's young people as they reach adulthood at a time of ongoing climate change.

QUALIFICATIONS

My professional training includes a medical degree from the University of Pennsylvania, masters and doctoral degrees in public health from Harvard University, residency training in Internal Medicine at the University of Pennsylvania and Harvard, and residency training in Environmental and Occupational Medicine at Harvard. I held faculty positions at the University of Pennsylvania School of Medicine (1988-90) and at Emory University's Rollins School of Public Health (1990-2005) and served as the Director of the National Center for Environmental Health and Agency for Toxic Substances and Disease Registry at the U.S. Centers for Disease Control and Prevention (2005-2010) and as Special Assistant to the Director for Climate Change and Health (2010) before joining the faculty at the University of Washington as Dean of Public Health, in 2010. I served as Dean through 2016 and subsequently as Professor in the Department of Environmental and Occupational Health Sciences. Commencing in May 2018, I will be heading the "Our Planet, Our Health" ("OPOH") initiative at the Wellcome Trust. OPOH is one of the world's leading research funding initiatives at the intersection of human health, climate change, urbanization, and food systems--the emerging paradigm known as planetary health. OPOH supports research on six continents, using a wide range of methods and perspectives. OPOH is committed to improving the evidence base in planetary health, to communicating that evidence effectively, and to engaging with governments, civil society, and the private sector to translate evidence into action to meet major environmental and health challenges.

Climate change and its impact on health have been one of my principal academic and scientific interests for over 20 years. I have followed the scientific literature closely during that time, and have published numerous research papers and book chapters (see **Exhibit A**). I have participated in writing and reviewing high-level reports on the health impacts of climate change, including reviewing, evaluating, and summarizing the evidence used in those reports. As a member of the Children's Health Protection Advisory Committee at the U.S. Environmental Protection Agency (EPA), I chaired the Committee's Climate Change working group. While working at the CDC, I initiated and oversaw the formation of that Agency's Climate and Health program, and served as the principal advisor to the Director on health aspects of climate change. I represented the CDC to the U.S. Global Climate Research Program. I served on the Advisory Board of the Yale Climate and Energy Institute, and on the American Association for the Advancement of Science Climate Science Panel. Beginning in May 2018, I will head the "Our Planet, Our Health" initiative at the Wellcome Trust in London, one of the world's largest sources of support for research at the intersection of health and climate change. I have spoken to numerous medical, public health, and other audiences on health aspects of climate change, and have taught this subject to undergraduate and graduate students.

This report contains my opinions, conclusions and the reasons therefore. My current curriculum vitae and a list of my relevant publications, is contained in **Exhibit A** to this expert report. My report contains citations to sources I have used or considered in forming my opinions, listed in **Exhibit B**. I am working pro bono to prepare this expert report in this action.

The opinions expressed in this expert report are my own and are based on the data and facts available to me at the time of writing. All opinions expressed herein are to a reasonable degree of scientific certainty, unless otherwise specifically stated. Should additional relevant or pertinent information become available, I reserve the right to supplement the discussion and findings in this report.

EXECUTIVE SUMMARY

Climate change, due in large part to human activity (principally the combustion of fossil fuels, and to a lesser extent land use changes and the release of climate-active air pollutants), threatens human health and well-being through a variety of pathways. The impacts on people can be divided into several categories: temperature-related effects; the effects of severe weather and disasters; the impact of reduced air quality; aggravation of allergies; increased risk of infectious diseases; nutritional effects; population displacement; civil conflict; and mental health impacts. While these risks, to some extent, will affect everybody, some groups are especially vulnerable, and children comprise one such group. The Plaintiffs in this case exemplify these vulnerabilities. Moreover, today's children will be tomorrow's adults, and will bear the risks that unfold over coming decades as the effects of climate change intensify. Climate change poses serious risks to the health and well-being of the Plaintiffs in this lawsuit.

EXPERT OPINION

Overview

Climate change affects human health through a range of pathways, as shown in **Figure 1**. Some of these are direct, such as the injuries that occur in a climate-related disaster. Some are indirect, such as nutritional challenges that result from climate impacts on crops. Still others are mediated through social processes, such as conflicts. The health effects of climate change have been extensively inventoried and reviewed, by the Intergovernmental Panel on Climate Change (IPCC),[1] by the Federal government,[2,3] in academic journals,[4-6] and in books.[7-9] Children represent a particular risk group, and the impacts of climate change on children have been specifically reviewed as well.[10-13] Below, I summarize the major health impacts of climate change, as recognized by the scientific community.

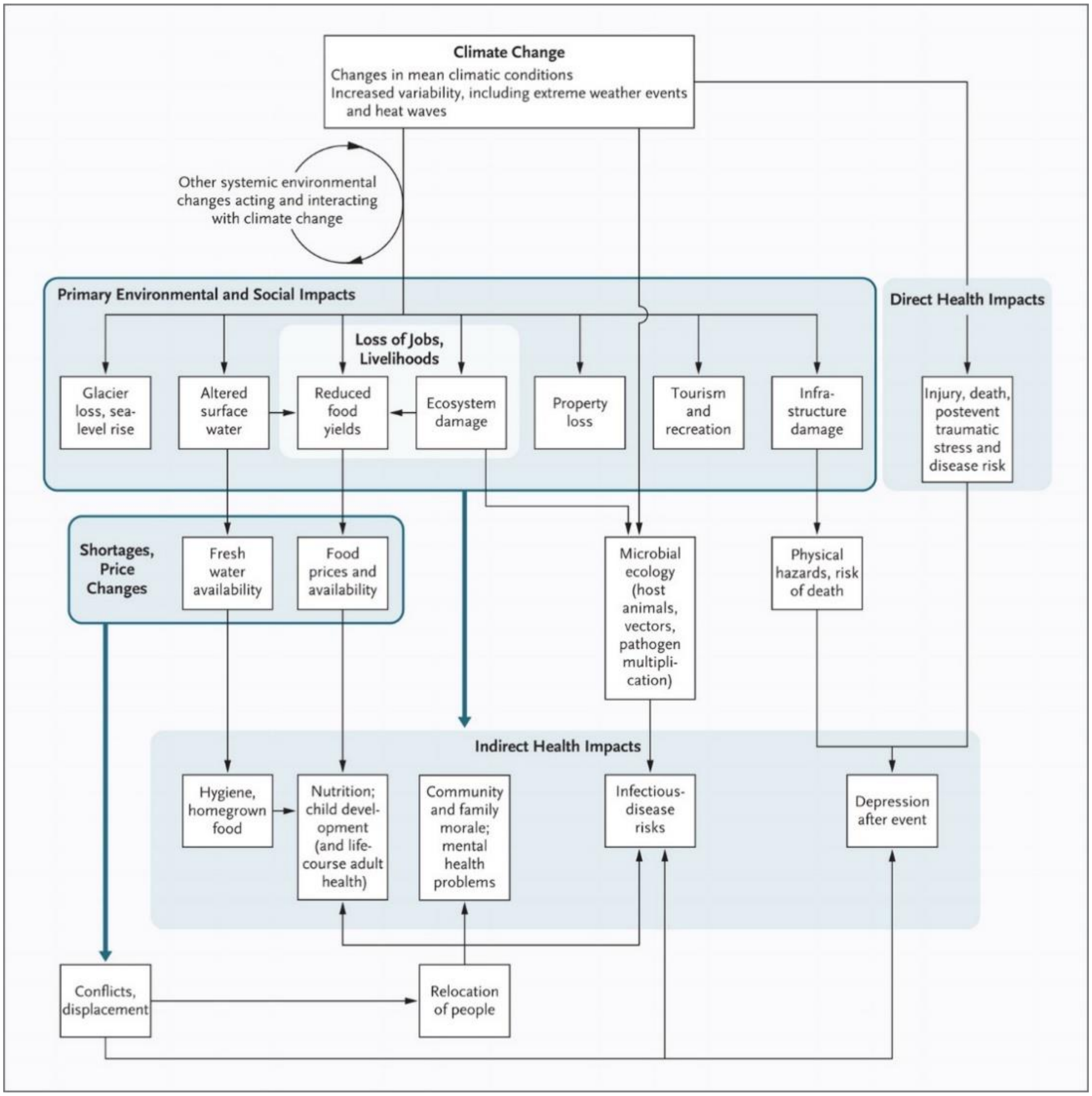


Figure 1: Processes and pathways through which climate change affects human health. Source: [4]

Temperature-related effects

Excessive heat—both during severe heat waves and as a long-term "new normal"—threatens health and well-being in numerous ways. Medical consequences range from relatively minor, self-limited conditions, such as heat rash and cramping, to severe and possibly fatal outcomes, such as heat stroke. More consequentially from a population point of view, mortality rates rise during periods of heat, mostly due to increases in cardiovascular deaths.[14] For example, the 1995 Chicago heat wave caused approximately 700 excess deaths;[15] the 2003 European heat wave had an impact two orders of magnitude higher, at an estimated 70,000 excess deaths;[16] and the 2010 Russian heat wave caused 11,000 excess deaths.[17]

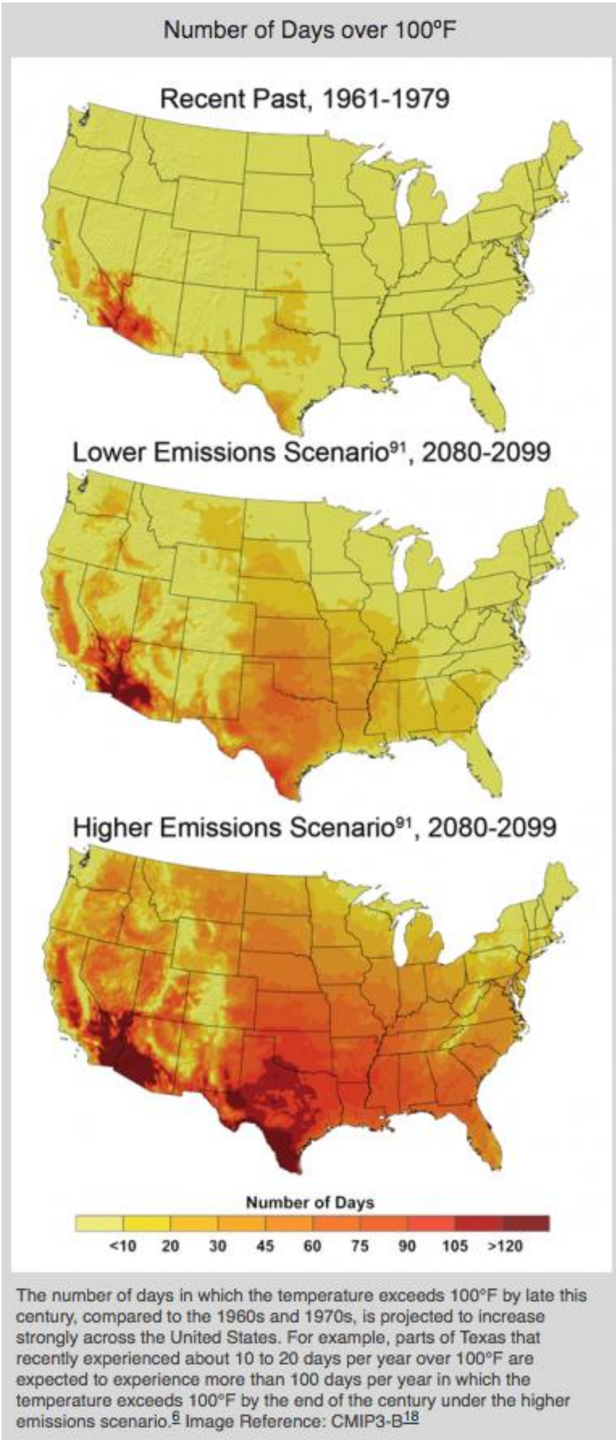


Figure 2. The number of days each year over 100°F later this century. Source: Karl TR, Melillo JM, Peterson TC, eds. *Global Climate Change Impacts in the United States.* Cambridge and New York: Cambridge University Press; 2009.

In addition to these lethal effects, heat is associated with a range of other impacts, from increased risk of kidney stones[18,19] to impaired sleep,[20] from increased violence[21,22] to substantial reductions in work capacity (with serious social and economic consequences).[23,24] Concomitant trends affect the risk posed by heat. For example, urbanization concentrates people in metropolitan areas, where the urban heat island effect amplifies the impact of rising temperatures.[25,26] Similarly, heat not only creates its own risks, but also reduces air quality by driving ozone formation; ozone is a respiratory toxin.[27] Some acclimatization to heat is possible, both physiologically and socially (through such means as air conditioning), but there are limits to adaptability. In coming years, extremely hot days will become more common (**Figure 2**).[28] Warmer weather will reduce the number of cold-related deaths in some areas, but not enough to compensate for projected increases in heat-related deaths.[29] Deprived populations such as the poor, those who are socially isolated, people of color, the very old, people with certain medical conditions, and outdoor workers are at especially high risk from severe heat.[3,30,31] Importantly, so are young people.[32] The risk begins as early as the prenatal period (heat increases the risk of preterm birth[33-35]) and continuing into infancy (a high-risk age group for mortality during heat waves[32]), later childhood (children's visits to physicians and emergency rooms increase disproportionately during heat waves[32,36]), and the teen years (when hot days endanger high school athletes[37]).

Severe weather and disasters

Severe weather events have been rising in frequency in recent decades, and continued increases are predicted.[38,39] For example, a recent analysis considered sea level together with wave, tide, and storm surge models; the authors reported that extreme flooding will become substantially more frequent along the Pacific coast, from California to Washington state, by 2050.[40] Such events are dangerous. Floods, hurricanes, and severe storms can cause traumatic injuries and death at the time of their occurrence. Other health impacts can persist well beyond the acute phase. In the short term, for example, before power is restored, people who utilize propane burners and generators face a risk of carbon monoxide poisoning.[41] Disasters often disrupt medical care, and can destroy clinical facilities, interfering with acute and chronic medical care.[42,43] Following floods, homes can experience extensive mold growth, posing respiratory risks.[44] In contrast to severe storms, droughts unfold more slowly, over months to years, threatening health in a range of ways: infectious disease risks due to reduced water quality and quantity, respiratory risks due to reduced air quality, and mental health risks.[45] In the aftermath of disasters, people's lives may be upended and their livelihoods compromised, and they may be forced to relocate; these outcomes threaten mental health, manifested in elevated rates of anxiety, depression, post-traumatic stress disorder, substance abuse, and domestic violence following disasters.[46] Deprived populations, such as poor and minority communities, and communities located in vulnerable places, are at increased risk from disasters caused or intensified by climate change.[47,48] Again, children face disproportionate risk from extreme events.[49] As noted by the American Academy of Pediatrics, "Extreme weather events place children at risk for injury, loss of or separation from caregivers, exposure to infectious diseases, and a uniquely high risk of mental health consequences, including posttraumatic stress disorder, depression, and adjustment disorder. Disasters can cause irrevocable harm to children through devastation of their homes, schools, and neighborhoods, all of which contribute to their physiologic and cognitive development."[10]

Air quality

Climate and other environmental changes affect the air that people breathe in diverse ways. First, the combustion of fossil fuels—a root cause of climate change—is also a leading source of many air pollutants (https://www.epa.gov/air-emissions-inventories). Air pollutants, including particulate matter, ozone, oxides of sulfur and nitrogen, and others, increase the risk of cardiovascular disease, respiratory disease, cancer, and other illnesses.[50] These impacts are so extensive that they generate billions of dollars in health care costs each year nationally.[51-53]

Climate change affects air quality in at least two other important ways.[54,55] First, warmer temperatures drive the formation of ozone, a respiratory toxin.[54,56] Higher ozone levels are reflected in increases in respiratory symptoms, lost work and school days, hospital and emergency department visits, and premature deaths.

Second, drier, hotter weather and degraded forests (due to such factors as pest infestations) have resulted in more frequent wildfires.[57] Wildfires release large amounts of smoke, a cardiopulmonary risk for those downwind.[58,59] For example, during September 2017 wildfires in the region caused those Plaintiffs from Washington and Oregon to be exposed to hazardous levels of smoke for several days in a row (**Figure 3**).

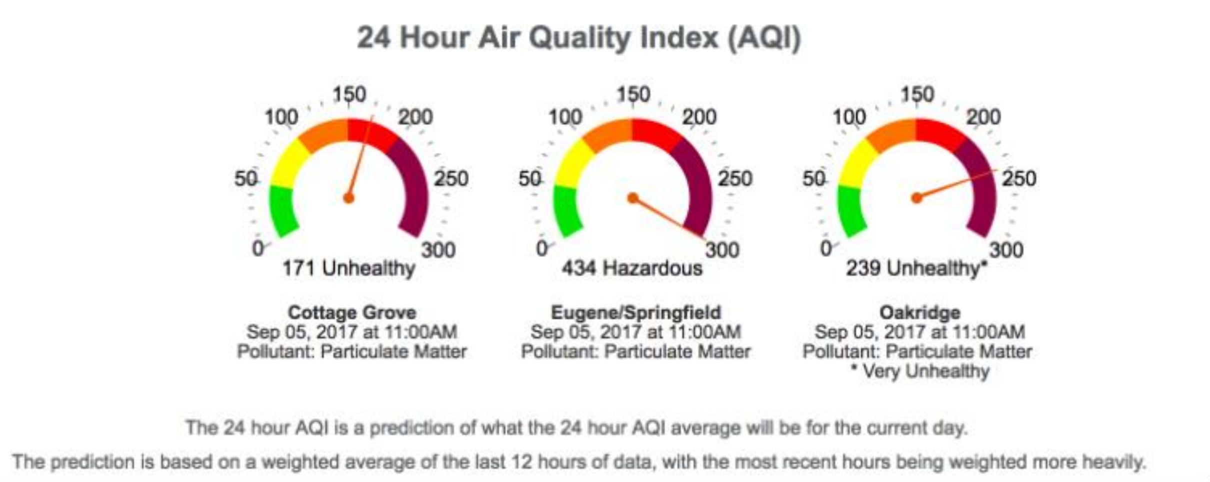


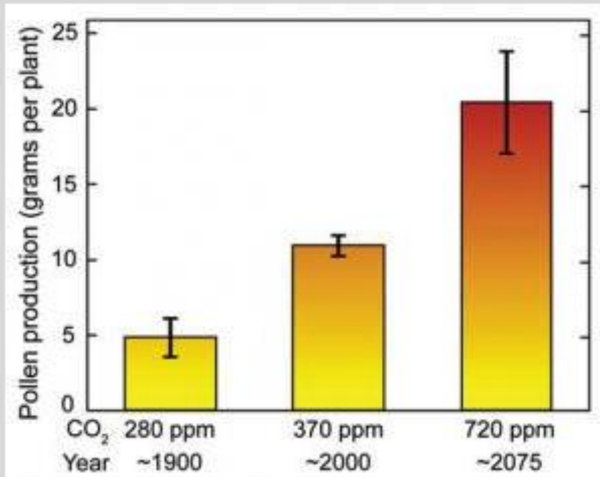
Figure 3: Air quality suffers due to wildfire smoke in Lane County, Oregon. The Air Quality Index for September 5, 2017, as reported by Lane Regional Air Protection Agency.

People with respiratory conditions such as asthma are especially susceptible to the effects of air pollutants.[60] So are children, owing to their narrow airways, their relatively high respiratory rates, and other factors;[61] as a result, worsening climate change, and resulting air quality degradation, are projected to pose a particular risk for children.[62]

Allergies

Climate change can exacerbate allergies in several ways. First, some allergenic plants such as ragweed and some allergenic trees experience faster growth and a prolonged growing season—a trend that has been documented in many parts of the United States.[63,64] Second, these plants can produce more pollen (**Figure 4**). Third, the amount of allergenic proteins contained in pollen can increase.[65,66] The result is increased suffering for people with allergies.[67]

Pollen Counts Rise with Increasing Carbon Dioxide



Pollen production from ragweed grown in chambers at the carbon dioxide concentration of a century ago (about 280 parts per million, ppm) was about 5 grams per plant; at today's approximate carbon dioxide level, it was about 10 grams; and at a level projected to occur about 2075 under the higher emissions scenario,[6] it was about 20 grams.[46]
Image Reference: Ziska and Caulfield[46]

Figure 4. Rising ragweed pollen counts with rising CO_2 levels. Karl TR, Melillo JM, Peterson TC, eds. *Global Climate Change Impacts in the United States*. Cambridge and New York: Cambridge University Press; 2009.

Climate change also is also likely to exacerbate allergy symptoms, as well as asthma, through indirect pathways. For example, climate change worsens air quality—a problem for people with allergies since air pollution potentiates allergic symptoms.[68] Similarly, climate change is associated with more frequent thunderstorms, which are in turn associated with exacerbations of asthma and allergic symptoms.[69-72] As asthma and allergies have become more widespread in recent years, the at-risk population for these impacts has also grown.[73-75] Allergies are highly prevalent among children,[76] and can affect their physical and emotional health by interfering with sleep, play, and school attendance and performance.[77-79]

Harmful algal blooms

Harmful algal blooms (HABs) occur when colonies of algae along seacoasts or in fresh water bodies proliferate, and produce toxic effects on people, pets, aquatic species, and birds. The causes of harmful algal blooms are complex, but growing evidence suggests that climate change contributes to these events.[80-82] Human illnesses from HABs, while not common, can feature severe symptoms ranging from diarrhea to respiratory illness to neurotoxicity, and may even be fatal.[83,84] HABs can harm people in other ways, by limiting recreational opportunities and the ability to eat fish and shellfish. Children are at particular risk from HABs due to their smaller body size, risky behaviors, and developmental stage.[85]

Infectious diseases

Climate change is likely to increase the risk of infectious diseases.[86] Two main categories of disease are especially salient: vector-borne diseases, and water- and foodborne diseases.

Vector-borne diseases are those that are spread by mosquitoes, ticks, and similar organisms.[87] Mosquitoes transmit such diseases as dengue fever,[88] malaria,[89] and West Nile virus;[90] and ticks such diseases as Lyme disease.[91-93] Many features of climate change can promote disease spread: changes in rain patterns that enhance mosquito habitat; changes in temperature that accelerate vector metabolism, breeding, and feeding; changes in vegetation that favor tick proliferation.[94] Some vector-borne diseases, such as Lyme disease, have expanded their geographic range and/or seasonal distribution in recent years (**Figure 5**; www.cdc.gov/lyme/stats/index.html). This trend is expected to continue in coming decades due to ongoing and worsening climate change (**Figure 6**).[91,95]

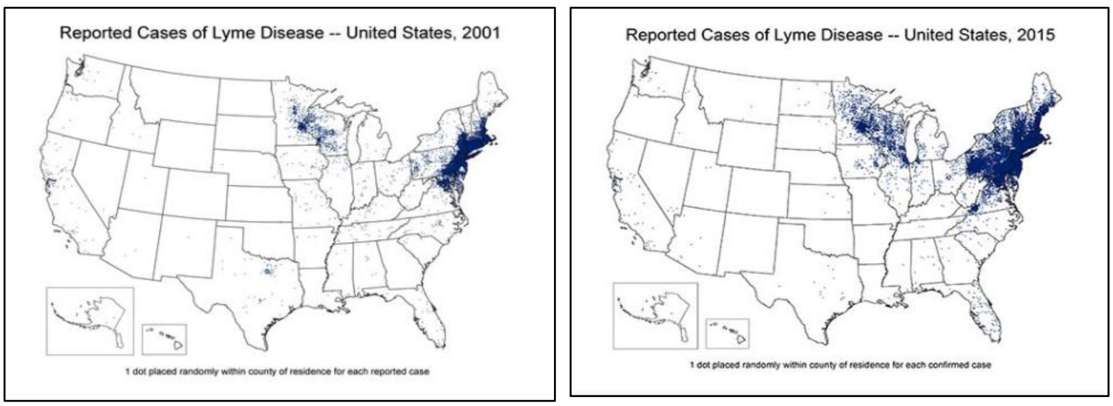


Figure 5: Increase in reported cases of Lyme disease in the US, in 2001 (on left) and 2015 (on right). Source: Centers for Disease Control and Prevention.

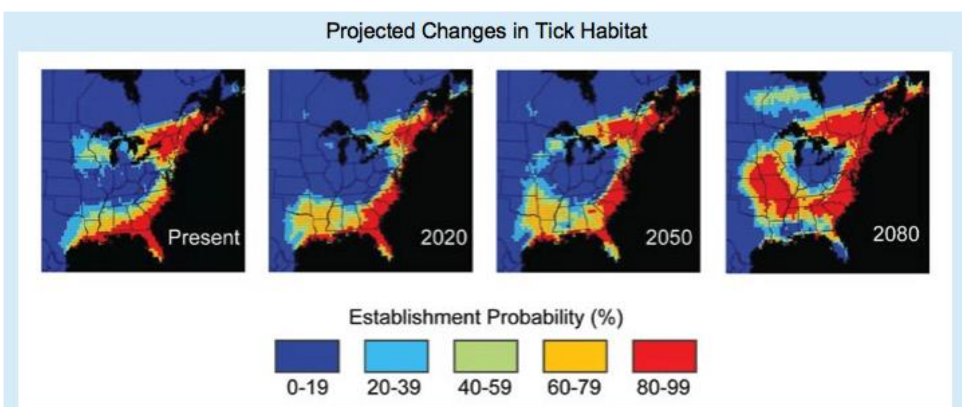


Figure 9.5. The maps show the current and projected probability of establishment of tick populations (*Ixodes scapularis*) that transmit Lyme disease. Projections are shown for 2020, 2050, and 2080. The projected expansion of tick habitat includes much of the eastern half of the country by 2080. For some areas around the Gulf Coast, the probability of tick population establishment is projected to decrease by 2080. (Figure source: adapted from Brownstein et al. 2005[96]).

Figure 6: Projected expansion of conditions favorable to ticks that transmit Lyme disease. Source: Melillo JM, Richmond TC, Yohe GW, eds. *Climate Change Impacts in the United States*. U.S. National Climate Assessment. U.S. Global Change Research Program, 2014. https://www.globalchange.gov/browse/multimedia/projected-changes-tick-habitat.

Other vector-borne diseases, such as dengue fever, which were previously rare in the U.S. except in returning travelers, have begun to appear as locally acquired cases in several states during the last decade,[96,97] and the risk of these diseases is expected to grow with advancing climate change.[98] Vector-borne disease spread is complex, and depends on many factors other than climate change, such as land use changes and the use of protective strategies (e.g., window screens, insect repellant). But continued climate change is likely to bring continued increased risk.

Also important are infectious diseases transmitted by water and food, such as cholera,[99] salmonella, and campylobacter.[100] The risk of these conditions may increase due to changes in hydrology, pathogen biology, and other factors. Two cardinal features of climate change are associated with increases in waterborne diarrheal diseases: warm weather[101,102] and severe rainfall events.[103,104] This suggests that continued climate change will increase the risk of waterborne infections. Foodborne diseases and waterborne diseases are closely linked, since food is often contaminated by water, and since the conditions that promote one also promote the other. Accordingly, climate change is expected to increase the risk of foodborne diseases as well.[105]

Evidence links other infectious diseases with climate and/or weather. One example is fungal diseases, because temperature, moisture, and wind conditions affect the growth and dispersal of fungi. Coccidioidomycosis, or "Valley Fever," is a fungal infection found mainly in Arizona and California. The incidence of this disease has risen considerably in recent decades,[106] and it has appeared in previously disease-free locations such as eastern Washington state.[107] There is evidence that changing rainfall patterns have contributed to this increase.[108,109] Another example is *Naegleria fowleri*, an amoeba that causes a devastating brain infection, primary amebic meningoencephalitis (PAM). This disease is acquired by swimming in contaminated water. Because lakes cannot support the *Naegleria* amoeba below a certain temperature, this has been a disease of the southern U.S. However, it recently emerged in Minnesota, where it killed a child. Investigation revealed that lake water where the child had swum and contracted the infection had reached record high temperatures.[110] Such risks—some known, some not yet recognized—will be a feature of continued climate change.

For many infectious diseases, those at greatest risk include the very young, the very old, and people with certain underlying illnesses or who are immunocompromised. Children have immature immune systems, and less resilience than adults to some abnormalities such as dehydration (a result of severe diarrhea).

Nutrition

Climate change threatens agricultural productivity in many parts of the world through complex pathways, including the effects of extreme heat, storms, droughts, and flooding; pests and weeds; and rising ozone levels.[111-113] Compounding these impacts on crops themselves is reduced work capacity among farmers.[24] The quantity of crops produced is not the only concern; quality also suffers. The protein and nutrient content of some grains and legumes, including wheat, rice, corn, and soy, declines with rising atmospheric concentrations of carbon dioxide (CO_2).[114] Fish represent a substantial source of dietary protein for many populations, but global fisheries, already compromised by overfishing,[115] are threatened by climate change, especially at low to mid-latitudes,[116,117] and aquaculture—potentially an important adaptation—is particularly threatened by ocean acidification.[118] Livestock production, including animal growth and milk production, is depressed with hot weather and other features of climate change.[119] Some regions, such as northern Canada and Russia, will enjoy improved agricultural output, but many more will suffer declines. When food supplies fall short of demand, prices rise, a special hardship for people who are food-insecure—including about one in eight U.S. households.[120] Families that have difficulty making ends meet tend to purchase less costly, less nutritious, calorie-dense foods[121,122]—a contributor to a range of chronic diseases.

Population displacement

In the U.S., as in much of the world, human habitation is concentrated in areas that are vulnerable to climate change—along coasts and rivers, and in warm climates. Some populations may be displaced with climate change, as drought, sea level rise, and severe weather events create shortages of food, water, and habitable land in vulnerable places.[123,124] This may occur relatively acutely, such as after a major disaster, or more deliberately and over a longer time frame, as places become progressively less habitable (or as it becomes prohibitively expensive to keep them habitable).[125,126] Key health risks among displaced populations relate to infectious diseases, nutrition, reproductive health, and mental health and psychosocial stressors.[127,128] Children are especially vulnerable to these impacts, especially those related to psychosocial stressors.[129,130]

Civil conflict

Worsening pressure on increasingly scarce resources, displaced populations, and other destabilizing forces are risk factors for civil conflict.[131-133] Changing weather patterns due to climate change may have contributed to the Darfur conflict in the first decade of the present century,[134] and to the uprisings in Syria and Egypt in the following decade.[135] Accordingly, the U.S. Department of Defense has identified climate change as a serous security threat.[136] The implications for health are both direct, threatening the safety of U.S. service members required to engage in armed conflicts, and indirect, diverting funds from health and other human services. At a more granular scale, warming temperatures are associated with higher levels of interpersonal violence,[21,137] resulting in injuries and fatalities, lasting psychological damage, and other harms.[138] Children are vulnerable to lasting effects from exposure to violence during childhood; such exposure is associated with medical, mental health, social, and behavioral problems both during childhood and during the adult years.[139-141]

Mental health impacts

Climate change and environmental degradation can threaten mental health in several ways. Disasters such as floods and hurricanes, as noted above, often result in large population burdens of depression, anxiety, and other manifestations of post-traumatic stress,[142] with children especially vulnerable.[129,130] The ongoing interruption of place attachment; the loss of accustomed weather patterns, biodiversity and other environmental features; and the insecurity that comes with uncertainty about the future, can trigger grief, distress, anxiety, and other mental disorders.[143-145] People with mental illnesses are also more susceptible to heat, because of the side effects of certain medications, inappropriate behavioral responses, and/or abnormal physiological homeostatic mechanisms.[146]

Children have specific vulnerabilities

In the context of this litigation, the risks of climate change for children are especially relevant. As noted above, children are particularly vulnerable to many of the health risks posed by climate change.[10,12,147] These include the effects of heat,[32] drought,[148] disasters[149-151] and resulting displacement,[129] air pollution,[152] allergen exposure,[67] and many infectious diseases, from dengue fever[153] to diarrhea.[154] As one recent commentary by a leading researcher noted, children "bear a disproportionate burden of disease and developmental impairment from both environmental pollution and climate change due to the combustion of coal, oil, gasoline, diesel and natural gas."[155] Climate change poses a wide range of risks that directly target children.

The Plaintiffs in this case exemplify the risks discussed here

The Plaintiffs in this case exemplify the health risks discussed above. First, according to the First Amended Complaint and Plaintiff declarations I reviewed, several of the Plaintiffs have medical conditions that place them at risk of one or more of the impacts described above, in particular asthma (Isaac V., Sahara V., Alex Loznak, and Nathan B.) and allergies (Levi D., Victoria B., Kiran Oommen, Jaime B., Zealand B., Sahara V., Avery M., Sophie K., Alex Loznak, and Nathan B.). Second, several of the Plaintiffs live in places where impacts such as wildfires, water scarcity, and coastal ecosystem changes have traumatized them and/or constrained their outdoor recreation opportunities (Xiuhtezcatl M. in Colorado; Kelsey Juliana, Tia Hatton, Kiran Oommen, Zealand B., Sahara V., Hazel V., Avery M., Miko V., Jacob Lebel, and Alex Loznak in various parts of Oregon; Levi D. on the Florida coast; Journey Z. on the Hawaiian coast; Jaime B. in Arizona; Aji P. in Washington; Sophie K. in Pennsylvania; Nicholas V. in Colorado; and Nathan B. in Alaska). Outdoor recreation is an important means of promoting children's health and development,[156-158] and interrupting access to such opportunities compromises health. Few places are immune from the health threats posed by climate change; for example, many of the Plaintiffs reside in Oregon, where climate-related risks to health have been well documented by the Oregon Health Authority.[159] Third, many of the Plaintiffs report sadness, anxiety, and fear regarding the future, reflecting their awareness of the risks of climate change; these reactions undermine mental health and happiness.[160,161] This inventory of specific risks in these individual children is by no means exhaustive; most of the risks discussed in this testimony will operate, to a greater or lesser extent, on most of the Plaintiffs in this case, as climate-related risks will affect all children. However, the broad nature of the health impacts of climate change in no way diminishes the specific risks to these Plaintiffs.

Government awareness of risks posed to youth by climate change

In August 2005, the U.S. EPA's Children's Health Protection Advisory Committee sent a formal letter to then-EPA Administrator Steven Johnson, entitled "Children's Environmental Health and Climate Change" (available at https://www.epa.gov/sites/production/files/2014-

05/documents/8302005.pdf). As Chair of the subcommittee on climate change, I led the preparation of that letter. The letter stated that

> *"Climate change will affect children's environmental health, in some cases disproportionately,"* noting that *"Children are especially vulnerable because of their developing organ systems, their high risks of certain exposures, and other reasons."*

and recommended that

> *"EPA should use all available regulatory authority to reduce greenhouse gases [GHGs] to avoid an irreversible course of global climate change with attendant harm to children."*

Administrator Johnson responded in November 2005 (available at https://www.epa.gov/sites/production/files/2014-05/documents/11182005.pdf) noting that: "The Agency and the Bush Administration agree that climate change is a priority."

In January 2013, the U.S. EPA published *America's Children and the Environment, Third Edition*, EPA 240-R-13-001. Among the important points made by this publication are the following:

> *"America's Children and the Environment, Third Edition ("ACE3") is EPA's report presenting data on children's environmental health. ACE brings together information from a variety of sources…." (p. 6).*
>
> *"Climate change may increase children's exposure to extreme temperatures, polluted air and water, extreme weather events, wildfires, infectious disease, allergens, pesticides, and other chemicals. These exposures may affect children's health in a number of direct and indirect ways. It is important to note that climate change will likely result in a mix of both positive and negative health impacts. For example, warmer summers may increase the number of heat-related injuries and deaths, while warmer winters may result in fewer cases of cold-related injuries and deaths. (Footnote omitted.) The effects of climate change will also vary from one location to another and will likely change over time as climate change continues. (Footnotes omitted.) Furthermore, the human health risks from climate change may be affected strongly by changes in health care advances and accessibility, public health infrastructure, and technology. (Footnotes omitted)." (p. 105).*
>
> *"Climate change is likely to change the timing, frequency, and intensity of extreme weather events, including heat waves, hurricanes, heavy rainfall, droughts, high coastal waters, and storm surges. (Footnotes omitted.) These events can cause traumatic injury and death, as well as emotional trauma. Extreme weather events are also associated with increased risk of food- and water-borne illnesses as sanitation, hygiene, and safe food and water supplies are often compromised after these types of events. (Footnotes omitted.) One study found that periods of heavy rainfall were associated with increased emergency*

room visits for gastrointestinal illness among children. (Footnote omitted.) Heavy rainfall may result in flooding, which can lead to contamination of water with dangerous chemicals, heavy metals, or other hazardous substances from storage containers or from preexisting chemical contamination already in the environment. (Footnotes omitted.) Elevated temperatures and low precipitation are also projected to increase the size and severity of wildfires. This can lead to increased eye and respiratory illnesses and injuries, which include burns and smoke inhalation. (Footnote omitted.) Extreme weather events can be especially dangerous for children because they are dependent on adults for care and protection. (Footnote omitted.)" (p. 106).

"Through various indirect pathways, climate change may lead to increasing levels and/or frequencies of childhood exposure to harmful contaminants. (Footnotes omitted.) Changes in temperature, rainfall, and crop practices related to climate change are likely to affect exposure to pathogens, pesticides, and other chemicals in a number of ways. Broader geographic distribution of pests and increased growth of invasive weeds will likely lead to greater use of pesticides. (Footnotes omitted.) Increased precipitation and increased variability in precipitation are likely to increase pathogen and contaminant levels in lakes and other surface waters. (Footnotes omitted.) The distribution of chemicals in the environment is likely to change: for example, an increase in ice melts caused by a warming climate may release some past emissions of globally transported chemicals, such as polychlorinated biphenyls (PCBs) and mercury, that have been trapped in polar ice. (Footnotes omitted.) Increasing concentrations of these chemicals in the atmosphere, and subsequent deposition to land and water, have the potential to increase concentrations of these chemicals in fish and other foods derived from animals. Warmer water temperatures may also increase the release of chemical contaminants from sediments, increasing their uptake in fish. (Footnote omitted.) Climate change may result in children spending more time indoors. Buildings that are tightly sealed in response to adverse weather conditions may result in increased exposure to contaminants from poor ventilation and higher concentrations of indoor pollutants such as radon, environmental tobacco smoke, and formaldehyde. (Footnote omitted.)" (p. 107).

"Children are expected to be especially sensitive to the effects of climate change for a number of reasons. Young children and infants are particularly vulnerable to heat-related illness and death. (Footnote omitted.) Compared with adults, children have higher breathing rates, spend more time outside, and have less developed respiratory tracts—all making children more sensitive to air pollutants. Additionally, children have immature immune systems, meaning that they can experience more serious impacts from infectious diseases. (Footnote omitted.) The greatest impacts are likely to fall on children in poor families, who lack the resources, such as adequate shelter and access to air conditioning, to cope with climate change. (Footnote omitted.)" (p. 107).

Finally, ACE3 cites Chapter 9, the health chapter, of the Third National Climate Assessment.[162] ACE3 does not directly quote from this chapter, but cites the chapter at numerous points, including the following:

> *"Climate change is projected to harm human health in a variety of ways through increases in extreme temperature, increases in extreme weather events, decreases in air quality, and other facts." (p. 25).*
>
> *"There are a variety of other impacts driven by climate change that are expected to pose significant health hazards, including increases in wildfire activity." (p. 25).*
>
> *"Extreme temperatures are projected to rise in many areas across the U.S., bringing more frequent and intense heat waves and increasing the number of heat-related illnesses and deaths." (p. 28).*
>
> *"These physical impacts on water quality will also have potentially substantial economic impacts, since water quality is valued for drinking water and recreational and commercial activities such as boating, swimming, and fishing." (p. 32).*

I have similarly communicated the health risks associated with climate change to Federal governmental bodies in the past. For example, on April 9, 2008, I testified on "Climate Change and Public Health" before the Select Committee on Energy Independence and Global Warming of the United States House of Representatives. At the time, I was Director of the CDC's National Center for Environmental Health and of the U.S. Agency for Toxic Substances and Disease Registry. A true and correct copy of my testimony is attached here as **Exhibit C**. Among the additional points I made during my testimony were the following:

> At p. 3, I noted that, while knowledge of the potential public health impacts of climate change will advance in the coming years and decades, the following are current best estimates of major anticipated health outcomes:
>
> • Direct effects of heat,
> • Health effects related to extreme weather events,
> • Air pollution-related health effects,
> • Water- and food-borne infectious diseases,
> • Vector-borne and zoonotic diseases, and
> • Other pathogens sensitive to weather conditions.
>
> At p. 5, I stated that "climate changes will likely affect air quality by modifying local weather patterns and pollutant concentrations, affecting natural sources of air pollution, and promoting the formation of secondary pollutants. Studies show that higher surface temperatures, especially in urban areas, encourage the formation of ground-level ozone. Ozone can irritate the respiratory system, reduce lung function, aggravate asthma, and inflame and damage cells that line the lungs.

> In addition, it may cause permanent lung damage and aggravate chronic lung diseases."
>
> At p. 7, I observed some demographic groups are more vulnerable to the health effects of climate change than others. Children are at greater risk of worsening asthma, allergies, and certain infectious diseases.

Therefore, the public health risks I describe in this report have been well known by the Federal government for a substantial period of time.

Today's children will be tomorrow's adults

Today's children will not be children forever; they are tomorrow's adults. After that, they will reach old age. The risks of climate change will therefore play out over the course of their lives, threatening today's children with cumulative risks that intensify over coming decades. Some exposures, sustained during childhood, raise the risk of adult diseases. Other risks will continue to operate on them as adults. And given the current trajectory of climate change—steadily rising temperatures, more chaotic weather, and related changes during coming decades—today's children can anticipate a lifetime of worsening risks. Each of the health effects described above poses risks not only to children, but also to adults. And each of these risks is increasing.

CONCLUSION

Based on the foregoing discussion, it is my expert opinion that climate change disproportionately threatens the physical and mental health, and well-being, of children as a class of people. Today's children already bear, and will continue to bear, a substantial climate health burden, both in their youth, and cumulatively as they reach adulthood and mature into old age. At least some of the Plaintiffs in this case, based upon their declarations and their allegations in the First Amended Complaint and my expert opinion, are already suffering health problems of the type that climate change aggravates and/or makes more likely, and such health impacts will worsen as temperatures continue to rise. Government actions that further exacerbate the severity of climate change, as well as the failure to take action to reverse climate change, represent substantial and serious threats to the health of these children.

It is my expert opinion that, while adaptation can offer some protection, it cannot fully counter the health risks of climate change, and that prevention is essential. Prevention, in this context, means prompt and aggressive action to eliminate the human causes of climate change. This will not prevent all of the public health impacts of climate change, since some are inevitable given the "climate commitment" already in place,[163] but it will reduce the risk and limit the cumulative harms experienced over the lifetimes of these children.

Signed this 10th day of April, 2018 in Seattle, Washington.

Howard Frumkin, MD, MPH, DrPH

EXHIBIT A

ABBREVIATED CURRICULUM VITAE
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July, 2017

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Education

A.B., 1977, Brown University, Providence
Magna cum laude, with Honors, in Science and Society
Thesis: *Government of Health: The Formation of the Rhode Island State Board of Health*
M.D., 1982, University of Pennsylvania School of Medicine, Philadelphia
M.P.H., 1982, Harvard School of Public Health, Boston
Major Area: Occupational and Environmental Health
Dr.P.H., 1993, Harvard School of Public Health, Boston
Major Area: Epidemiology.
Thesis: *Epidemiologic Studies of Asbestos*

Postgraduate Training

1982-1984: Intern and Junior Resident, Internal Medicine, Hospital of the University of Pennsylvania, Philadelphia.
1984-1985: Senior Resident, Primary Care Internal Medicine, Cambridge Hospital, Cambridge, MA.
1985-1987: Resident, Environmental and Occupational Medicine, Harvard School of Public Health, Boston.
1985-1988: Fellow in Epidemiology, Harvard School of Public Health, Boston.
2008-09: National Preparedness Leadership Initiative, Harvard University.

Employment

1988-1990: University of Pennsylvania School of Medicine, Section of General Medicine and Clinical Epidemiology Unit:
Assistant Professor of Medicine
1990-2005: Emory University, Rollins School of Public Health:
Assistant to Full Professor and Department Chair, Environmental and Occupational Health
2005-2010: U.S. Centers for Disease Control and Prevention:
Director, National Center for Environmental Health and Agency for Toxic Substances and Disease Registry (2005-2010)
Special Assistant to CDC Director for Climate Change and Health (2010)
2010-2018: University of Washington School of Public Health:

Dean (2010-2016) and Professor of Environmental and Occupational Health Sciences
2018-: Wellcome Trust, London, United Kingdom
Head, Our Planet, Our Health initiative

Board Certification
American Board of Internal Medicine, 1985.
American Board of Preventive Medicine (Occupational Medicine), 1988.

Relevant Service Activities

Board service (previous):

- Bullitt Foundation
- Seattle Parks Foundation
- Washington Global Health Alliance
- Regional Open Space Strategy for Central Puget Sound
- Children and Nature Network
- U.S. Green Building Council
- Physicians for Social Responsibility
- American Public Health Association
- National Environmental Education Foundation

Committee service (current):

- National Academy of Science, Engineering, and Medicine, Committee on Measuring Community Resilience
- ecoAmerica Climate for Health, Leadership Circle
- Global Consortium on Climate and Health Education (Columbia University), Advisory Council
- Medical Society Consortium on Climate & Health (George Mason University), Advisory Committee
- Canadian Urban Environmental Health Research Consortium, Advisory Panel

Committee service (previous):

- Wellcome Trust, "Our Planet, Our Health" Funding Committee (Chair) and Advisory Committee
- Planetary Health Alliance (Harvard University), Steering Committee
- Yale Climate and Energy Institute, Advisory Board
- U.S. EPA Children's Health Protection Advisory Committee (Chair, Smart Growth and Climate Change Work Groups)
- Procter & Gamble, Sustainability Expert Advisory Panel
- National Academies of Sciences, Committee on the Challenge of Developing Sustainable Urban Systems.
- National Academies of Sciences, Committee on Sustainability Linkages in the Federal Government
- National Building Museum, Intelligent Cities Forum, Advisory Board

Professional Engagement with Climate Change

- Chaired the Climate Change work group of EPA's Children's Health Protection Advisory Committee (2004-05)
- Initiated CDC's Climate Change and Health program (2007)
- Special Assistant to the CDC Director for Climate Change and Health (2010)
- Edited the special issue of the *American Journal of Preventive Medicine* on Climate Change and Human Health (2008)
- Represented CDC at the US Global Change Research Program (2006-10)
- Reviewer for early editions of the National Climate Assessment health chapter and lead author on the health chapter in NCA3 (2013-14)
- Reviewer for IPCC health chapters (2014)
- Served on the AAAS Climate Science Panel (2013-14)

Editorial positions

Current:

- *American Journal of Industrial Medicine*
- *Salud Pública de México*
- *Environmental Health Perspectives*
- *American Journal of Preventive Medicine*
- *ECOHEALTH*

Previous:

- *International Journal of Occupational and Environmental Health*
- *Annual Review of Public Health*

Honors and Awards

Valedictorian, Clarkstown High School (1973)
Valedictorian, Brown University (1977)
Bicknell Premium in American History, Brown University (1977)
Phi Beta Kappa, Brown University (1977)
Fellow, College of Physicians of Philadelphia (1989)
Fellow, American College of Occupational and Environmental Medicine (1993)
Fellow, American College of Physicians (1993)
Great Teacher lectureship, Emory University (1998)
Fellow, Collegium Ramazzini (2001)
Betty Baker Environmental Justice Award, Community Against Pollution, Anniston, Alabama (2004)
Environmental Professional of the Year, Georgia Environmental Council (2004)
Emory University School of Medicine Dean's Teaching Award (2004)
Atlas Award for co-editing a book addressing climate change (2012)
American Journal of Public Health Paper of the Year award, for "Aging, Climate Change, and Legacy Thinking" (2013)
Honorary member, AIA Seattle (2014)
Residency fellowship, Rockefeller Foundation Bellagio Center (2015)
Elected member, Washington State Academy of Sciences (2017)
Multiple invited lectureships

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EXHIBIT C
TESTIMONY

April 9, 2008 testimony on "Climate Change and Public Health" before the Select Committee on Energy Independence and Global Warming of the United States House of Representatives.

Testimony
Select Committee on Energy Independence and Global Warming United States House of Representatives

Climate Change and Public Health

Statement of
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Director, ***National Center for Environmental Health*****,** ***Centers for Disease Control and Prevention and Agency for Toxic Substances and Disease Registry***
U.S. Department of Health and Human Services

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Introduction

Good morning Chairman Markey, Representative Sensenbrenner, and other distinguished members of the Committee. I am Howard Frumkin, Director of the National Center for Environmental Health at the Centers for Disease Control and Prevention (CDC), and Assistant Administrator of the Agency for Toxic Substances and Disease Registry (ATSDR). I am here to speak on our emerging understanding of climate change and its potential impact on health, and to discuss steps we are taking as public health officials regarding these potential consequences. I recognize that this topic remains controversial and some my testimony may not necessarily reflect broad consensus across the Administration. In addition, CDC is not a regulatory agency and does not express any opinions on regulatory decisions pending before the Environmental Protection Agency.

Background

Scientific evidence supports the view that the earth's climate is changing. CDC considers climate change a serious public health concern, The programs and expertise used by CDC to address a broad range of public health challenges also are applicable to preparing for and responding to public health needs related to climate change. In this testimony, I will address the following dimensions of climate change and public health:

1) The likely public health threats of climate change,

2) The people most vulnerable to these threats, and

3) CDC activities to protect the public's health from these anticipated threats.

Climate change strategies are typically framed by two broad approaches. *Mitigation* encompasses efforts to reduce climate change itself, while *adaptation*, encompasses activities to manage those effects of climate change that are inevitable despite mitigation efforts. This framing aligns closely with the public health framework of prevention and preparedness. Like prevention, mitigation seeks to prevent negative outcomes. Like adaptation, preparedness acknowledges that, while not all negative outcomes can be prevented, they can be reduced and managed. For climate change, adaptation/preparedness is more broadly accepted as a public health activity. However, there is also a role for public health to play by articulating the health implications of climate change mitigation options, both by highlighting co-benefits to health of certain options and by identifying potential negative health outcomes of other possible mitigation strategies.

Climate Change is a Public Health Concern

Over the next few decades in the United States, climate change is likely to have a significant impact on health. The anticipated health impacts of climate change have been well-reviewed and articulated by the Intergovernmental Panel on Climate Change[1] and by the U.S. Climate Change Science Program through

[1] Intergovernmental Panel on Climate Change, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, P.P. Palutikof, P.J. van

their Synthesis and Assessment Products[2]. While knowledge of the potential public health impacts of climate change will advance in the coming years and decades, the following are current best estimates of major anticipated health outcomes:

- Direct effects of heat,
- Health effects related to extreme weather events,
- Air pollution-related health effects,
- Water- and food-borne infectious diseases,
- Vector-borne and zoonotic diseases, and
- Other pathogens sensitive to weather conditions.

The United States is a developed country with a variety of climates. Because of its well-developed health infrastructure, and the greater involvement of government and nongovernmental agencies in disaster planning and response, the health effects from climate change are expected to be less significant than in the developing world. Nevertheless, Americans may experience difficult challenges, and different regions of the country may experience these challenges at varying degrees.

Heat Stress and Direct Thermal Injury

der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22. Available at: http://www.ipcc.ch/ipccreports/assessments-reports.htm.

[2] U.S. Climate Change Science Program. Public Review Draft of Synthesis and Assessment Product 4.6. Executive Summary. Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems. Available at: http://www.climatescience.gov/Library/sap/sap4-6/public-review-draft/default.htm

With climate change, the United States would expect to see an increase in the severity, duration, and frequency of extreme heat waves. Heat causes a range of health effects, from mild (heat cramps, heat exhaustion) to severe (such as heat stroke, which can be fatal). Certain populations are especially vulnerable to these health effects, including the elderly, those with certain underlying medical conditions, those who are socially isolated, and those without air conditioning. Midwestern and northeastern cities are at greatest risk, as heat-related illness and death appear to be related to exposure to temperatures much hotter than those to which the population is accustomed.[3]

Extreme Weather Events

Scientific evidence suggests climate change will likely modify extreme weather events, such as floods, droughts, and heavy precipitation. In addition, some evidence suggests hurricanes could become more intense. The health effects of extreme weather events range from loss of life and acute trauma to indirect effects such as loss of home, large-scale population displacement and subsequent mental health effects, damage to sanitation infrastructure (drinking water and sewage systems), interruption of food production, and damage to the health-care infrastructure. Displacement of individuals often results in disruption of health care, of particular concern for those with underlying chronic diseases. Future climate projections also show likely increases in the frequency of heavy rainfall events, posing an increased risk of flooding. Climate change models

[3] McGeehin MA, Mirabelli M. The potential impacts of climate variability and change on temperature-related morbidity and mortality in the United States. Environ Health Perspect 109 (suppl 2), 185-189 (2001)

also suggest some areas of the United States may have less rainfall leading to severe drought, reducing availability and quality of water.

Air Pollution-Related Health Effects

Climate changes will likely affect air quality by modifying local weather patterns and pollutant concentrations, affecting natural sources of air pollution, and promoting the formation of secondary pollutants. Studies show that higher surface temperatures, especially in urban areas, encourage the formation of ground-level ozone. Ozone can irritate the respiratory system, reduce lung function, aggravate asthma, and inflame and damage cells that line the lungs. In addition, it may cause permanent lung damage and aggravate chronic lung diseases.

Water- and Food-borne Infectious Diseases

Altered weather patterns resulting from climate change could affect the distribution and incidence of food- and water-borne diseases. Changes in precipitation, temperature, humidity, and water salinity have been shown to affect the quality of water used for drinking, recreation, and commercial use. For example, outbreaks of *Vibrio* bacteria infections following the consumption of seafood and shellfish have been associated with increases in temperatures. Heavy rainfall has also been implicated as a contributing factor in the overloading and contamination of drinking water treatment systems, leading to illness from organisms such as *Cryptosporidium* and *Giardia*. Storm water runoff from heavy precipitation events can also increase fecal bacterial counts in coastal waters as well as nutrient load, which, coupled with increased sea-surface temperature, can lead to increases in the frequency and range of harmful algal blooms (red tides) and potent marine biotoxins such as ciguatera fish poisoning.

Vector-borne and Zoonotic Diseases

Vector-borne and zoonotic diseases, such as, Lyme disease, West Nile virus, malaria, plague, hantavirus pulmonary syndrome, and dengue fever have been shown to have a distinct seasonal pattern, and in some instances their frequency has been shown to be weather sensitive. Because of the sensitivities of the vectors and animal hosts of these diseases to climactic factors, climate change-driven ecological changes, such as variations in rainfall and temperature, could significantly alter the range, seasonality, and human incidence of many zoonotic and vector-borne diseases. More study is required to fully understand all the implications of ecological variables necessary to predict climate change effects on vector-borne and zoonotic diseases. Moderating factors such as housing quality, land-use patterns, and vector control programs make it unlikely that climate change will have a major impact on tropical diseases such as malaria and dengue fever in the United States. However, climate change could facilitate the establishment of new vector-borne diseases imported into the United States, or alter the geographic ranges of some of these diseases that already exist in the country.

Climate Change Vulnerability

The effects of climate change will likely vary by geographic area and demographic group. With respect to geographic vulnerability, urban centers in the west, southwest, mid-Atlantic, and northeast regions of the United States are expected to experience the largest increases in average temperatures; these areas also may bear the brunt of increases in ground-level ozone and associated airborne pollutants.[4] Populations in midwestern and northeastern cities are expected to experience more heat-related illnesses as heat waves increase in frequency, severity, and duration. Different rates of coastal erosion, wetlands destruction, and topography are expected to result in dramatically different regional effects of sea level rise. Distribution of animal hosts and vectors may change; in many cases, ranges could extend northward and increase in elevation. The West coast of the United States is expected to experience significant strains on water supplies as regional precipitation declines and mountain snow packs are depleted.

Some demographic groups are more vulnerable to the health effects of climate change than others. Children are at greater risk of worsening asthma, allergies, and certain infectious diseases. Those with underlying diseases and the elderly are at higher risk for health effects due to heat waves, extreme weather events, and exacerbations of chronic disease. In addition, people of lower socioeconomic status are particularly vulnerable to extreme weather events. The health effects of climate change on a given community will depend not only on a

[4] Bernard SM, et al. The potential impacts of climate variability and change on air pollution-related health effects in the United States. Environ Health Perspect. 2001 May; 109 Suppl 2:100-209.

community's exposures and demographics, but also on how these characteristics intersect. For example, heat waves are both more likely to occur in urban areas and more likely to affect certain populations: the home-bound, elderly, poor, minority and migrant populations, and populations that live in areas with less green space and with fewer centrally air-conditioned buildings.

Given the differential burden of climate change health effects on certain populations, public health preparedness must include assessments to identify the most vulnerable populations and anticipate their risks. At the same time, health communication targeting these vulnerable populations must be devised and tested, and early warning systems focused on vulnerable communities should be developed. With adequate notice and a vigorous response, adverse health effects from climate change may be reduced.

CDC's Current Public Health Preparedness for Climate Change

Climate change is anticipated to have a broad range of impacts on the health of Americans and the nation's public health infrastructure. As the nation's public health agency, CDC is uniquely poised to lead efforts to anticipate and respond to the health effects of climate change. In preparing for climate change, CDC works closely with a broad array of partners including other Federal Agencies (such as the Environmental Protection Agency, National Aeronautics and Space Administration, National Academy of Sciences, United States Department of Agriculture, Food and Drug Administration, National Institutes of Health) through the U.S. Climate Change Science Program; state and local organizations (such as the National Association of County and City Health Officials, Association of State and Territorial Health Officials, and state and local veterinary officials); faith-based organizations; and many other organizations and agencies. Preparedness for the health consequences of climate change aligns with traditional public health contributions, and – like preparedness for terrorism and pandemic influenza – reinforces the importance of a strong public health infrastructure. CDC's expertise and programs in the following areas provide a strong platform:

- *Surveillance of Water-borne, Food-borne, Vector-borne, and Zoonotic Diseases:* CDC has a long history of surveillance of infectious, zoonotic, and vector-borne diseases. Preparing for climate change will involve working closely with state and local partners to document whether potential changes in climate have an impact on infectious and other diseases and to use this information to help protect Americans from the potential change in a variety of water-borne, food-borne, vector-borne, and zoonotic diseases. Among the tracking systems CDC has developed for these diseases is ArboNet, the national arthropod-borne viral disease tracking system. Currently, this system supports nationwide West Nile virus surveillance that links all 50 states and four large metropolitan areas to a central database that records and maps cases in humans and animals and would detect real-time changes in distribution and prevalence of arthropod-borne viral diseases. CDC also supports the major foodborne surveillance and investigative networks of FoodNet PulseNet, and OutbreakNet that rapidly identify and provide detailed data on cases of foodborne illnesses, the organisms that cause them, and the foods that are the sources of infection. Altered weather patterns resulting from climate change may affect the distribution and incidence of food- and water-borne diseases, and these changes can be identified and tracked through PulseNet, the Electronic Foodborne Disease Outbreak Reporting System (eFORS) and the Waterborne Disease Outbreak Surveillance System (WBDOSS)

- *Environmental Public Health Tracking:* CDC is pioneering new ways to understand the impacts of environmental hazards on people's health. CDC's Environmental Public Health Tracking Program has funded several states to build a health surveillance system that integrates environmental exposures and human health outcomes. The Tracking Network will contain critical data on environmental trends and on the incidence, trends, and potential outbreaks of diseases, including those affected by climate change.

- *Geographic Information Systems (GIS):* CDC has applied GIS technology in unique ways to a variety of public health issues. It has been used in data collection, mapping, and communication to respond to issues as wide-ranging and varied as the World Trade Center collapse, avian flu, SARS, Rift Valley fever, and plague. GIS allows CDC to overlay public health disease data with enviro-climatic datasets such as temperature and precipitation information to determine if associations exist. In addition, GIS technology was used to map issues of importance during the CDC response to Hurricane Katrina. This technology represents an additional tool for the public health response to climate change.

- *Modeling:* Projections of future climate change can be used as inputs into models that assess the impact of climate change on public health. For example, CDC has conducted heat wave modeling for the city of Philadelphia to predict the most vulnerable populations at risk for hyperthermia. CDC has also worked with others to model the potential impacts of climate change on the distribution of plague and tularemia in the United States.

- *Preparedness Planning:* The principles that guide us to prepare for terrorism and pandemic influenza also apply to preparedness for the health impacts of climate change. For example, CDC scientists have developed tools for local emergency planners and decision-makers to use in preparing for and responding to the threats posed by heat waves in urban areas. With other Federal partners, CDC helped develop an Excessive Heat Events Guidebook, which provides a comprehensive set of guiding principles and a menu of options for cities and localities to use in developing Heat Response Plans. These plans clearly define specific roles and responsibilities of government and non-governmental organizations during heat waves. They identify local populations at increased high risk for heat-related illness and death and define which strategies will be used to reach them during heat emergencies.

- *Training and Education of Public Health Professionals*: Preparing for the health consequences of climate change requires that professionals have the skills required to conceptualize the impending threats, integrate a wide variety of public health and other data in surveillance activities, work closely with other agencies and sectors, and provide effective health communication for vulnerable populations. CDC is holding a series of workshops to explore key dimensions of climate change and public health, including drinking water, heat waves, health communication, and vulnerable populations. In addition, CDC recently published an article outlining the public health approach to climate change to guide public health professionals in prevention and preparedness.

- *Health Protection Research:* CDC can also promote research to further public health preparedness for climate change. This includes predictive research to model potential impacts of climate change on health outcomes, epidemiologic research to identify modifiable risk factors, and intervention research to determine the most effective public health practices. For example, CDC has conducted research to model the impact of the urban environment on temperature-related morbidity and mortality. The Agency has also conducted epidemiologic research on the relationship between rainfall and other climactic factors on Hantavirus pulmonary syndrome and plague. Finally, intervention research will help us focus public health action on the most appropriate target audiences.
- *Communication*: CDC has expertise in communicating health and risk information to the general public, and has deployed this expertise in areas as diverse as smoking, HIV infection, and cancer screening. Effective communication can alert the public to health risks associated with climate change and encourage constructive protective behaviors.

While CDC can conduct targeted research or offer technical support and expertise in these and other activities to states, local governments, tribes, and territories be carried out at the state and local level and through other public health partners. For example, CDC can support climate change preparedness activities conducted by state and local public health agencies and climate change and health research in universities, approaches currently used by CDC to address a variety of other health challenges.

Advancing Public Health Prevention and Preparedness for Climate Change

In addition to leveraging existing programs across the agency, CDC has identified the following opportunities for advancing public health prevention and preparedness for climate change:

1) Improve surveillance systems for food-borne, water-borne, vector-borne, zoonotic, and other diseases in cooperation with state and local partners to have a better understanding of the impact of climate change on public health, and to potentially develop models and early warning systems to improve health outcomes.

2) Building research capacity within the Agency: CDC could convene staff experienced in epidemiology, infectious disease ecology, disaster preparedness, modeling and forecasting, climatology/earth science, and communication. This group could support internal research on the links between climate change and public health outcomes. Enhanced capacity within the agency would position CDC to serve as a trusted resource for decision makers and the public, a role we currently provide for public health issues such as vaccinations for foreign travel.

3) Supporting academic capacity to research linkages between climate change and public health: This capacity would include research in such areas as forecasting and modeling anticipated health effects, vector-borne and zoonotic diseases, food-and water-borne diseases, vulnerable populations, and heat waves.

4) Providing research-based communication and technical assistance on the health effects of climate change and best approaches to preparedness: Important audiences for outreach include health professionals, state and local health departments, university environmental studies departments, science teachers, federal, state and local officials, community groups, faith-based organizations, industry, and the public.

Conclusion

An effective public health response to climate change can prevent injuries, illnesses, and death while enhancing overall public health preparedness. Protecting Americans from adverse health effects of climate change directly correlates to CDC's four overarching Health Protection Goals of Healthy People in Every Stage of Life, Healthy People in Healthy Places, People Prepared for Emerging Health Threats, and Healthy People in a Healthy World.

While we still need more emphasis on public health preparedness for climate change, many of our existing programs and scientific expertise provide a solid foundation to move forward. The activities needed to protect overall public health and to protect Americans from adverse health effects of climate change are mutually beneficial. CDC also has a role in examining the health implications of various mitigation efforts aimed at slowing, stabilizing, or reversing climate change by reducing greenhouse gas emissions. While these solutions will occur mainly in sectors other than health, such as energy, transportation, and architecture, the health sciences can contribute useful information regarding the choice of safe, healthful technologies.

Thank you again for the opportunity to provide this testimony on the potential health effects of global climate change and for your continued support of CDC's essential public health work.

Exhibit 3

EXPERT REPORT OF G. PHILIP ROBERTSON

University Distinguished Professor of Ecosystem Ecology
Michigan State University

Kelsey Cascadia Rose Juliana; Xiuhtezcatl Tonatiuh M.,
through his Guardian Tamara Roske-Martinez; et al.,
Plaintiffs,

v.

The United States of America; Donald Trump,
in his official capacity as President of the United States; et al.,
Defendants.

IN THE UNITED STATES DISTRICT COURT
DISTRICT OF OREGON

(Case No.: 6:15-cv-01517-TC)

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TABLE OF ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

BECCS:	bioenergy with carbon capture and storage
C:	carbon
C_{eq}:	carbon equivalent; used to quantitatively compare greenhouse gases via a common metric based on global warming potentials for individual gases
CO_2:	carbon dioxide; contains 27.3% carbon
CO_{2eq}:	carbon dioxide equivalent
EPA:	U.S. Environmental Protection Agency
DOE:	U.S. Department of Energy
GtC:	gigatonne of carbon, equivalent to 1 billion tonnes of carbon, or 1 PgC; 1 GtC = 1,000 MtC
ha:	hectare, equivalent to 2.47 acres
IPCC:	United Nations Intergovernmental Panel on Climate Change
Mha:	million hectares, 1 Mha is equivalent to 2.47 million acres
MtC:	million tonnes of carbon, sometimes abbreviated MMTC; 1,000 MtC = 1 GtC
N_2O:	nitrous oxide
NRCS:	Natural Resources Conservation Service
PgC:	petagram of carbon, equivalent to 10^{15} gC
ppm:	parts per million
tC:	tonne of carbon, equivalent to 1,000 kgC or 10^6 gC
USDA:	U.S. Department of Agriculture

Avoided Emissions: Greenhouse gas emissions not yet released that could be avoided if practices were altered from conventional practices. This includes fossil fuel emissions that are avoided by substituting biofuel combustion for fossil fuel combustion.

Carbon Sequestration: Any process that removes carbon dioxide from the atmosphere and stores the carbon portion in natural sinks like soils.

Negative Emissions: Greenhouse gas (CO_{2eq}) removed from the atmosphere with the carbon portion sequestered for long periods of time – sometimes indefinitely – within natural carbon sinks like soils and forests. In this report, negative emissions are those above and beyond the existing rate of natural sinks.

Federal Land: All U.S. federally-owned or federally-managed lands including forest lands, range lands, other agricultural lands, wetlands, and waterways.

Lands of the United States: All lands, both publicly owned and privately owned, within the boundaries of the United States.

Conterminous lands of the United States: All lands, both publicly and privately owned, within the 48 adjoining states plus the District of Columbia; also known as the contiguous U.S.

US Forests: All forestlands within the United States

Federal Forestland: All U.S. federally-owned or federally-managed forestlands.

INTRODUCTION

I, G. Philip Robertson, have been retained by the Plaintiffs in the above-captioned matter to provide expert testimony about the potential capacity for improved management of United States forest, range and agricultural lands to achieve net negative carbon emissions and avoid future greenhouse gas emissions. In this report I provide background on the global carbon cycle, describe how different land management practices can contribute to negative and avoided emissions, and provide a quantitative assessment of the potential for changes in management practices to provide meaningful greenhouse gas mitigation.

I have worked in the field of carbon and nitrogen biogeochemistry for 40 years since beginning my PhD studies in 1976. I am currently University Distinguished Professor of Ecosystem Ecology in the Department of Plant, Soil and Microbial Sciences at Michigan State University, where I have held a regular faculty position since 1987. I have been a University Distinguished Professor for the last seven years. Since 2017 I have also held the title of Scientific Director for the Department of Energy's Great Lakes Bioenergy Research Center at the University of Wisconsin and Michigan State University. For my entire career the main focus of my research has been studying the processes that regulate biogeochemical cycles of carbon and nitrogen at multiple scales, including plant, soil, and microbial interactions that affect the delivery of important ecosystem services such as climate stability, water quality, and plant productivity. I work primarily in agricultural ecosystems, and more broadly on the issue of agricultural sustainability, which includes the responses of cropping systems to climate change and the potential for land management to contribute to greenhouse gas mitigation. My CV, which includes a statement of my qualifications, is contained in **Exhibit A** to this expert report. A list of publications I authored within the last ten years is attached as **Exhibit B** to this expert report.

In preparing my expert report and testifying at trial, I am not receiving any compensation and am providing my expertise pro bono to the Plaintiffs given the financial circumstances of these young Plaintiffs. I have not provided previous testimony within the preceding four years as an expert at trial or by deposition. My report contains citations to all documents that I have used or considered in forming my opinions, listed in **Exhibit C** to this report.

The opinions expressed in this report are my own, not necessarily the opinions of any of the institutions for which I work or donate my time. The opinions expressed herein are based on the data and facts available to me at the time of writing, as well as based upon my own professional experience and expertise. All opinions expressed herein are to a reasonable degree of scientific certainty, unless otherwise specifically stated. Should additional relevant or pertinent information become available, I reserve the right to supplement the discussion and findings in this expert report in this action.

EXECUTIVE SUMMARY

Earth's carbon is found in six reservoirs: rocks, oceans, atmosphere, plants, soil, and fossil deposits. In the carbon cycle, carbon moves from one reservoir to another. The human-induced transfer of carbon from fossil deposits to the atmosphere is causing Earth to warm. Even when that transfer ceases, in order to return the atmospheric reservoir to a point conducive to human well-being, we will need to remove carbon from the atmosphere and store it in other reservoirs. This is known as carbon sequestration or negative emissions. The potential for increased carbon sequestration from U.S. forest, range, and agricultural land management is, at peak, around 0.414 GtCeq per year (414 MtCeq per year). This could result in negative emissions within the US totaling about 21 GtCeq by 2100. Changes to land management practices could avoid the emissions of another 0.12 GtCeq per year, totaling 9.7 GtCeq by 2100. All told, over the period 2020 to 2100, changes to land management practices in the U.S. could mitigate more than 30 GtCeq between 2020 and 2100, which is over 30% of the negative and avoided emissions needed, after phasedown of fossil fuel emissions, to return Earth's atmosphere to a more stable state.

Three types of CO_2 removal are most widely discussed today: 1) Improved land management, 2) Bioenergy with CO_2 capture and storage (referred to as BECCS), and 3) Direct air capture. BECCS and direct air capture are both theoretically possible but currently unproven at any meaningful scale, and thus are not analyzed in this report. Of these three, improved land management represents the most mature, technically feasible, widely deployable, and lowest cost option currently available. Thus, this report focuses on improving land management to remove and store CO_2 and to reduce future emissions of three key greenhouse gases – CO_2, nitrous oxide, and methane.

Soil represents one of the largest actively cycling reservoirs of carbon on earth, most of which is stored in the form of soil organic matter, largely comprised of decomposing plant residue. Almost everywhere, conversion of native forest and grasslands to agriculture has resulted in a 30–50% loss of this carbon to the atmosphere as further decomposition to CO_2 is accelerated. Almost all soils actively managed for agriculture, as well those that have been abandoned from agriculture due to degraded fertility, have soil carbon levels well below their original levels, providing significant opportunities to sequester additional carbon.

There are a number of well-tested methods to increase soil carbon through agricultural practices on land used to grow annual crops. Avoiding tillage with no-till technology is one well-recognized practice to rebuild soil carbon. Other practices can be just as effective: adding winter cover crops to avoid bare soil for most of the year can increase soil carbon, as can diversifying crop rotations – growing more than one or two crops in sequence – and applying compost or manure. Growing perennial grasses or trees on degraded or low value agricultural soils can also result in significant carbon gains. On pastures and rangeland, soil carbon storage can be improved by increasing plant productivity via improved plant species and by avoiding over grazing via careful attention to the number of livestock per acre. About 43% of all pasture and rangeland in the U.S. is managed by federal agencies.

Forests can also be managed to enhance carbon sequestration in trees and soil. Faster growing species accumulate more carbon over their lifetimes and therefore planting more of these species will store more carbon in wood, as will growing trees in longer rotations (the number of years between harvests). A number of management factors can increase forest soil carbon. About 42% of all forestland in the conterminous U.S. is managed by federal agencies.

In addition to increasing carbon sequestration, changes in land management practices on federal and private lands can also reduce the amount of greenhouse gas emissions stemming from land use. Nitrous oxide is a greenhouse gas 250-300 times more potent than CO_2. Agriculture is responsible for 84% of global anthropogenic nitrous oxide emissions, and most agricultural emissions (62%) come from soils amended with nitrogen from fertilizers, manures, or legumes. Reducing nitrogen fertilizer rates to those needed for optimum yields is the most reliable means to reduce nitrous oxide emissions from fertilized cropping systems.

Methane is 28-36 times more potent than CO_2. Agricultural methane emissions come from digestive fermentation by livestock (52%), rice cultivation (22%), biomass burning (19%), and livestock manure handling (8%). Rice cultivation practices and livestock management offer important land-use related methane mitigation opportunities. Methane from rice production can be minimized through periodic drainage of flooded rice fields.

Finally, there is an opportunity to reduce greenhouse gas emissions and increase carbon sequestration by growing cellulosic bioenergy crops such as switchgrass on marginal lands that were formerly in agriculture and on lands now used to grow corn for grain ethanol.

All told, technology is available today to store carbon or avoid future greenhouse gas emissions from agriculture in the U.S. equivalent to more than 30 GtCeq by 2100. Farmers, ranchers, and landowners have shown a willingness to accept payments for implementing such practices. Financial incentives and federal policies will need to be aligned with the sequestration practices described below in order to achieve this scale of increased sequestration.

EXPERT OPINION

1.0 Introduction

Carbon is one of the most abundant elements on Earth. Most of the carbon on Earth is stored in rocks. The rest of Earth's carbon is in our oceans, atmosphere, plants, soil, and fossil fuels. Earth's carbon cycle involves the flow of carbon between each of these carbon reservoirs (or sinks). Some of the flow is very slow and some is fast. When carbon moves out of one reservoir it enters another, as depicted in **Figure 1**.

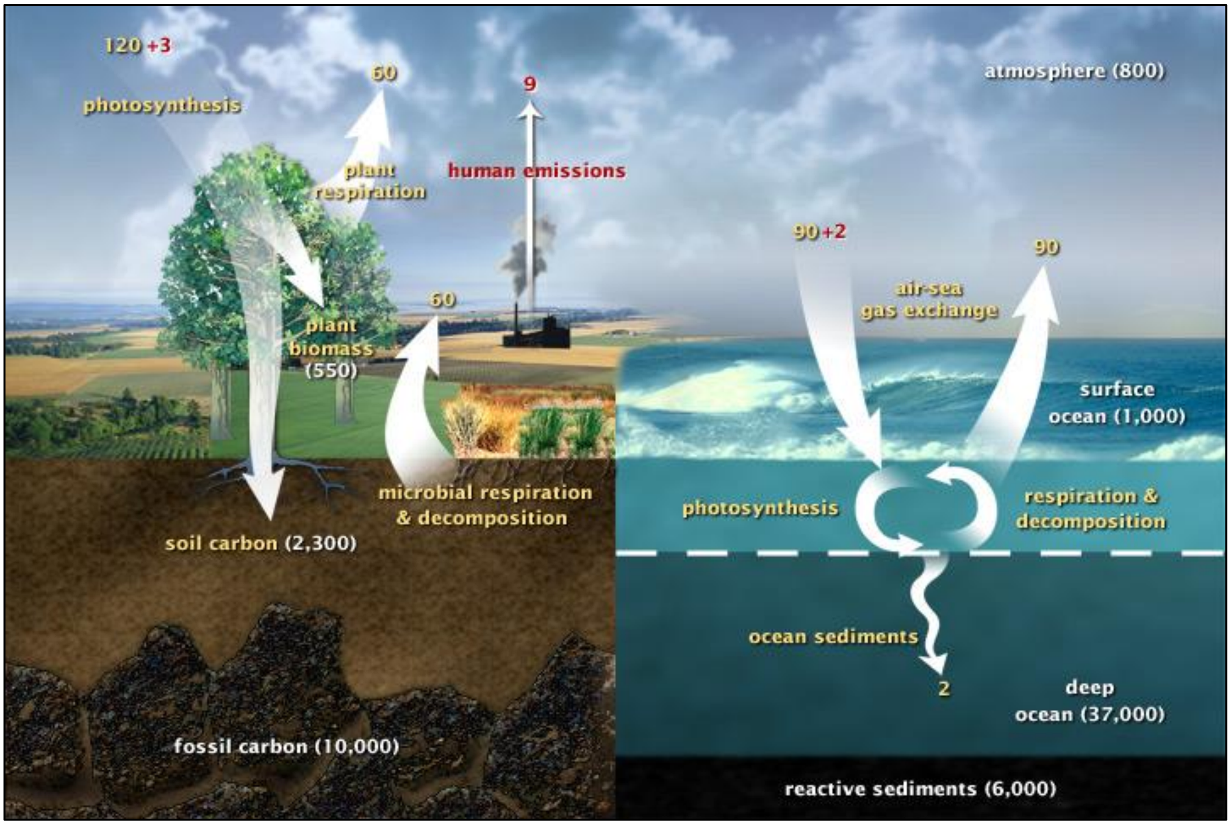

Figure 1. This diagram of the fast carbon cycle shows the movement of carbon between land, atmosphere, and oceans. Yellow numbers are natural fluxes, and red are human contributions in gigatonnes of carbon (GtC) per year. White numbers indicate stored carbon (carbon locked in deep geological reservoirs is not included except for fossil fuel reserves that could be mined). The human contribution, though seemingly small, adds up to a large imbalance and consequent increase in atmospheric CO_2. (https://earthobservatory.nasa.gov/Features/CarbonCycle/)

The atmosphere's CO_2 content is largely determined by the balance between processes that remove CO_2 from the atmosphere, such as photosynthesis and CO_2 absorption by seawater, and processes that return CO_2 to the atmosphere, such as respiration and fossil fuel burning. About 50% of the CO_2 that humans add to the atmosphere each year by burning fossil fuels is removed annually by natural removal and storage processes; the remainder accumulates in the atmosphere.

CO_2 transferred from the fossil deposits reservoir to the atmosphere through the burning of fossil fuels results in rising temperatures on Earth, as predicted by theory in the 19th century. In order to restore the Earth's energy balance so that temperatures can stabilize at safe levels for humanity and our natural systems, the carbon content of the atmosphere must be reduced. Such reductions will happen naturally over millennia if carbon emissions from the fossil reservoir cease. However, to avoid unsafe temperature increases, CO_2 must be removed more quickly. Managing plant and soil reservoirs for greater carbon storage represents a way to reduce – or mitigate – atmospheric CO_2. Increasing the amount of carbon stored in these reservoirs is commonly referred to as carbon sequestration, carbon storage and removal, or negative emissions.

Decreasing the amount of carbon stored in the atmosphere is widely acknowledged to require removing and storing CO_2 in other carbon reservoirs (negative emissions) as well as curtailing CO_2 sources such as fossil fuel burning (decarbonization) and deforestation. Of almost 900 mitigation scenarios evaluated by the Intergovernmental Panel on Climate Change (IPCC) with integrated assessment models,[1] all of the 116 deemed effective involved curtailing sources of CO_2 and more than 100 also involved CO_2 removal.[2, 3] Both CO_2 source reduction *and* CO_2 removal are thus central to future climate mitigation efforts. Indeed, under any climate recovery scenario, negative CO_2 emissions (removal and storage) will be required starting immediately to bring atmospheric CO_2 concentrations back within safe limits for our biological and human systems.[4, 5]

Three types of CO_2 removal are most widely discussed today: 1) Improved land management, 2) Bioenergy with CO_2 capture and storage (referred to as BECCS), and 3) Direct air capture.[3, 6, 7] Improved land management entails managing ecosystems to sequester more carbon in living biomass such as long-lived trees and in dead biomass such as organic matter in soils and ocean sediments. Bioenergy with CO_2 capture and storage refers to extracting energy by burning biomass and storing the resulting CO_2 in geologic reservoirs. Direct carbon capture involves extracting CO_2 directly from the air via enhanced weathering of rocks and minerals or direct air capture, with subsequent geologic storage. BECCS and direct air capture are both theoretically possible but currently unproven at any meaningful scale, and thus are not further analyzed in this report. Enhanced rock weathering and ocean fertilization have also been proposed but are less widely discussed or tested.[7, 8] Of this group, improved land management represents the most mature, technically feasible, widely deployable, and lowest cost option currently available.[3, 7] We have known about this option and its environmental co-benefits for decades.

In addition to managing land for negative emissions, land management can also contribute to climate mitigation by avoiding further greenhouse gas emissions.[4, 9] This can be done, for example, by reducing deforestation, a practice responsible for ~10% of total global carbon emissions today,[10] almost all outside the U.S. But greenhouse gases are also emitted by other land management and agricultural practices. For example, nitrogen fertilizer emits CO_2 when manufactured and emits nitrous oxide when applied to soils. Methane is emitted by soils under rice cultivation. Land management practices that avoid or reduce greenhouse gas emissions thus represent an additional climate mitigation opportunity. Some management changes have the potential to both curtail CO_2 emissions and remove CO_2 from the atmosphere. For example, producing ethanol from perennial grasses instead of corn grain both consumes less fossil fuel (curtailing CO_2 emissions) and stores more soil carbon (enhancing CO_2 removal and storage).

In the pages that follow are current opportunities for improved land management practices in the U.S. that are feasible and currently available to mitigate climate change. I emphasize those land management practices most likely to produce significant negative emissions—those that remove and store CO_2 from the atmosphere—and as well those practices capable of reducing emissions of CO_2 and the other biogenic greenhouse gases nitrous oxide and methane, respectively responsible for 82%, 10% and 5% of total U.S. greenhouse gas emissions.[11]

2.0 Scale of the Problem

From pre-industrial times fossil fuels have added 327 GtC to the atmosphere (half of that just since the 1980s),[12] with another 156 GtC added by deforestation. In 2014 fossil fuel burning added 8.8 GtC to the atmosphere,[13] with the U.S. responsible for 1.5 GtC[11] or about 17% of the global total that year. In recent years global deforestation has added annually another 0.9 GtC,[10] none from the U.S.[11]

To avoid or deflect the most disruptive effects of climate change now underway – sea level rise, shifting climate zones, species extinctions, coral reef decline, climate extremes, expanded forest burning, and human health impacts – requires returning atmospheric CO_2 concentrations, currently above 400 parts per mission, to 350 parts per million or below.[5, 14] This CO_2 level would largely restore Earth's energy balance, keeping temperatures within the Holocene range to which human societies, agriculture, and other species are adapted. This could be achieved by limiting total cumulative fossil fuel emissions to 500 GtC coupled with cumulative negative emissions equivalent to 100 GtC by 2100.[4] Hansen et al.[4] identify two major ways that land management can achieve a 100 GtC drawdown this century: 1) negative emissions from forest and soil carbon storage including reforestation and improved agricultural practices, and 2) avoided emissions from ending deforestation and deriving bioenergy from dedicated energy crops that do not compete with food crops. I agree these strategies have the potential to produce that quantity of negative emissions and both are discussed in more detail, below.

Ocean and land sinks today remove from the atmosphere about half of the CO_2 emitted by anthropogenic activities, or ~4.9 GtC annually for the 1990-2000 period.[10] About a third of the emitted CO_2, 2.6 GtC for this period, is removed by land sinks.[10] In the U.S., land sinks remove annually 0.2 GtC.[11] Negative emissions as discussed here are in addition to these existing natural sinks.

3.0 Soil Carbon Cycling and Storage

Carbon accumulates naturally during soil development as plants colonize new substrates such as sand and rock surfaces, transform atmospheric CO_2 to new biomass via photosynthesis, and then leave behind carbon-rich leaves, wood, roots, and other biomass that then decompose. Some plant parts decompose quickly, others more slowly. Wood, for example, is very resistant to microbial attack, and some of the natural carbon products that are highly resistant to microbes can persist for thousands of years. Soil organic carbon can also be trapped within soil aggregates, which are hardened clusters of soil particles (grains of sand, silt, and clay) wherein very low oxygen levels inhibit microbial activity. And some decomposition products, usually in the form of complex organic molecules, can be highly resistant to decay especially when bound to soil mineral surfaces.

Over time, most soils accumulate organic carbon to some equilibrium value that represents a few percent of total soil mass; in most soils this value is less than 5%. In waterlogged or cold soils such as those under bogs and tundra, decomposition occurs very slowly—microbial activity is suppressed by low oxygen or low temperatures or both—and in these locations, carbon can accumulate to very high proportions of soil mass.

Soil thus contains organic carbon of different ages and different susceptibilities to microbial decomposition. Soil disturbance—both natural and anthropogenic—can stimulate decomposition by altering the soil physiochemical environment. Clearing land for agriculture does exactly this: plowing the soil breaks apart aggregates and exposes protected carbon to microbial attack, and allowing soil to remain bare for much of the year causes it to be wetter and warmer—perfect conditions for microbes to convert soil organic carbon back to CO_2 in their quest for energy. Almost everywhere, conversion of native forest and grassland soils to agriculture results in a 30–50% loss of carbon from the top soil layers within just a decade or two (**Figure 2**),[15] a general pattern well-recognized since the 19th century.[16] Global estimates of this loss total 133 GtC, split nearly evenly between crop and grazing lands.[17]

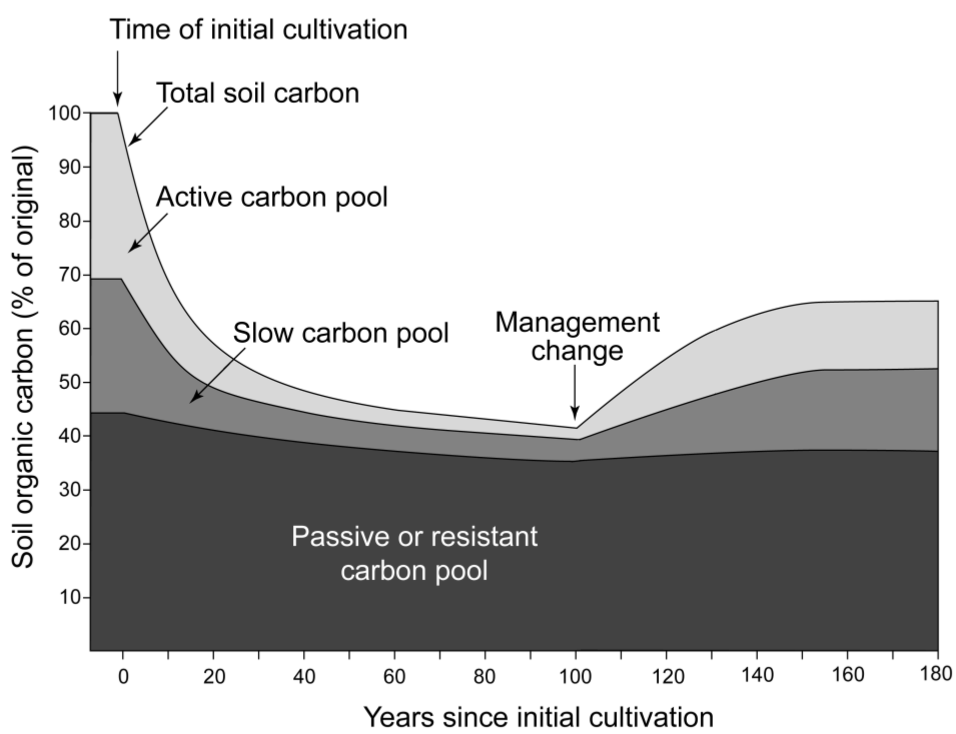

Figure 2. Changes in soil organic matter fractions following cultivation of a soil profile under native vegetation. Redrawn from Grandy and Robertson (2006).[26]

The basis for soil carbon gain is thus the net balance between photosynthesis, which fixes CO_2

into biomass carbon, and decomposition, which transforms biomass carbon back to CO_2. Thus the organic carbon content of soils is regulated by the balance between the rate of carbon added to soils from plant residues (both aboveground biomass and roots), plus, in agricultural soils, organic amendments such as compost and manure, and the rate of carbon lost from soil, mainly via decomposition, though soil erosion can be locally important.

3.1 Measuring Soil Carbon Storage

The total amount of organic carbon in a soil sample can be measured by a variety of techniques, most reliably by thermal oxidation.[18] Historically, carbon has been assessed by combusting a small soil sample at temperatures sufficient to convert organic carbon to CO_2. This generally entails placing a soil sample of known weight into a high-temperature furnace for several hours; the difference in mass on re-weighing represents oxidized carbon and by difference, the carbon content of the soil prior to combustion. A variation on this technique uses a chemical oxidizing agent rather than direct heat to combust the carbon. Today soil carbon is most commonly analyzed by gas chromatography: an automated sampler drops a tiny amount of ground, well-mixed soil into an oxygen-infused chamber that is subsequently ignited; the CO_2 liberated is then measured by gas chromatography or infrared gas absorption analysis.[19] Data from samples so analyzed can be used with high confidence; identical samples typically vary no more than 5-10%.

Due to the natural variability of soil at even small scales, most field experiments to document the effects of a management practice on soil carbon typically compare practices for similar slope positions, and often in replicated small plots, in order to detect differences with statistical confidence. Even so, to dependably detect soil carbon change typically requires a decade or more[20] because change occurs slowly such that it is much easier to detect with confidence a 10% carbon change over ten years that a 1% change over one year. Thus, both long-term sampling and experiments are important for assessing changes in soil carbon.

Soil carbon also varies with depth in the soil profile, so it is also necessary to design sampling programs to directly compare similar depths. Typically, the upper few cm of soil contain the most carbon, with concentrations falling rapidly in lower layers. Lower subsoil carbon concentrations plus its greater natural variability make it especially difficult to detect soil carbon change in lower horizons.[21] Thus, most of what we know about the effects of land management practices on soil carbon stores comes from changes in surface horizons,[22] typically the upper 25-30 cm where most root growth and biological activity occurs.

3.2 Soil Carbon Gain by Improved Land Management

Soils globally contain ~1,800 GtC to 1 m depth, comprising the largest terrestrial organic carbon pool and representing about twice the amount of carbon that is in the atmosphere (830 GtC). Soils of the conterminous U.S.[†] contain ~81 GtC to 1 m depth.[23] Thus a relatively small percentage increase in soil carbon represents a potentially strong climate change mitigation opportunity.[24]

[†] This includes soils on both federal and private lands in the lower 48 United States.

Soil carbon stocks can be increased by increasing the rate of carbon additions to soil or by decreasing the rate of decomposition, or both. Croplands and grazing lands can be managed for enhanced carbon gain, but for each there are limits to the extent of gains possible. First, with changes to soil management that lead to carbon gain, soil carbon stocks tend towards a new equilibrium asymptotically, such that gains diminish as the new equilibrium level is approached, usually over a few decades (**Figure 2**).[25] Second, this equilibrium level is finite for a given soil at a given location: soils tend to have a saturation level above which no further soil carbon increase is likely possible.[26] Furthermore, if this equilibrium is reached because of high exogenous inputs such as compost or manure, cessation of these inputs will lead to a new, lower equilibrium.[27]

Nevertheless, almost all soils in the U.S. actively managed for agriculture, as well as those that have been abandoned from agriculture due to degraded fertility, have soil carbon levels well below saturation, providing significant opportunities to manage for additional carbon. Cropland surface soils of the central U.S. are believed to have lost ~50% of their pre-cultivation carbon stocks by 1950.[28]

A number of agricultural practices have the potential to increase soil carbon. In most cases these practices differ by management system: practices for croplands are different from practices for grazing lands and both are different from practices for managed forests. Nevertheless, the principles in all cases are the same, and some practices can be applied across systems. Practices below are grouped into three categories: those relevant to cropland and grazing lands management, wetlands restoration, and forest management.

In Section 5, below, the total potential impact for the U.S. (GtC) is estimated based on the average likely carbon gain (GtC ha^{-1} yr^{-1}) for a given practice multiplied by the areal extent (acreage) on which the practice could be implemented, and then again by the number of years between 2020 and 2100 that the average gain might persist. In some cases, multiple practices could be implemented on the same lands – many cropland management practices, for example, such as no till adoption and diversified crop rotations. In other cases, practices are mutually exclusive – cropland management practices, for example, cannot be applied to set-aside cropland converted to perennial grasses. And some practices are already implemented to limited degrees.

Areal extents of potential practices are thus additional to any existing implementation, and are intentionally conservative in order to avoid the likelihood of double counting. The maximum extents possible are, of course, constrained by available land area; all private and public lands within the conterminous U.S. (the lower 48 states), on which Section 5 estimates are based, contains 159 Mha of cropland, 265 Mha of rangeland and pasture, and 256 Mha of forest lands.[29]

About 43% of total rangeland and pasture[30] and 42% of total forest land[31] in the conterminous U.S. are owned by the Federal Government and thus practices could be implemented directly. On privately held lands practices can be encouraged through financial incentives such as tax abatements or direct payments, used since the 1930s to advance national conservation goals. In 2017, for example,[32] the USDA spent $2.0 billion for the Conservation Reserve program, which kept 9.4 Mha of environmentally sensitive land set aside from production, including 0.8 Mha of restored wetlands; $2.8 billion for the Environmental Quality Incentives Program and the

Conservation Stewardship Program, which provide landowners conservation assistance to reduce soil erosion and enhance water, air, and wildlife resources on crop and grazing lands; and $0.5 billion for the Agricultural Conservation Easement Program, which helps to conserve grazing and wetlands in particular. Other than fire suppression, minor assistance was provided to private forest landowners, chiefly through the $0.02 billion Forest Stewardship program.

The duration of a given practice's carbon gain is likewise constrained by the average amount of time it takes the sink, whether soil or trees, to reach local equilibrium. For soils this will vary mainly by climate, management, and initial carbon content – for example, a degraded or long-cultivated soil will take longer to equilibrate than will a soil closer to its original carbon content. For trees this will vary mainly by location, species, and soil fertility – for example, trees in the Rocky Mountains grow more slowly than trees in the Pacific Northwest, and red pine grows faster than Douglas fir. On the other hand, the duration of avoided emissions is not constrained by biology – the emissions reductions will persist for as long as the practice persists.

3.2.1 Cropland Management

Cropland Management: Tillage

Farmers plow to control weeds, manage residues, and prepare the seed bed for planting. Plowing also causes carbon loss by mixing plant residues throughout the surface soil, bringing it into contact with microbes and other soil organisms like earthworms, and with moister soil more favorable to microbial activity. Plowing also breaks apart soil aggregates, especially the larger ones, exposing trapped organic carbon to aerobic microbes that readily respire it to CO_2.[33] In fact much of the early increase in atmospheric CO_2 starting in the 19th century was the result of pioneer cultivation,[34] which stimulated microbial activity and the conversion of soil organic matter to CO_2.

Modern advances in tillage technology provide many more options than traditional moldboard plowing, which inverts the upper 20–30 cm of soil. Contemporary lower-impact options, typically termed conservation tillage, range from chisel plowing, which avoids inverting the soil profile, to no till, which leaves the soil profile completely undisturbed. With no till, weeds are usually suppressed with herbicides or, at smaller scales, with cover crops and mechanical crimping, and seeds are planted with equipment that places seeds in slits cut through the preceding crop's residue, which is left to decompose on the soil surface rather than buried. Both of these practices can significantly increase the amount of carbon stored in the soil.

The primary impetus for the development of no-till and other conservation tillage techniques was erosion control.[35] Under no-till corn, for example, erosion can be reduced as much as 90%[36-39] by reducing the exposure of soil aggregates to raindrop impacts and to freeze-thaw and wet-dry cycles, allowing more to remain intact, protecting entrapped carbon from microbial oxidation to CO_2.[40] And plant residue, by remaining on the soil surface, decomposes more slowly.[41]

Carbon accumulation due to no-till has been documented in soils worldwide, including the U.S. since the 1950s.[35] Long-term field experiments comparing no-till to conventional tillage show typical no-till increases of 0.1–0.7 tC ha^{-1} yr^{-1}.[42, 43] West and Marland[44]estimated average rates of

0.3 tC ha^{-1} yr^{-1}, a rate consistent with other syntheses[45-48] including Eagle et al.'s,[48] who included the impact of nitrous oxide emissions in their overall estimate. Where soil carbon is already high, no-till has less capacity to increase soil carbon; no till also has less capacity to increase soil carbon in cooler or wetter areas where it can sometimes reduce crop yield.[49] Other forms of conservation tillage can also build soil carbon but at lower rates and less consistently.[50]

Importantly, to achieve a long-term increase in soil carbon from no-till practices, the no-till practices must be implemented continuously. Stored soil carbon can be quickly oxidized to CO_2 when no-till soils are tilled,[15, 51] with much of the no-till carbon benefit lost after a single tillage event.[52] Thus, while no-till is practiced on as much as 36% of U.S. soils annually, because it is practiced at least three years in a row on less than 13% of U.S. cropland,[53] and almost certainly less on a permanent basis, there presently is little long-term climate benefit. Efforts to use no-till as a negative CO_2 emissions strategy must consider no-till longevity an important design component.

An exception to this continuous long-term no-till rule is the potential for burying surface soil carbon with a single inversion tillage. In humid climates with poorly drained soils, a one-time deep inversion tillage may promote soil carbon storage by moving high-carbon surface soils to >50 cm depth, where decomposition is slowed due to cooler, wetter conditions with less oxygen. At the same time, low carbon soil at depth is moved to the surface where it can accumulate more carbon. In one of the only long-term deep tillage experiments, Alcántara et al.[54] found carbon accumulation rates equivalent to ~1 tC ha^{-1} yr^{-1} in Germany.

A further consideration is the potential for soil carbon to change at depths below the top soil horizon. Almost all quantitative assessments of no-till to date have assessed changes in soil carbon in the upper 25-30 cm of the soil where roots, soil organic matter, and microbes are most concentrated. However soil carbon also occurs at lower depths,[17] and there is the potential,[22, 55] but little quantitative evidence,[21, 56] for soil carbon changes at depth to counteract surface soil gains in some locations.

Although carbon savings associated with no-till also accrue from reduced fuel use due to fuel saved by not plowing, this saving is typically small (typically <0.05 tC ha^{-1} yr^{-1}),[44, 57] though permanent in that it is not subject to re-release like stored soil carbon.

Cropland Management: Summer Fallow and Winter Cover Crops

In most annual cropping systems soils are left bare for a substantial portion of the year**.** Without plants, soils lose carbon because there are fewer carbon inputs from roots and aboveground residues and because decomposition rates are higher – soils are wetter and warmer without plant transpiration and shading.[58] For most annual crops in the U.S. (e.g., corn, soybean, cotton, sorghum, peanut, and vegetables) the fallow period occurs over winter, stretching from mid-fall to late-spring (5-7 months). For fall-planted crops like winter wheat and winter canola, the fallow period occurs over summer and lasts from the mid-summer harvest to at least late fall (~3 months), or, where followed by a summer crop, to the following spring (9-10 months). Thus for most U.S. cropland the soil is bare for much of the year. In semi-arid regions summer fallows are often used to conserve soil moisture for a following crop.

Eliminating summer fallow periods can, in the U.S., sequester up to 0.3 tC ha^{-1} yr^{-1} of soil carbon depending on climate and tillage method. Eagle et al.[48] estimated an average soil carbon gain of 0.16 tC ha^{-1} yr^{-1}. Less the CO_2 cost of the additional nitrogen fertilizer used reduces the net benefit to 0.09 tC ha^{-1} yr^{-1}. Where summer fallow is used for water conservation, summer fallow cannot likely be eliminated but could be used less frequently, such as every third or fourth year instead of every second or third year.[59, 60]

Winter cover crops include annual grasses such as rye and legumes such as clover that are typically planted in the fall following harvest of the preceding crop. Prior to winter the cover crop germinates and grows to a size that allows it to survive wintertime temperatures in a dormant state, after which it grows rapidly the following spring. Before planting the following summer crop, the cover crop is killed and then either left to decompose on the soil surface or, more commonly but not necessarily, buried with tillage. Adding winter cover crops to a rotation can add 0.03–0.55 tC ha^{-1} yr^{-1} of soil carbon,[61, 62] depending on climate, even when the cover crop is tilled under — providing in many cases a carbon gain equal to no-till.[63]

Winter cover crops provide the additional co-benefit of reducing the need for nitrogen fertilizer due to their ability to scavenge the previous crop's leftover soil nitrogen that would otherwise be leached to groundwater or emitted to the atmosphere, and, in the case of legume cover crops, the ability to capture or "fix" nitrogen from air. This captured or new nitrogen is then made available to the next crop, reducing the need to apply fossil fuel-derived nitrogen fertilizers, thereby creating additional carbon savings by avoiding one of the most significant sources of greenhouse gases in intensively managed field crops.[64]

A recent meta-analysis[65] estimates average carbon sequestration potentials for winter cover crops of 0.32 tC ha^{-1} yr^{-1} globally, with a number of studies reporting rates as high as 1 tC ha^{-1} yr^{-1}. Including fertilizer savings, Eagle et al.[48] estimate a net potential carbon benefit of 0.37 tC ha^{-1} yr^{-1} for winter cover crop use in the U.S., not including CO_2 and nitrous oxide savings from reduced nitrogen fertilizer use, which they estimate could add another 0.16 tC ha^{-1} yr^{-1} of carbon savings. Poeplau and Don's[65] analysis suggest a new soil carbon equilibrium is reached after 155 years;[9] the reduced CO_2 and nitrous oxide savings from reduced nitrogen fertilizer use, where it occurs, would last indefinitely. For a variety of reasons, including additional seed and labor expenses as well as the risk of not killing the cover crop in a timely manner, cover crops are planted today on only ~3% of U.S. cropland.[66]

Cropland Management: Diversifying Crop Rotations

Crop species vary in the amount of biomass they produce, in the proportion of biomass that goes unharvested, including roots, and in the resistance of unharvested residue to decomposition. Thus, diversifying crop rotations is a time-tested means to build and retain soil carbon. In the U.S. as early as 1933 Salter and Green[67] reported on a 31 year experiment in which more complex rotations retained more soil carbon. In central Ohio they found that continuous corn (corn planted year after year) lost three times more soil carbon than did a three-year corn-wheat-oats rotation; continuous wheat and continuous oats similarly lost twice as much carbon as did the three year rotation (**Figure 3**).

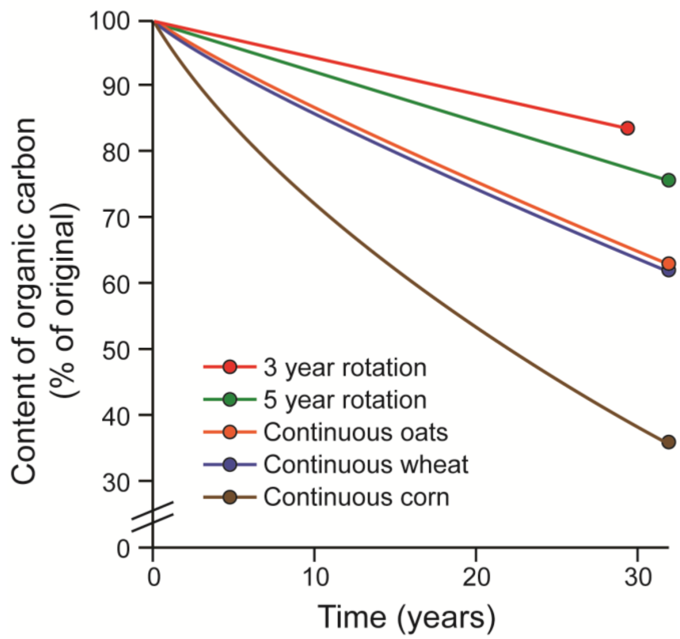

Figure 3. Rotation effects on soil carbon maintenance over a 31-year experiment. Redrawn from Salter and Green (1933).[58]

Diversifying annual crop rotations can thus significantly increase carbon stores.[50, 60, 68] The addition of perennial species such as hay and alfalfa to annual crop rotations, because of the deep and persistent roots of perennial crops and their longer growing season, can boost soil carbon still further,[42] as can the inclusion of legumes such as clover.[69] Measurements of soil carbon change under more diverse annual cropping systems range from 0.02 to 1.1 tC ha^{-1} yr^{-1},[46, 50, 70, 71] but results are highly dependent on associated full-rotation changes in crop residues, tillage, and other factors that affect soil carbon stores. In consideration of these unknowns, Eagle et al.[48] estimate an average net carbon benefit of 0.05 tC ha^{-1} yr^{-1} for diversifying crop rotations to a sequence more complex than corn – soybean, mainly achieved by lower nitrous oxide emissions.

Cropland Management: Manure and Compost Addition

Organic materials such as compost and manure, when added to productive soils, tend to increase soil carbon stocks only as long as additions are sustained.[27] Added to less productive soils, however, benefits can persist because of their additional impact on soil water holding capacity, porosity, aeration, infiltration, and nutrient holding capacity. These soil fertility co-benefits can increase crop productivity and subsequent residue inputs. Thus, while the climate benefit of moving compost or manure from one part of the landscape to another must be considered,[72] where soil fertility is sufficiently improved to increase productivity the soil carbon gain is a legitimate and persistent climate benefit.

In one recent example, Ryals et al.[73, 74] added compost to rangeland, which, exclusive of carbon in the compost addition itself, appeared to increase soil carbon storage by 25-70% or 0.51-3.3 tC ha^{-1} three years after a single compost addition.[74] Where manure is derived from crop harvest, which is the case for most dairy and feed-lot cattle in the U.S., its return to soil can be considered another form of crop residue return and thus also a climate-legitimate carbon gain when compared to business-as-usual practices. Estimates of soil carbon gain from long-term applications of livestock manure to arable soils range from 0.2 to 0.53 tC ha^{-1} yr^{-1}.[75, 76] Eagle et al.[48] estimate a range of 0.05 to 1.4 for an average of 0.71 tC ha^{-1} yr^{-1} that does not include CO_2 savings from reduced nitrogen fertilizer use. Sequestration will likely continue for the duration of manure additions, in our case >80 years – the world's longest-running manure addition experiment has found soil carbon stocks still increasing after 120 years,[77] though stocks will equilibrate to some lower level upon cessation.[77, 78]

3.2.2 Cropland Conversion to Perennial Grasses

Cropland Conversion: Set-aside Highly Erodible Cropland

Converting degraded or highly erodible cropland to perennial grasslands has the potential to sequester soil carbon insofar as perennial grasses have greater root carbon stocks than annual crops and because they are grown without tillage. Nevertheless, such conversions must be planned carefully to result in a legitimate climate benefit: Converting annual cropland to perennial grassland has no climate benefit where equivalent food production must be made up by more intensive crop production elsewhere, especially if such displaced crop production causes deforestation.[79] Indirect land use change effects, while disputed by some,[80] are undoubtedly possible and can potentially exceed local carbon savings.[81]

Nevertheless, USDA conservation programs that pay farmers to convert privately-owned annual cropland with conservation value (e.g., highly erodible land) to grasslands or trees can lead to significant soil carbon savings as a valuable co-benefit. For example, around 9 Mha are currently enrolled in the U.S. Conservation Reserve Program, down from a high of 15 Mha in 2007.[82] Sperow et al.[83] estimate that an additional 30 Mha could be added to the 9 Mha currently enrolled based on a USDA erodibility index.

Several recent reviews of soil carbon gain on conversion of annual grain to perennial grasses report average carbon sequestration potentials that range from 0.28–1.3 tC ha^{-1} yr^{-1}.[84-87] Including the upstream savings from reduced agronomic inputs and nitrous oxide emissions (but not fossil fuel carbon offsets), Eagle et al.[48] estimate an average carbon benefit of 0.97 tC ha^{-1} yr^{-1}.

Cropland Conversion: Cellulosic Bioenergy on Grain Ethanol Lands

Where annual crops are currently used for grain-based biofuel production, conversion to dedicated cellulosic feedstocks such as perennial grasses could likewise sequester soil carbon and in this case without potential indirect land use change effects. Cellulosic feedstocks would additionally provide greater life cycle carbon savings than the grain-based feedstocks they would replace.[88] In 2017 ~38% of total U.S. corn acreage, or 13 Mha, was used for grain ethanol production;[89] converting this cropland to a perennial cellulosic crop would result in carbon savings additional to those from no-till conversion (assuming conversion from no-till to avoid double counting the no-till and perennial conversion benefits).

The rate of soil carbon gain for annual cropland converted to perennial biofuel crops would be similar to that for set-aside cropland (0.97 tC ha^{-1} yr^{-1}). This assumes little of the converted annual cropland was under permanent no-till management (see Section 3.2.1, above).

Cropland Conversion: Cellulosic Bioenergy on Former Cropland

The potential for additional mitigation from planting marginal lands – former cropland now abandoned – to cellulosic biofuel crops is also significant. Additional to the fossil fuel offset benefit is the soil carbon gain, especially on soils abandoned due to low fertility. Again, placement of such crops would need to avoid land with significant standing carbon stocks such as forests and wetlands to achieve a short-term climate benefit. Robertson et al.[88] note that about 55 Mha of the 70-100 Mha of cropland abandoned since 1900 that is neither forest nor wetland would be needed to meet expected 2050 biofuel needs.[90] Planting these lands to higher productivity grass species would cause carbon accumulation additional to that already occurring in these lands.

The rate of soil carbon gain for former cropland converted to perennial biofuel crops would be similar to that for set-aside cropland but discounted by the carbon gain already occurring under existing unmanaged vegetation.[88] Assuming that the managed grasses are about twice as productive as the pre-existing vegetation, the discounted credit is likely to be ~50% of the grassland conversion credit of 0.97 tC ha^{-1} yr^{-1}, or 0.48 tC ha^{-1} yr^{-1}. This value does not include a fossil fuel offset credit.

3.2.3 Grazing Lands Management

Grazing Lands Management: Improved Animal Stocking Rates

Grazing lands, whether planted pastures as are typical in the eastern U.S., or extensive rangelands as are typical in the western U.S., are dominated by perennial grasses managed without annual tillage. Soil carbon stores can be improved significantly by increasing plant productivity via improved attention to livestock stocking rates.[86] On rangelands, estimates of soil carbon increases resulting from improved stocking rates range from 0.07 to 0.31 tC ha^{-1} yr^{-1},[91, 92] with higher rates for the Rocky Mountains and Great Plains region. In a new meta-analysis of some 50 studies, Conant et al.[86] estimate an average soil carbon sequestration potential for improved stocking management on extensive rangelands of 0.28 tC ha^{-1} yr^{-1}. Because of a relatively low sequestration rate, time to equilibration will likely exceed 80 years.

On pasturelands, Eagle et al.[48] note the potential for intensive rotational grazing to improve soil carbon storage due to increased plant productivity and careful attention to stocking rates. The average sequestration rate for the few available published studies is 0.25 tC ha^{-1} yr^{-1}.

Grazing Lands Management: Improved Plant Species Composition

Grazing lands carbon sequestration can also be increased by improving grass species composition. Interseeding legumes such as alfalfa on rangeland[93] can increase long-term carbon accrual by 3.1 tC ha^{-1} yr^{-1}, and interseeding improved grass species can improve average soil C by similar amounts.[94] Eagle et al.[48] estimate an average soil carbon gain of 0.40 tC ha^{-1} yr^{-1} for improved species composition on rangelands. Henderson et al.[95] estimate an average gain of 0.56 tC ha^{-1} yr^{-1} for planting legumes in pastures, even after decrementing rates for increased nitrous oxide emissions.

3.2.4 Frontier Technologies

There are unconventional technologies also under study for increasing carbon removal and storage through agricultural land management practices, some more mature than others. While these practices may eventually prove to increase the carbon sequestration potential within the U.S., I do not include these technologies in my quantitative assessment of negative emissions because their feasibility and benefits are yet too uncertain. The technologies include, but are not limited to:

1) Very high animal stocking rates on extensive rangeland for short periods of time, known by a number of names including intensive rotational grazing (as for pasturelands) and mob grazing, have shown promise for improving productivity and soil carbon stocks. In at least one study additional soil carbon accumulation was ~3 tC ha^{-1} yr^{-1} compared to continuous grazing.[96] These results are too early to generalize, however,[97] and recommendations await the results of further experimentation.

2) Biochar additions to soils have shown, in many cases, a propensity to increase long-term soil stocks via direct carbon stock change and improved soil fertility that, like compost, can boost productivity in degraded or infertile soils. Biochar is charcoal: a pyrolysis byproduct of the thermochemical conversion of wood to other energy products such as biogas and liquid bio-oil.[98] Most biochar is highly resistant to microbial attack, and additions to a wide variety of soils have demonstrated its general tendency to persist—indeed, many soils of fire-prone ecosystems in the U.S. contain substantial amounts of natural biochar.[99]

But biochar additions can also enhance the decomposition of native soil organic matter,[100, 101] offsetting the soil carbon benefit of biochar itself, and as well biochar may be of greater mitigation value if converted directly to energy to offset fossil fuel use.[8] A biochar recommendation awaits further research to clarify both the long-term soil carbon gain in field studies and life cycle carbon analysis in comparison to alternative uses.

3.2.5 Wetlands Restoration

Wetlands Restoration: Histosols

Histosols are soils high in organic matter due to their formation under waterlogged conditions that inhibit microbial activity. As wetland plants such as sphagnum moss produce biomass, a significant fraction accumulates as peat and high-carbon sediments. When drained for agriculture, histosols tend to be extremely productive, but once exposed to oxygen, microbial activity accelerates and histosols can lose carbon quickly at rates as high as 20 tC ha^{-1} yr^{-1}.[102] About 8% of histosol soils in the U.S. have been drained for agriculture, mostly in Florida, Michigan, Wisconsin, Minnesota, and California.

Carbon accumulation in these soils can be restored (carbon loss reversed) by taking them out of production and restoring the high water table. Although restoring wetland conditions will also restore methane production, the combination of reversed carbon loss and abated nitrous oxide emissions usually will exceed the additional methane loss, leading to a large net emissions reduction.[103] However, the area of cultivated histosols soils is relatively small in the U.S.—used mostly for vegetables and sugar cane production—so the overall mitigation potential is modest.[24] And as for cropland conversion to perennial grasslands, care must be taken to avoid indirect land use change effects. In 2017, the USDA paid farmers to maintain 0.8 Mha of restored wetlands[32] through the Farmable Wetlands Program (https://www.fsa.usda.gov/programs-and-services/conservation-programs/farmable-wetlands) within the Conservation Reserve Program (see Section 3.2); at least another 0.8 Mha is readily available.[48]

Estimates of carbon gain under restored histosols vary widely, from 0.6 to 20 tC ha^{-1} yr^{-1}.[48] An average value, considering other greenhouse gas impacts such as increased methane emissions, was estimated by Alm et al.[104] to be around 2.7 tC ha^{-1} yr^{-1} for Finnish peatlands; more recently Griscom et al.[9] suggest an average value from a global peatlands database of 3.65 tC ha^{-1} yr^{-1}.

Wetlands Restoration: Non-Histosols

A substantial fraction of non-histosol wetlands have been drained for agriculture in the U.S., and despite being below the threshold for definition as histosols, prior to agricultural conversion they generally had higher soil organic matter content than well-drained soils. About 80% of wetland drainage in the U.S. has been attributed to agriculture, or ~32 Mha since 1780. Estimates of soil carbon accumulation upon restoration are highly uncertain but in the range of 0.41 tC ha^{-1} yr^{-1},[105] much smaller than for histosol wetlands with their substantially greater soil carbon content, and in the range that could be offset by increased methane emissions. Thus it is not yet clear whether non-histosol wetland restoration is an effective carbon sequestration strategy.

3.2.6 Forest Management

Forests, like croplands and grazing lands, can be managed to enhance carbon sequestration via changes to forestry practices or by conserving standing forests. Generally forest management includes reforestation, which refers to the reestablishment of trees following forest harvest, but does not include *afforestation*, defined by IPCC[105] as the establishment of trees on lands that have been deforested for 50 years or more. In the U.S., afforestation largely comes at the expense of current crop and pasturelands[106] and thus will create indirect land use change effects elsewhere, likely resulting in little if any net climate benefit.[107, 108] About 42% of total forestland in the conterminous U.S. is publicly owned and managed by federal agencies.

Forest Management: Improved Stand Management

Improved forest management designed to enhance carbon sequestration in tree biomass includes choices of tree species (fast versus slow growing), harvest age or rotation length, and the use of practices such as fertilization, controlled burning, and thinning to increase forest productivity and carbon storage. Delaying rotation increases carbon storage because carbon continues to accumulate as the trees grow;[109, 110] even relatively old growth forests continue to accumulate carbon in soil stocks, including carbon in slow-to-decay fallen trees on the forest floor.[111, 112] But even without additional carbon sequestration, preservation of an existing forest biomass stock keeps it from the atmosphere for the period delayed.

Rotation lengths differ regionally by tree species and ownership and can be managed readily. Softwoods and mixed species in nonindustrial private forests of the southern U.S. are typically managed on rotations of 25 to 35 years or longer, although rotations in commercial forestry may be half this length.[113] In the western U.S., commercial rotations tend to be 45–60 years because of longer-lived species.

Delaying harvest and converting unmanaged forests to faster-growing species to increase forest productivity can sequester, on average, 1.4–2.1 tC ha^{-1} yr^{-1}.[113, 114] Using an economic model, the U.S. Environmental Protection Agency (EPA)[106] estimated that 7-105 MtC yr^{-1} (0.07 – 0.105 Gt C yr^{-1}) could be stored by all forests in the conterminous U.S. at carbon prices from $1 to $50 per tCO_2 for 100 years or more; at a conservative $15 per tCO_2,[8] this amounts to 60 MtC yr^{-1}. Their variable price economic model yields a 55 MtC yr^{-1} average by mid-century, which is consistent with Griscom et al.'s[9] U.S. projection of 18 MtC yr^{-1}, not including planted forests nor fire management, which they consider alone could avoid 11 tC ha^{-1} yr^{-1} of carbon loss in fire-prone forests such as those in the western U.S.

Reforestation, not considered here because of overlap with marginal lands included in cellulosic biofuel estimates (Sections 3.2.2 and 4.2.4), could also provide substantial negative emissions. Griscom et al. project potential sequestration of 98 MtC yr^{-1} were all once-forested U.S. pastureland, mostly east of the Missouri River and including lands currently grazed, reforested. Such a strategy, however, would require diet shifts away from meat to avoid indirect land use effects, whereby displaced food production results in conversion of natural areas (with its carbon loss) elsewhere, such as Amazonia. On the other hand, reforestation on marginal lands not used for grazing could provide carbon benefits similar to conversion to cellulosic biofuels once biofuels were no longer used for fossil fuel displacement.[115]

Forest Management: Improved Soil Management

Soil carbon stocks in U.S. forests are, in aggregate, substantial;[116] about 50% of the carbon in U.S. forests is in the soil and another 8% in detrital material on the forest floor.[117] Various activities can affect forest soil carbon storage: rotation length, harvest intensity, and fire management are among the most important. Kimble et al.[117] estimate that in total, U.S. forests managed for timber could sequester 25 to 103 MtC yr^{-1} (0.25 – 0.103 GtC yr^{-1}), for average sequestration rates of 0.12 – 0.51 tC ha^{-1} yr^{-1}, or a mean of 0.32 tC ha^{-1} yr^{-1}, a more conservative rate than earlier IPCC[105] estimates for temperate forests of 0.53 tC ha^{-1} yr^{-1}. This sequestration would be additional to the current U.S. forest soil background sink recently estimated[118] at 13-21 MtC yr^{-1}. Kimble et al.[119] further estimate that soils under agroforestry systems – e.g. alleycrops, riparian buffers, windbreaks, and urban forests – could sequester nationally another 17-28 MtC yr^{-1}, or an average of 22.5 MtC yr^{-1}.

4.0 Agricultural Greenhouse Gas Abatement by Land Management

4.1 Measuring Nitrous Oxide and Methane Fluxes

Nitrous oxide and methane, like CO_2, are naturally occurring greenhouse gases. They are distinguished in part by their substantial global warming potentials, the degree to which they are responsible for radiative forcing of the atmosphere compared to CO_2. Over a 100-year time horizon, nitrous oxide has 265-300 times the global warming potential of CO_2, and methane 28-36. [10, 120] Another way of thinking about global warming potentials is that 1 Mt of avoided nitrous oxide emission is equivalent to 265-300 Mt of sequestered CO_2. Thus, though their atmospheric concentrations are substantially lower than those of CO_2, they pack significant punch and concentrations of each have risen by about 45% since 1970.[1] In order to directly compare the atmospheric impact of all three gases, emissions of nitrous oxide and methane are multiplied by 298 and 25, respectively,[102] and expressed as CO_2 or carbon equivalents (CO_2eq or Ceq).

Nitrous oxide is naturally emitted by bacteria in soils and other environments as a byproduct of their nitrogen metabolism. Some nitrous oxide is also emitted naturally from fires. Agriculture is responsible for 84% of anthropogenic nitrous oxide emissions,[121] and most agricultural emissions (62%) come from soils amended with nitrogen from fertilizers, manures, or legumes. Thus a major mitigation opportunity related to land management is improved nitrogen fertilizer efficiency.

Agricultural methane emissions come from enteric fermentation by livestock (52%), rice cultivation (22%), biomass burning (19%), and livestock manure handling (8%).[121] From the standpoint of land management, rice cultivation offers today a substantial cropland mitigation opportunity where rice is grown.

The non-CO_2 greenhouse gas exchanges with the atmosphere (fluxes) are not easily quantified. Most of what we know comes from thousands of gas flux measurements made from small chambers (often 25-30 cm diameter) placed on the soil surface. As gases accumulate in the chamber, over the course of an hour or two gas samples are withdrawn and analyzed for nitrous oxide or methane. The rates of gas accumulation are calculated from these samples and represent net emissions.[122]

Like soil carbon, the spatial variability of fluxes from soil is very high. Consequently, evaluations of abatement by different agricultural practices are usually made in experimental plots to isolate the effect of the practice from natural soil variability. Such comparisons provide a high degree of confidence when they are made at appropriate times: unlike soil carbon stocks, gas fluxes are also highly variable in time. It's thus important to compare fluxes during periods of low fluxes and high fluxes, and sampling campaigns are expensive because of this need for frequent sampling. Nevertheless, nitrous oxide and methane fluxes have been measured in agricultural systems for over 40 years, and we have a reasonable understanding of the major factors that regulate fluxes and can identify a number of mitigation paths.

4.2 Avoided Emissions by Improved Land Management

4.2.1 Reduced Nitrous Oxide Emissions from Field Crops

About 50% of anthropogenic nitrous oxide emissions are from nitrogen-fertilized field crops such as corn and wheat, where natural soil bacteria that produce nitrous oxide are stimulated by more available soil nitrogen. While factors other than fertilizer can also accelerate nitrous oxide production, it has been known from field studies since the 1970s[123-125] that nitrogen fertilizers are responsible for most agricultural nitrous oxide emissions (e.g., **Figure 4**). In fact, most IPCC national greenhouse gas inventories tally agricultural nitrous oxide emissions as a fixed percentage of nitrogen fertilizer use.[126, 127] Recent evidence that N_2O emissions increase exponentially with nitrogen fertilizer additions in excess of crop need[128, 129] places even more importance on fertilizer nitrogen rate as a predictor of agricultural emissions; this exponential increase is incorporated in both commercial greenhouse gas reduction protocols[130, 131] and in USDA protocols for quantifying farm-level emissions.[132] These protocols are now being built into the COMET-Farm tool that allows farmers and ranchers to calculate the greenhouse gas impacts of current and projected practices.[133]

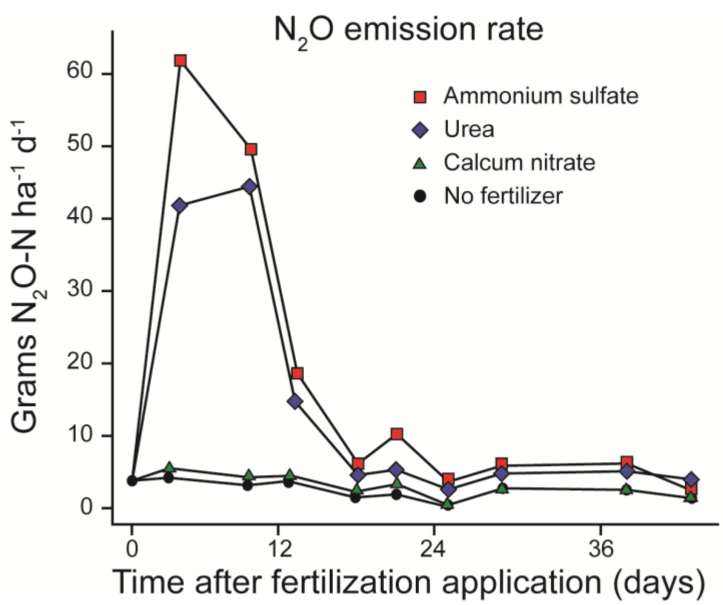

Figure 4. Nitrous oxide (N_2O) emission response to nitrogen fertilizer. Redrawn from Brietenbeck et al. (1980).[111]

While other management interventions are also known to reduce nitrous oxide emissions at specific locations,[132] reducing nitrogen fertilizer inputs to the rate needed for optimum yields (called by agronomists the economically optimum rate) is the most reliable means to reduce nitrous oxide emissions from fertilized cropping systems.[134] Carbon equivalent savings for a 15-20% increase in fertilizer use efficiency (equivalent to a 15-20% reduction in average nitrogen fertilizer use) in rainfed crops range from 0.15 to 0.29 tC_{eq} ha^{-1} yr^{-1}.[103, 134-136]

Millar et al.[134] used an optimum fertilizer rate calculator to show that nitrogen fertilizer rates on corn could be reduced for seven Midwest states by at least 15% without affecting yields. A 15% reduction represents an average avoided nitrous oxide emission of 2.2 kg N_2O ha^{-1} yr^{-1}, equivalent to 0.18 tCeq ha^{-1} yr^{-1} assuming a conservative emission factor of 0.017 kg of nitrous oxide nitrogen per kg of nitrogen fertilizer applied.[129] In 2014 the U.S. consumed 13.3 Mt of fertilizer N;[137] a 15% savings (2.0 Mt N) would additionally save 15% of the CO_2 cost of manufacture, equivalent to 2.2 MtC yr^{-1} (0.0022 GtC yr^{-1}) at a fertilizer production cost of 4 kg CO_2 per kg of nitrogen.[138]

At midcentury, others[139, 140] project a 50% increase in nitrogen fertilizer use efficiency, from 53% today to 75% in the future. If implemented immediately, this would lead to a 32% reduction in nitrogen fertilizer use,[9] for avoided nitrous oxide emissions of 0.36 tC_{eq} ha^{-1} yr^{-1} and avoided CO_2 from fertilizer production of 2.2 Mt C yr^{-1}. Cropland affected by this savings is assumed to be that planted to crops in 2012 (139 Mha) less the acreage in soybeans and peanuts,[141] major commodity crops that require no nitrogen fertilizer.

4.2.2 Rice Water Management for Methane

Rice in the U.S. grows in flooded soils that create the oxygen-depleted soil environment necessary for methane production. While rice is not a major cereal crop in the U.S., annual rice-related methane production is 3.1 GtCeq[11], about 2% of 2015 U.S. methane emissions and about 2% of total worldwide methane production from rice.[142]

Methane from flooded rice is most readily controlled by periodic drainage. Sass et al.[143] documented a 50% reduction in emissions in Texas with a single mid-harvest drainage, and almost complete cessation with a 2-day drainage every three weeks. Others have found similar responses around the world, particularly in China.[144] Eagle et al.[145] suggest a U.S. rice methane mitigation potential of 0.54 tCeq ha^{-1} yr^{-1} based on improved drainage practices. Additional mitigation can be achieved with new high-yielding rice cultivars that increase root zone porosity and consequent methane oxidation.[146]

4.2.3 Cellulosic Bioenergy Production on Grain Ethanol Lands

As noted earlier, about 44% of U.S. corn acreage is currently used for grain-based ethanol production. Were this acreage turned to biomass production for cellulose-based ethanol production, using technology that is currently in commercial use in the U.S., the climate benefit of ethanol production would be substantially improved because the production of cellulosic biomass crops like switchgrass require very few fossil fuel inputs, unlike the production of corn grain. Whereas grain-based ethanol avoids only 18% of the CO_2eq that would otherwise be emitted by gasoline, cellulosic ethanol avoids nearly 90%[147, 148]. Thus, substituting cellulosic feedstocks such as switchgrass on current corn grain ethanol cropland could provide a substantially greater fossil fuel offset than grain ethanol feedstocks, in addition to providing soil carbon sequestration as noted above in Section 3.2.

The additional climate benefit can be calculated from a standard life cycle analysis model such as GREET.[149, 150] Not including the soil carbon benefit already considered above, switchgrass with a conservative biomass yield of 8 Mg ha^{-1} yr^{-1} can provide 1.44 tC ha^{-1} yr^{-1} of fossil fuel CO_2 savings when converted to ethanol.[150, 151] The difference from corn grain (0.73 tC ha^{-1} yr^{-1} for a grain biomass yield of 11 Mg ha^{-1} yr^{-1}) represents a net avoided CO_2 emission benefit of

0.71 tC ha^{-1} yr^{-1}. The difference would be greater with a higher yielding cellulosic biomass crop.

4.2.4 Cellulosic Bioenergy Production on Marginal Lands

Cellulosic biofuels can also be grown on former agricultural lands, as noted earlier. To meet expected 2050 liquid transportation fuel demands requires ~55 Mha of the 70-100 Mha of crop and pastureland abandoned from agriculture since 1900, excluding urban, forest, and wetlands.[88] Planting this acreage to switchgrass with an avoided CO_2 emission benefit of 1.08 tC ha^{-1} yr^{-1} for an average 6 Mg ha^{-1} yr^{-1} yield[150, 151] would generate a significant avoided CO_2 emissions savings. This value does not include the soil carbon sequestration included as negative emissions. Note that this is not BECCS, insofar as the carbon in the fuel is not geologically sequestered as CO_2.

5.0 Total Mitigation Potentials

Several published studies have estimated a total biophysical potential for soil carbon sequestration globally and in the United States with land management technologies that are currently available. Before summarizing the U.S. carbon mitigation potential it is worth considering the global perspective.

5.1 Global Estimates of Potentials for Soil Carbon Gain

Recent global estimates of the biophysical potential for cropland and grazing land soils to sequester carbon range from 0.4–1.5 GtC yr^{-1} (**Table 1**).[24, 105, 152-156] Each of the estimates in Table 1 assume adoption of some combination of improved cropland and grazing land management, agroforestry, and restoration of degraded lands and histosol wetlands. Note that they do not include other sequestration practices described above, including sequestration due to improved forest management and conversion of grain ethanol lands to cellulosic biofuel crops, nor savings from avoided emissions such as those from improved nitrogen fertilizer use. That these global estimates are similar to one another arises from considering the same types of practices and using similar well-constrained field estimates that are based on long-term experiments for major mitigation practices such as no-till.

To calculate the total century-long mitigation potential requires knowing for how long these rates are sustainable. As noted earlier, soil carbon accumulation tends to behave asymptotically – after some period maximum rates slow until a new equilibrium is reached (**Figure 2**). Although very long term experiments in agricultural systems are rare, it's clear that the applicable period likely differs among management practices, climate zones, and initial soil carbon levels. Many researchers assume conservatively that average maximum rates occur for at least 20 years with the rate of sequestration after then declining to a new steady state that occurs about 40 years post management change,[28, 44] although some (e.g.[152]) assume >50 years persistence. A 30-year period at average sequestration rates seems a reasonable working value and is the value I have used for the calculations contained in this report.

Year	Estimate (GtC_{eq} yr^{-1})	Improved cropland management	Improved grazing land management	Set-aside of erodible cropland to grassland	Restoration of degraded land	Agroforestry	Restored peat soils	Reference
1998	0.4–0.9	x		x	x			Paustian et al.[152]
1999	0.5–0.6	x			x			Lal and Bruce[153]
2000	0.82	x	x	x		x	x	IPCC[105]
2004	0.4–1.2	x	x	x	x	x		Lal[154]
2008	1.4–1.5	x	x	x	x		x	Smith et al.[103]
2014	0.7–1.4	x	x	x	x	x		Sommer and Bossio[156]
2016	0.3–1.5	x	x	x	x	x	x	Paustian et al.[24]

Table 1. Published estimates of global soil carbon sequestration potentials based on biophysical processes that could be enhanced by land management actions. Not included are sequestration potentials from forest management, cellulosic biofuel crops, or carbon additions such as compost or biochar, nor savings from avoided emissions such as those from avoided nitrogen fertilizer use.

If the average global sequestration rate of 1.2 GtC yr^{-1} for the three most recent analyses[24, 155, 156] is multiplied by a conservative 30-year sequestration period, then we can calculate an end-of-century value of ~36 GtC sequestered for this set of soil carbon practices.

Expanding the scope to include forests and coastal wetlands readily boosts global negative emissions potentials well past the 100 GtC end-of-century target for restoring a 350 ppm CO_2 atmosphere.[4] In one recent analysis Griscom et al.[9] consider at the global scale 20 conservation, restoration, and land management actions that, in aggregate, could sequester or avoid as much as 6.5 GtC yr^{-1} for at least a 25 year period. They include aggressive reforestation, forest management, coastal wetland and peatland restoration, and **Table 1** practices to yield 169 GtC of negative emissions by the year 2100 if implemented soon. If reforestation were to more reasonably include reforesting only 25% of the once-forested areas, rather than 100%, their estimate reduces to 148 GtC by 2100.

Avoided emissions, including stopping deforestation and wood fuel harvest, improved nitrogen fertilizer management, and avoided coastal wetland and peatland conversion provides another 128 GtC of savings, for a global end-of-century total of 276 GtC.

It is worth emphasizing that these practices are feasible and available for implementation today, and would provide land-based CO_2 mitigation additional to the existing 2.6 GtC yr^{-1} land sink (Section 2.0).

Including frontier technologies such as biochar additions and the development of microbiome-assisted carbon accrual could further increase soil carbon sequestration potentials, perhaps by as much as 1.8 fold.[24] Worth noting too is the French government's "4 per mille" initiative announced at the time of the 2016 Paris climate accord,[157] which aims to increase global soil carbon stocks by 0.4% per year, an aspirational goal equivalent to sequestration rates of 3.4 GtCeq yr^{-1} (272 GtC if sustained through 2100) that has attracted significant attention.[158-160] Many, myself included, feel this rate is overambitious in part because we don't know the saturation potentials for most soils, but the initiative has raised awareness and will likely spur further research to identify additional soil carbon management interventions.

5.2 U.S. Potentials for Negative and Avoided Emissions by Land Management Change

Table 2 presents a summary synthesis of the management practices identified in the sections above for the U.S. Negative emissions, including Cropland management (Section 3.2.1), Cropland conversion to perennial grasses (3.2.2), Grazing land management (3.2.3), Wetland histosols restoration (3.2.4), and Forest management (3.2.6), sum to a potential total carbon storage rate of 414 MtCeq yr^{-1} (0.414 GtCeq yr^{-1}).

This rate is similar to those calculated for other recent U.S. summaries[28, 83, 159, 161] when considering individual practices. While other syntheses estimate a lower range of 75-174 MtCeq yr^{-1}, with an average rate of 85 MtCeq yr^{-1}, they do not include carbon sequestered due to improved forest management or the establishment of cellulosic bioenergy crops. These alone add 198 MtCeq yr^{-1}. A 2007 Congressional Budget Office analysis[162] that included forest management estimated a 2030 sequestration potential of 479 MtCeq yr^{-1}. Thus the present analysis (summing to 414 MtCeq yr^{-1} for negative emissions) is consistent with earlier analyses.

As noted earlier, the duration of individual sequestration rates by different practices differ. Sequestration rates for all practices could be sustained for at least 30 years, and some for 50-80 years or more as noted in Section 5.1. With these durations, total negative emissions sum to 20.9 GtCeq through 2100 (**Table 2**).

Avoided emissions are also additional in the present analysis. These include a) improved fertilizer efficiency (Section 4.2.1), b) rice water management for methane (4.2.2), and c) cellulosic bioenergy production (Sections 4.2.3 and 4.2.4). These provide additional mitigation potentials that themselves sum to an annual capacity of 122 MtCeq yr^{-1} (0.122 GtCeq yr^{-1}), totaling 9.7 GtCeq through 2100 (**Table 2**). It is worth noting that the capacity of these activities is on-going and permanent, i.e. most of their carbon benefits are not subject to saturation as are biological carbon sinks, nor subject to re-emission upon management change or natural disturbance such as forest fires. It is also worth noting that, except for cellulosic biofuels, there is likely no overlap with decarbonization pathways for energy use. Should, however, energy analyses include cellulosic biofuel production at the magnitude noted here, then the avoided emissions here (72 MtC yr^{-1} or 5.7 GtC for 80 years) would be double counted so this total should be appropriately discounted. The negative emissions due to cellulosic biofuels – soil carbon capture – does not contribute to avoided fossil fuel use so should remain part of this total.

Practice change	Local rate (tCeq ha^{-1} yr^{-1})	Areal extent (Mha)	Annual total (MtCeq yr^{-1})	Dura-tion (yr)	Yr 2100 total (GtCeq)
Negative emissions					
Cropland management (3.2.1)					
No till adoption	0.40	94[a]	37.6	30	1.13
Reduced summer fallow	0.09	20[a]	1.8	30	0.05
Winter cover crops	0.52	66[a]	34.3	80[f]	2.75
Diversified crop rotations	0.05	46[a]	2.3	80	0.18
Manure & compost additions	0.71	8.5[a]	6.0	80	0.48
Cropland conversion to perennial grasses (3.2.2)					
Set-aside highly erodible cropland	0.97	26[b]	25.2	30	0.76
Cellulosic bioenergy on grain ethanol lands	0.97	13[c]	12.6	30	0.38
Cellulosic bioenergy on marginal lands	0.48	55[d]	26.4	30	0.79
Grazing land management (3.2.3)					
Improved stocking rates on rangeland	0.28	216[e]	60.5	80	4.84
Improved species composition	0.56	80[a]	44.8	30	1.34
Wetland histosol restoration (3.2.4)	3.65	0.8[a]	2.9	80	0.23
Forest management (3.2.6)					
Improved soil management – timberland	0.32	256[e]	81.9	50	4.10
Improved soil management – agroforestry			22.5	50	1.13
Improved stand management			55.0	50	2.75
Subtotal – Negative emissions			414.		20.9
Avoided emissions					
Improved fertilizer efficiency (4.2.1)					
Avoided nitrous oxide emissions	0.36	125[c]	45.0	80	3.60
Avoided CO_2 – fertilizer production			4.4	80	0.35
Rice water management for methane (4.2.2)	0.54	1.3[a]	0.7	80	0.06
Cellulosic bioenergy production					
Production on grain ethanol lands (4.2.3)	0.71	17[c]	12.1	80	0.97
Production on marginal lands (4.2.4)	1.08	55[d]	59.4	80	4.75
Subtotal – Avoided emissions			122.		9.7
Total potential			535.		30.6

[a] Eagle et al.[48, 145] [b] Sperow et al.[83] [c] ERS[89] [d]Robertson et al.[88] [e]Bigelow and Borchers[29] [f]Poeplau and Don[65] [g]USDA[163]

Table 2. Potential sources and magnitude of U.S. greenhouse gas mitigation from changes in land management practices that lead to negative emissions (carbon storage) and avoided emissions for the period 2020-2100. Numbers in parentheses refer to sections in text for local sequestration values.

Assuming no overlap, and over an 80- year end-of-century lifetime, then, these avoided emissions practices sum to 9.7 GtCeq through 2100.

Altogether, then, I conclude that U.S. potentials for mitigating greenhouse gas emissions through negative emissions due to land management practices on forest, range and crop lands in the conterminous U.S. sum to 20.9 GtCeq for the period 2020-2100. This represents more than 20% of the global natural sequestration target needed to bring CO_2 concentrations to 350 ppm.[4] Including avoided emissions due to land management practices brings the sum to 30.6 GtCeq for the period 2020-2100, or >30% of the total needed.

That the federal government manages 43% of rangeland and 44% of forests in the conterminous U.S. (see Section 3.2) allows an estimate of the sequestration potential on public grazing and forest lands of 115 MtCeq yr^{-1}, or 6.2 GtCeq through 2100. About 56% of this total is sequestration on forest lands, the remainder on rangelands.

In its annual inventory of greenhouse gas emissions and sinks for the U.S., the USEPA[11] estimates for U.S. land management a background sink of 212 MtCeq yr^{-1} (0.212 GtCeq yr^{-1}) for 2015. The primary drivers of these sinks in 2015 were forest growth (181 MtCeq yr^{-1}) and forestland expansion (21 MtCeq yr^{-1}), with urban tree growth and landfills (9 MtCeq yr^{-1}) contributing most of the remaining sink. Decrementing this by concomitant changes in methane and nitrous oxide emissions brought the net land management sink to 207 MtCeq yr^{-1}. The 535 MtCeq yr^{-1} potential land management sink noted in **Table 2** (both negative and avoided emissions) is additional to this existing background sink. Were the strategies in this report fully implemented, a future USEPA inventory might tally a net U.S. sink close to 750 MtCeq yr^{-1} (0.750 GtCeq yr^{-1}).

5.3 Barriers that Prevent Optimized Biotic Greenhouse Gas Mitigation in the U.S.

The principal barriers to adopting management practice changes to mitigate greenhouse gas emissions in the U.S. are neither knowledge-based nor technical. There is ample evidence, detailed and summarized above, that land management changes can achieve real and verifiable negative and avoided emissions with high confidence. The values in **Table 2** are, in general, conservative – they include values from field observations and experiments conducted throughout the U.S. and similar ecoregions, i.e. they are empirically-based, representative estimates from farm, rangeland, and forest systems typical of the U.S. Further research will lead to their refinement, but it seems unlikely that average values will change more than 20-30%, and, importantly, the values are in any case as likely to increase in magnitude as to decrease. Further, as noted earlier, not all possible practices to drive negative or avoided emissions are included.

Research and experience show that farmers, ranchers, and forest managers who own and manage non-federal lands are willing to accept payments for providing ecosystem services such as soil organic matter accrual, nitrate leaching avoidance, wetland protection, and greenhouse gas avoidance.[164, 165] For example, in 2017, USDA and its partners worked with 680,000 land managers to fund the development of conservation plans for 27 million acres of working lands.[166] Both research[164, 165, 167-169] and over-subscribed USDA conservation programs point to farmers' and other landowners' openness to accepting conservation and other ecosystem service payments through a variety of mechanisms, including auctions. Thus, the principal barrier for engaging landowners and managers is not feasibility or lack of interest, but lack of policy support and financial incentive.

How much financial incentive is necessary? The success of USDA conservation programs show that farmers and ranchers are willing to accept relatively low payments for changing specific practices, sometimes as low as a few dollars per acre. In many cases the payments depend on co-benefits. Building soil carbon, for example, benefits soil fertility, water holding capacity, and drainage, and experimental auctions have shown lower payments would be required than, for example, reducing nitrous oxide emissions, which are considered by farmers to have fewer co-benefits.[165, 170] Practices with higher management costs – cover crops, for example – would likewise require higher payments. That said, most analyses to date that include economic costs conclude that many practices could be implemented at costs as low as \$10 per MtCO_2 (\$2.70 per MtC). Griscom et al.[9], for example, state that 1/3 of the potentials they consider could be provided at this cost, with the remainder requiring no more than \$100 per MtCO_2, which is consistent with the expected avoided cost of holding warming to below 2 °C by 2100.[171] USEPA modeling[106] concludes that some forest and agricultural management practices could be incentivized at carbon prices as low as \$1 per MtCO_2, with full implementation at \$50.

Various voluntary efforts such as the USDA Building Blocks for Climate Smart Agriculture and Forestry (https://www.usda.gov/oce/climate_change/buildingblocks.html)[172] provide frameworks for farmers, ranchers, and landowners to respond to climate change. For example, the Building Blocks program provides a series of measures intended to assist a wide variety of land management stakeholders to increase carbon storage and reduce greenhouse gas emissions; ten categories of activities range from soil health and nitrogen stewardship to grazing and pastureland management. The program provides case studies to inspire users and provides technical assistance through NRCS and other USDA professionals to help individual land managers meet personal greenhouse gas reduction goals. Only three years old, the effectiveness of the Building Blocks initiative is largely untested but it provides an evidence-based framework for engaging landowners and managers in the sorts of meaningful activities identified herein. The Building Blocks framework is an important start, but the quantitative goal it contains (33 MtCeq yr^{-1} by 2025) is far below the 535 MtCeq yr^{-1} identified in the present analysis, and because the initiative is strictly voluntary with no incentives, it is unlikely to meet even this goal.

More useful is the on-line COMET-Farm tool (http://cometfarm.nrel.colostate.edu)[133] that allows farmers and ranchers to calculate the greenhouse gas impacts of current and projected land management practices. Calculations are based on the USDA's methods for quantifying farm-level emissions (https://www.usda.gov/oce/climate_change/estimation.htm).[132] Calculations are specific to individual fields as identified by aerial and satellite imagery, and cover most of the crop and grazing land practices in Sections 3.2 and 4.2, including avoided emissions from improved nitrogen fertilizer management, all of which make comparisons between business-as-usual and alternative practices straightforward and directly relevant to the land being managed.

Likewise, national carbon registries offer a framework to provide landowners and carbon markets detailed evidence-based protocols for voluntarily quantifying the carbon captured or emissions avoided by specific land management practices. Both the American Carbon Registry (www.americancarbonregistry.org) and the Verified Carbon Standard (www.verra.org), for example, provide protocols for awarding carbon credits based on avoided nitrous oxide emissions by improved nitrogen fertilizer management[130, 131] as well as avoided methane emissions from improved rice management and wetland restoration.[173]

That said, scaling up sequestration nationwide on the order discussed in the present report will require revisiting the many federal policies and incentives that influence agricultural, grazing, and forestry practices on both private and public lands of the U.S. Without supportive federal policies and payments sufficient to cover costs, farmers, ranchers, and forest owners are unlikely to participate in sufficient numbers to effect meaningful change.

6.0 Concluding Opinions

Based upon a review of the literature, my own research, and in consultation with other experts in the field, it is my expert opinion that through improved land management practices, at a combined peak rate of 535 MtCeq yr^{-1} (0.535 GtCeq yr^{-1}), about 31 GtCeq of additional emissions could be sequestered and avoided by land management changes on U.S. forestland, rangelands, and farms between 2020 and 2100. Some 21 GtC could be provided by negative emissions, i.e. natural carbon removal and storage by practices such as improved cropland and rangeland management. Another 10 GtC could be provided by avoided emissions from practices such as improved nitrogen management and cellulosic bioenergy production. We have known for decades the potential for most of these practices to contribute to negative or avoided emissions. Sequestration on this scale would meet the scientific prescription for sequestration set forth by Hansen et al.[4, 174, 175]

Signed this 13th day of April, 2018 in Cambridge, UK.

G. Philip Robertson

EXHIBIT A: CURRICULUM VITAE

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Education

1976 B. A. Hampshire College, Amherst, Massachusetts
1980 Ph.D. Biology (Ecology & Evolutionary Biology), Indiana University (advisor P.M. Vitousek)

Professional Experience

1985-now Assistant, Associate, Professor, and University Distinguished Professor, Dept. of Plant, Soil, and Microbial Sciences and W.K. Kellogg Biological Station, Michigan State University

1981-1985 Postdoctoral Research Associate, Dept. of Crop and Soil Sciences and Dept. of Microbiology and Public Health, Michigan State University (advisor J.M. Tiedje)

1980-1981 SCOPE-Mellon Postdoctoral Fellow, UNEP International Nitrogen Unit, Royal Swedish Academy of Sciences, Stockholm (advisor T. Rosswall)

Primary Grant Support (past 10 years)

current DOE Office of Science (Biological and Environmental Sciences Division): Great Lakes Bioenergy Research Center; co-PI and Science Director, with T. Donohue (PI; UW-Madison) and R. Landick; 60 co-I's. $120M (2017-2022).

current NSF (Coupled Natural-Human Systems): A Social-Ecological Analysis of Nitrogen in Agricultural Systems of the Upper Midwest; co-PI with D. Stuart (PI), D. Basso, S.T. Marquart-Pyatt, J. Zhao; $1.5M (2013-2018).

current USDA (ARS): Collaborative Long-term Agricultural Research (LTAR): Ecosystem Services from Row-crop Agriculture; PI, with co-PI S.K. Hamilton. $97,182 (2015-2020).

current USDA (Foreign Agricultural Services): Nitrous oxide quantification and mitigation in Mexican grain crops; co-PI with postdoc N. Millar (PI); $78,000 (2017-2018).

current NSF (Division of Environmental Biology): LTER: The Ecology of Row Rrop Ecosystems and Landscapes at the KBS LTER Site. Co-PI with S.K. Hamilton (PI), S. E. Evans, D. A. Landis, J. A. Lau, S. T. Marquart-Pyatt, and S. M. Swinton; $2.3M (2016-2018).

2008-2017 DOE Office of Science (Biological and Environmental Sciences Division): Great Lakes Bioenergy Research Center; co-PI with T. Donohue (PI), K. Keegstra, B. Dale, J. Ralph, R. Landick; and ~50 co-I's; $250M (2008-2017) [Research Leader for Sustainability].

2010-2017 NSF (Division of Environmental Biology): Long Term Ecological Research in Field Crop Ecosystems; PI with co-PIs S.K. Hamilton, K.L. Gross, D.A. Landis, T.M. Schmidt, S. Snapp, S.M. Swinton; $5.9M.

2014-2017 NSF (EAGER) Development of a New Technique to Measure Ecosystem-level Soil Nitrous Oxide Fluxes using Micrometeorological Towers; co-PI with postdoc I. Gelfand (PI), M. Zondlo (Princeton); $150,000.

2010-2015 NSF (EHR Graduate Education Division); GK-12 Pre-doctoral Fellowship Program: Biofuel Sustainability in K12 Classrooms of Rural Michigan; co- PI, with T. Getty (PI), C.W. Anderson, J. Lau, and K, Gross; $2.7M.

2011-2015 USDA (AFRI Organic Transitions Program): Cover Crops and N_2O Emissions, N Availability and Carbon Accumulation in Organic versus Conventionally Managed Systems; co-PI with PI D. Mutch; $749,000.

2014-2015 USDA NIFA (SARE): Linking soil testing with farmer decision making – an interdisciplinary approach; co-PI with PhD student B. O'Neill; $6,853

2014-2015 USDA NIFA (SARE): Assessing soil carbon pools across rotational and diversified cropping systems in experimental plots and on-farm; co-PI with PhD student C. Sprunger; $6,382

2006-2013 EPRI (Electric Power Research Institute): Developing greenhouse gas emission offsets by reducing nitrous oxide emissions in agricultural crop production; PI with R. Gehl, P. Grace; $1.2M.

2011-2013 NSF (Division of Environmental Biology): Dissertation Research: Denitrification in subsurface soils; co-PI with graduate student I. Shcherbak; $9,832.

2004-2010 NSF (Division of Environmental Biology): Long Term Ecological Research in field crop ecosystems; PI with S.H. Gage, K.L. Gross, S.K. Hamilton, D.A. Landis, T.M. Schmidt, S.M. Swinton; $5.1M.

2005-2009 NSF (Social, Bahavioral, and Economic Sciences): Ecosystem services from low-input cropping systems; co-PI with S.M. Swinton (PI), F. Lupi; $400,000.

2006-2009 NSF (EHR Graduate Education Division): GK-12 Pre-doctoral Fellowship Program: Ecological literacy in the K-12 classrooms of rural Michigan; PI, with T. Getty, A. Anderson, J. Conner, G. Mittelbach; $1.6M.

2006-2009 NSF (Division Biological Infrastructure Program): A field-based science and education facility at the Kellogg Biological Station; PI with K.L. Gross; $249,500.

2006-2008 USDA-CSREES (MSU Sustainable Agriculture Award); Ecosystem services and economic benefits of reduced input agricultural systems; PI with PhD student S. Parr; $50,000.

2006-2007 NSF (Division of Environmental Biology): Doctoral Dissertation Research: Soil resource aggregation and ecosystem function; PI with PhD Student T. Loecke; $9,945.

Professional Affiliations and Awards

Fellow, AAAS (elected 2015)

Fellow, Soil Science Society of America (elected 2003)

Member of AAAS, AIBS, Soil Science Society of America, American Geophysical Union, Ecological Society of America

Professional Service (last 10 years)

current DOE Office of Science Biological and Environmental Research Advisory Committee (BERAC) (since 2010)

current U.S. National Climate Assessment Agricultural Indicators Team (since 2013)

current Research Committee, USDA Long-term Agricultural Research Network (since 2014)

1988-2016 NSF Long-Term Ecological Research Science Council (chair 2007-2011)

2011-2016 Science Advisory Board, Regional Approaches to Climate Change for Pacific Northwest Agriculture (USDA Wheat Climate Change Center)

2016 DOE ARPA-E Competitive Grants Panel (ROOTS)

2015 Co-organizer, USDA LTAR Common Experiment Workshop, Minneapolis MN

2012-2015 NSF DEB Ecosystems Panel (2012, 2013, 2014, 2015)
2014-2015 Scientific Program Committee for the 2015 Climate Change and Cereal Production Symposium, Minneapolis MN
2014 Committee of Visitors, NSF Biology Directorate
2014 Chair, US LTER Network Chair Nominating Committee
2013 Review editor, U.S. National Climate Assessment
2011-2014 Lead Author, US National Climate Assessment (Midwest Chapter)
2011-2014 USDA ERS Workgroup on Quantifying GHG Emissions from Agriculture
2013-2014 Chair, Organizing Committee and Writing Team, DOE Bioenergy Sustainability Workshop
2011-2013 Climate Action Reserve Science Advisory Board
2011-2012 Advisory Committee, Walmart Jack-n-Coke Sustainability Project
2009-2012 NEON Domain Science and Education Coordination Committee
2011 USDA Long-term Agricultural Research Network Review Panel
2010-2011 Council on Agricultural Science and Technology (CAST) Task Force on the Role of Agriculture in Greenhouse Gas Fluxes and Carbon Sequestration
2007-2011 Chair (elected), NSF Long-term Ecological Research (LTER) Network Science Council and Executive Board
2001-2010 Science Committee, Ecological Society of America
2005-2012 Scientific Rapid Response Team, Ecological Society of America
2000-2009 Advisory Board for Biosphere-Atmosphere IGERT, Univ. Michigan
2007 NSF External Site Review Team, Central Arizona Phoenix LTER Site
2004-2007 U.S. Carbon Cycle Scientific Steering Group
2005-2007 co-Chair, Consortium of Regional Ecological Observatories for NEON (COREO)
2005-2007 co-Chair, Great Lakes Ecological Observatory for NEON (GLACEO)
2001-2006 Executive Committee, Consortium for Agricultural Soil Mitigation of Greenhouse Gases (CASMGS)

Editorships

1984-1989 Editor, *Plant and Soil*
1988-1992 Editor, *Ecology* and *Ecological Monographs*
2004-2009 Editor, *Biogeochemistry*
2009-2015 Guest Editor, *PNAS*

Invited Symposia/Workshop/Seminar Presentations (last 5 years)

2017 University & Industry Consortium Symposium, Baltimore MD
American Society of Plant Biology Plenary Symposium, Honolulu HI
National Academies of Sciences, Science Breakthroughs 2030, Washington DC
Sustainable Agriculture and Research Education, Extension Academy, KBS
American Society of Agronomy Bioenergy Symposium, Tampa FL
USDA SARE Extension Academy, Michigan

2016 JASON Spring Science Meeting, McLean VA
NSF CNH Nitrogen Roundtable, Michigan

2015 IPCC Workshop on Climate Change and Agriculture, Dublin (discussant)
Temperate Agriculture Research Network Workshop, Paris (discussant)
North Central Cropping Systems Extension Academy, Michigan
Agricultural Sustainability Workshop, China Agricultural University, Beijing

USDA NIFA Science Outcome Series, Washington DC
USDA Long-term Agricultural Research Design Workshop, Minneapolis (co-organizer)

2014 Fate of the Earth Symposium, East Lansing
Climate Change and Midwest Agriculture Conference, Missouri Botanical Garden, St. Louis
Brazilian Bioenergy Science and Technology Conference, Sao Paulo Brazil
American Society of Agronomy Bioenergy Feedstock Symposium, Minneapolis

2013 Philip C. Hamm Memorial Lecture, University of Minnesota
DOE Genome-Sustainability Workshop, Washington, DC (lead organizer)
MSU Biotechnology Symposium, East Lansing
Biogeochemistry Program, Cornell (student-invited speaker)
Dept. of Crop and Soil Sciences, Cornell University (student-invited speaker)
REEACH Program, Washington State University

2012 NSF Long-term Ecological Research Mini-Symposium, Washington, DC
USDA N2O Cropping Practices Workshop, Ft. Collins, CO (organizer)
American Society of Agronomy Symposium on Nitrogen and Climate Change, Cincinnati
SARE North Central Region Climate and Energy Conference, Michigan
Society for Environmental Journalists Climate Change Workshop, Michigan
China Agricultural University Workshop on Nitrogen Management, Beijing
Dept. of Plant, Soil, and Microbial Sciences, MSU

2011 American Society of Plant Biology Plant Science Summit, Washington, DC
EPRI Greenhouse Gas Emissions Offsets Workshop on Creating Nitrous Oxide (N2O) Emissions Offsets in U.S. Agriculture, Washington, DC
Soil and Water Conservation Society Conference on Conservation Science and Policy, Washington, DC (with N. Millar)
American Chemical Society Symposium on Nitrogen and the Human Endeavor, Denver (with R. Gehl)
International Nitrogen Initiative Workshop on Nitrogen-Climate Interactions on Terrestrial and Aquatic Ecosystems, Agriculture, and Human Health in the US, Ft. Collins
Ecological Society of America Symposium on the Emergence and Future Role of Long-term Socio-ecological Research for Earth Stewardship, Austin, TX (with S. Collins)
Dept of Physics Soiree, California Polytech, San Luis Obispo

Presentations to Congressional Committees

2014 Briefing for the U.S. Senate on Long-term Ecological Research: Regional Data for Large Scale Environmental Issues (AIBS-sponsored).

2008 Briefings for the U.S. House Science and Technology Committee and the U.S. Senate Agriculture, Nutrition, and Forestry Committee on the Sustainability of Cellulosic Biofuels (lead organizer; ESA-sponsored) (described at www.esa.org/pao/policyActivities/briefing062008.php)

2005 Briefing for the U.S House Science Committee on Broader Impacts of Long-Term Ecological Research Program (AIBS-sponsored)

2003 Briefings for 1) the U.S Senate Agriculture, Nutrition and Forestry Committee and 2) the U.S. House Agriculture Committee on Findings of the NRC Committee to Evaluate the USDA Research, Extension, and Education Activities (Frontiers in Agricultural Research) (NRC-sponsored)

2002 Briefing for the U.S. House Agriculture Committee on Greenhouse Gas Mitigation Potentials for US Agriculture (CASMGS-sponsored)

2001 Testimony before the U.S. Senate Agriculture, Nutrition, and Forestry Committee on Research, Extension and Education in the Farm Bill for the National Academy of Sciences (available at http://www4.nas.edu/ocga/testimon.nsf) (NRC-sponsored)

2000 Briefing for the U.S. Senate Agriculture, Nutrition, and Forestry Committee on Carbon Sequestration Potentials in the US (SSSA and ESA sponsored)

Public Presentations (last 5 years)

2017 American Chemical Society, Keynote Speaker, Saginaw MI (Environmental Sustainability)
Kellogg Company Earth Day Speaker, Battle Creek MI (Climate Change)

2016 Flint Sierra Club, Flint MI (Ecosystem Services from Agriculture)
Larry Meillor Show, Wisconsin Public Radio (Bioenergy Sustainability)
Sierra Club, Midland MI (Climate Change and Agriculture)
K-12 ICCARS (Investigating Climate Change and Remote Sensing) Series, Wayne County MI
Community Climate Change Discussion, KBS

2015 Osher Lifelong Learning Lecture Series, Saginaw MI (Climate Change and Michigan Agriculture)
Our Changing Earth Lecture Series, Midland MI (Climate Change and Michigan Agriculture)
K-12 Partnership Teacher Workshop, KBS (Climate Change and Michigan Agriculture)

2014 Michael Patrick Shiels Radio Show (National Climate Assessment)
Stateside with Cynthia Canty on Michigan Public Radio (Climate Change and Agriculture)
Michigan Basin Geologists (Climate Change)
Kalamazoo Interfaith Climate Coalition (Climate Change and Agriculture)

2013 MSU Science Festival, East Lansing (Climate Change)

Contributed Papers at National Meetings (last 5 years; >250 published abstracts since 1980)

2017 12 total: **DOE Genomic Science Program**, Washington DC (Cole et al.; Liang and Robertson; Roley et al.); **Ecological Society of America**, Portland OR (Glanville and Robertson; Sánchez et al.); **Soil Ecological Society**, Fort Collins CO (Glanville and Robertson; Liang and Robertson; O'Neill et al.; O'Neill et al.); **American Society of Agronomy**, Tampa FL (Liang and Robertson, Millar and Robertson, Kahmark et al.)

2016 10 total: **American Society of Agronomy**, Phoenix AZ (Liang and Robertson; Millar and Robertson; Glanville and Robertson; Thelen et al.; Valdez et al.); **Ecological Society of America**, Fort Lauderdale FL (Roley et al.); **American Geophysical Union**, San Francisco CA (Abraha et al.; Gelfand et al.; Hess et al.); **Keystone Symposium Conference**, Santa Fe NM (Chicoine et al.)

2015 20 total: **American Society of Agronomy**, Minneapolis MN (Millar et al.; Smith et al.); **Ecological Society of America** Baltimore MD (Abraha et al.; Sprunger et al.; Su et al.); **LTER National All Scientist Meeting**, Estes Park CO (Abraha et al.; Gelfand et al.; Glanville et al.; Liang and Robertson; Robertson et al.; Sprunger and Robertson; Su et al.); **American Geophysical Union**, San Francisco CA (Abraha et al.; Gelfand et al.; Hess et al.; Hussain et al.; Tao et al.; Walbridge et al.; Zhang et al.); **Soil Ecological Society**, Colorado Springs CO (Haddix et al.)

2014 11 total: **American Society of Agronomy Meeting,** Long Beach CA (Jones et al.; Millar et al. (2); Robertson et al.; Sprunger and Robertson; Thelen et al.); **Ecological Society of America,** Sacramento CA (Hess et al.; Iverson et al.; Roley et al.); **American Geophysical Union**, San Francisco CA (Gelfand et al.; Hussain et al.).

2013 10 total: **American Society of Agronomy Meeting**, Tampa FL (Kahmark et al.; Millar et al. (2); Ruan et al.; Shcherbak et al); **Ecological Society of America**, Minneapolis MN (Gelfand et al.); **American Geophysical Union**, San Francisco CA (Abraha et al.; Gelfand et al.; Su et al.); **Energy Utility Environment Conference,** Phoenix AZ (Diamant et al.).

University Service (last 5 years)

current	Member, GLBRC Management Team (since 2008)
current	Member, Provost's Promotion and Tenure Advisory Committee (since 2013)
current	Member, KBS LTER Executive Committee (chair 1988-2016)
2013-2014	Member, Provost Search Committee
2012-2013	Chair, Dean Search Committee, College of Agriculture and Natural Resources

Department Service (last 5 years)

current	Member, KBS Outreach Committee
current	Member, Kellogg Farm Research Advisory Committee
current	Member, PSM Research Committee
2015-2016	Member, KBS Faculty Advisory Committee
2015-2016	Chair, Search Committee for Cropping System Agronomist (PSM)
2013-2014	Member, Soil Biology Search Committee (PSM)
2012-2013	Chair, PSM Promotion and Tenure Committee
2012-2013	Chair, PSM Dept. Advisory Committee
2011-2012	Member, CSS Dept. Advisory Committee
2011-2012	Co-chair, PSM Promotion and Tenure Committee

Teaching Activities

Courses Taught

Agricultural Ecology (CSS 412/442): 1989-1990, 2011-2016
Forest & Agricultural Ecology (CSS/FOR 404): 1992, 1994-2000
Biogeochemistry (CSS/MPH 426): 1996-2003, 2006-2007
Soil Biology (CSS 360): 2006-2007
Also: Geostatistics (CSS 412; 1987); Landscape Ecology (CSS 412; 1988); Root Resource Interactions (EEB 891; 1989); Plant Ecology (BOT 450; 1992); Terrestrial Ecology and Evolution (1993); Ecology (ZOL 250; 1993); Advanced Terrestrial and Aquatic Ecology (1995); Scientific Presentations (CSS 893; 1998); Soil Organic Matter Dynamics (CSS 893; 2004); Biogeochemistry of Sustainable Agriculture (CSS 893; 2004)

Graduate Students Supervised

Michel Cavigelli (Ph. D., 1998); Timothy Bergsma (Ph.D. 2000); Pongthep Sunwararee (Ph. D. 2003); Stuart Grandy (Ph.D. 2005); Terry Loecke (Ph.D. 2007); Sara Parr Syswerda (PhD. 2009) ; John Hoben (M.Sc. 2009); Iurii Shcherbak (Ph.D. 2013) ; Leilei Ruan (Ph.D. 2014); Christine Sprunger (Ph.D. 2015); Di Liang (Ph.D.; current); Kathyrn Glanville (Ph.D.; current)

Postdoctoral Scholars

Katherine M. Klingensmith (1988-1990); Jacqueline Henrot (1989-1991); Keith Paustian (1989-1994); Harold Collins (1994-1996); Per Ambus (1996-1998); Craig Russell (1997-1999); Kevin Kosola (1997-2000); Ann-Marie Fortuna (2001-2002); Tim Parshall (2002-2004); Claire McSwiney (2002-2007); Laurel Hartley (2006-2008); Poonam Jasrotia (2007-2011); Neville Millar (2005-2012); Ilya Gelfand (2008-2017); Sarah Roley (2012-2017)

Publications

Robertson, G.P. and P.M. Vitousek. 1981. Nitrification potentials in primary and secondary succession. *Ecology* 62:376-386.

Robertson, G.P. 1982. Factors regulating nitrification in primary and secondary succession. *Ecology* 63:1561-1573.

Robertson, G.P. 1982. Nitrification in forested ecosystems. *Philosophical Transactions of the Royal Society London* B 296:445-457.

Robertson, G.P. 1982. Regional nitrogen budgets: approaches and problems. *Plant & Soil* 67:73-80.

Robertson, G.P. 1984. Nitrification and nitrogen mineralization in a lowland rainforest succession in Costa Rica, Central America. *Oecologia* 61:99-104.

Robertson, G.P. and J.M. Tiedje. 1984. Denitrification and nitrous oxide production in successional and old growth Michigan forests. *Soil Science Society of America Journal* 48:383-389.

Robertson, G.P. and J.M. Tiedje. 1985. An automated method for sampling the contents of stoppered gas collection vials. *Plant and Soil* 83:453-457.

Robertson, G. P. 1986. Nitrogen: Regional contributions to the global cycle. *Environment* 28: 16-21.

Robertson, G.P. and T. Rosswall. 1986. Nitrogen in West Africa: the regional cycle. *Ecological Monographs* 56:43-72.

Matson, P.A., P.M. Vitousek, J.J. Ewel, M.J. Mazzarino and **G.P. Robertson.** 1987. Nitrogen transformations following tropical forest felling and burning on volcanic soil. *Ecology* 68:491-502.

Robertson, G.P., P.M. Vitousek, P.A. Matson and J.M. Tiedje. 1987. Denitrification in a clear-cut Loblolly pine (*Pinus taeda* L.) plantation in the southeastern U.S. *Plant and Soil* 97:119-129.

Robertson, G.P. and J.M. Tiedje. 1987. Nitrous oxide sources in aerobic soils: nitrification, denitrification, and other biological processes. *Soil Biology and Biochemistry* 19:187-193.

Robertson, G.P. 1987. Geostatistics in ecology: interpolating with known variance. *Ecology* 68:744-748.

Robertson, G.P., M.A. Huston, F.C. Evans and J.M. Tiedje. 1988. Spatial variability in a successional plant community: patterns of nitrogen availability. *Ecology* 69:1517-1524.

Robertson, G.P. and J.M. Tiedje. 1988. Deforestation alters denitrification in a lowland tropical rainforest. *Nature* 336:756-759.

Sollins, P., **G.P. Robertson,** and G. Uehara. 1988. Nutrient mobility in variable- and permanent-charge soils. *Biogeochemistry* 6:181-199.

Groffman, P.M., J.M. Tiedje, **G.P. Robertson** and S. Christensen. 1988. Denitrification at different temporal and geographic scales: proximal and distal controls. pp. 174-192. In J.R. Wilson, ed. *Advances in N Cycling in Agricultural Ecosystems*. Comm. Agric. Bur. International, Wallingford, U.K.

Paul, E.A. and **G.P. Robertson.** 1989. Ecology and the agricultural sciences: a false dichotomy? *Ecology* 70:1594-1596.

Robertson, G. P. 1989. Nitrification and denitrification in humid tropical ecosystems. Pages 55-70 in J. Proctor, ed. *Mineral Nutrients in Tropical Forest and Savanna Ecosystems*. Blackwell Scientific, Cambridge, MA.

Palm, C., **G. P. Robertson,** and P. M. Vitousek. 1989. Nitrogen availability. Pages 162-168 in J. M. Anderson and J. S. I. Ingram, eds. *Tropical Soil Biology and Fertility: A Handbook of Methods*. CAB International, Wallingford, UK.

Robertson, G.P., M.O. Andreae, H.G. Bingemer, P.J. Crutzen, R.A. Delmas, J.H. Duyzer, I. Fung, R.C. Harriss, M. Kanakidou, M. Keller, J.M. Melillo, and G.A. Zavarzin. 1989. Trace gas exchange and the physical and chemical climate: critical interactions. Pages 303-320 in M.O. Andreae and D.S. Schimel, eds. *Trace Gas Exchange between Terrestrial Ecosystems and the Atmosphere*. John Wiley, Berlin.

Schimel, J. P., **G. P. Robertson,** D. Baldocchi, J. E. Bogner, E. A. Davidson, J. Duyzer, D. Ehhalt, D. Fowler, P. Groffman, K. Haider, V. A. Isodorov, L. Klemedtsson, J. M. Melillo, K. A. Smith, W. H. Su, and W.

Wieprecht. 1992. Impacts of trace gas fluxes in mid-latitude ecosystems. *Ecological Bulletin (Stockholm)* 42:124-132.

Robertson, G.P., J.R. Crum, and B.G. Ellis. 1993. The spatial variability of soil resources following long-term disturbance. *Oecologia* 96:451-456.

Robertson, G.P. 1993. Fluxes of nitrous oxide and other nitrogen trace gases from intensively managed landscapes: a global perspective. Pages 95-108 in L.A. Harper, A.R. Mosier, J.M. Duxbury, and D.E. Rolston. eds. *Agricultural Ecosystem Effects on Trace Gases and Global Climate Change.* American Society of Agronomy, Madison, Wisconsin.

Henrot, J. and **G.P. Robertson**. 1994. Vegetation removal in two soils of the humid tropics: effect on microbial biomass. *Soil Biology and Biochemistry* 26:111-116.

Robertson, G.P. 1994. The impact of soil and crop management practices on soil spatial heterogeneity. Pages 156-161 in C.E. Pankhurst, B.M. Doube, V.V.S.R. Gupta, and P.R. Grace, eds. *Soil Biota Management in Sustainable Farming Systems*, CSIRO Press, Melbourne, Australia.

Robertson, G.P. and K.L. Gross. 1994. Assessing the heterogeneity of below ground resources: quantifying pattern and scale. Pages 237-253 In M.M. Caldwell and R. Pearcy, eds. *Exploitation of Environmental Heterogeneity by Plants: Ecophysiological Processes Above- and Belowground*. Academic Press, San Diego.

Smith, K.A., **G.P. Robertson,** and J.M. Melillo. 1994. Exchange of trace gases between the terrestrial biosphere and the atmosphere in the mid-latitudes. Pages 179-204 in R.G. Prinn, ed. *Global Atmospheric-Biospheric Chemistry*. Plenum Press, NY.

Cavigelli, M.A., **G.P. Robertson**, and M.J. Klug. 1995. Fatty acid methyl ester (FAME) profiles as measures of soil community structure. *Plant and Soil* 170:99-113.

Paustian, K., **G. P. Robertson,** and E. T. Elliott. 1995. Management impacts on carbon storage and gas fluxes (CO_2, CH_4) in mid-latitude cropland and grassland ecosystems. *Advances in Soil Science* 27:69-84.

Robertson, G.P. and D.W. Freckman. 1995. The spatial distribution of nematode trophic groups across a cultivated ecosystem. *Ecology* 76:1425-1432.

Robertson, G.P., K.M. Klingensmith, M.J. Klug, E.A. Paul, J.R. Crum, and B.G. Ellis. 1997. Soil resources, microbial activity, and plant productivity across an agricultural ecosystem. *Ecological Applications*, 7:158-170.

Robertson, G.P. 1997. Nitrogen use efficiency in row crop agriculture: crop nitrogen use and soil nitrogen loss. Pages 347-365 *in* L. Jackson, ed. *Ecology in Agriculture*, Academic Press, NY.

Ambus, P. and **G.P. Robertson.** 1998. Automated near-continuous measurement of carbon dioxide and nitrous oxide fluxes from soil. *Soil Science Society of America Journal* 62:394-400.

Hedin, L. O., J. C. von Fischer, N. E. Ostrom, B.P. Kennedy, M. G. Brown, and **G. P. Robertson.** 1998. Thermodynamic constraints on nitrogen transformations and other biogeochemical processes at soil-steam interfaces. *Ecology* 79:684-703.

Ostrom, N. E., K. E. Knoke, L. O. Hedin, **G. P. Robertson**, and A. J. M. Smucker. 1998. Temporal trends in nitrogen isotope values of nitrate leaching from an agricultural soil. *Chemical Geology* 146: 219-227.

Robertson, G.P. and E.A. Paul. 1998. Ecological research in agricultural ecosystems: contributions to ecosystem science and to the management of agronomic resources. Pages 142-164 in P.M. Groffman and M.L. Pace (eds) *Successes, Limitations and Frontiers in Ecosystem Science*, Cary Conference VII, Springer-Verlag, NY.

Ambus, P. and **G. P. Robertson.** 1999. Fluxes of CH_4 and N_2O from aspen stands grown under ambient and twice-ambient CO_2. *Plant and Soil* 209:1-8.

Bergsma, T. T., Q.C. Bergsma, N.E. Ostrom, and **G. P. Robertson.** 1999. A heuristic model for the calculation of dinitrogen and nitrous oxide flux from ^{15}N-labeled soil. *Soil Science Society of America Journal* 63: 1709-1716.

Paul, E. A., D. Harris, H. P. Collins, U. Schulthess, and **G. P. Robertson.** 1999. Evolution of CO_2 and soil carbon dynamics in biologically managed, row-crop agroecosystems. *Applied Soil Ecology* 11: 53-65.

Groffman, P. M., E. A. Holland, D. D. Myrold, **G. P. Robertson,** and X. Zou. 1999. Denitrification. Pages 272-290 in G. P. Robertson, C. S. Bledsoe, D. C. Coleman, and P. Sollins, eds. *Standard Soil Methods for Long-Term Ecological Research*. Oxford University Press, NY.

Holland, E. A., **G. P. Robertson,** J. Greenberg, P. Groffman, R. Boone, and J. Gosz. 1999. Soil CO_2, N_2O, and CH4 Exchange. Pages 185-201 in G. P. Robertson, C. S. Bledsoe, D. C. Coleman, and P. Sollins, eds. *Standard Soil Methods for Long-Term Ecological Research*. Oxford University Press, NY.

Martinelli, L. A., M. C. Piccolo, A. R. Townsend, P. M. Vitousek, E. Cuevas, W. McDowell, **G. P. Robertson,** O. C. Santos, and K. Treseder. 1999. Nitrogen stable isotopic composition of leaves and soil: tropical versus temperate forests. Pages 45-65 *in* A. R. Townsend, editor. *New Perspectives on Nitrogen Cycling in the Temperate and Tropical Americas.* Kluwer Academic Press, Dordrecht, The Netherlands. Also published as Biogeochemistry 46:45-65.

Robertson, G. P.,D. Wedin, P. M. Groffman, J.M. Blair, E. Holland, K. Nadelhoffer, and D. Harris. 1999. Soil carbon and nitrogen availability: nitrogen mineralization, nitrification, and soil respiration potentials. Pages 89-105 in G. P. Robertson, C. S. Bledsoe, D. C. Coleman, and P. Sollins, eds. *Standard Soil Methods for Long-Term Ecological Research*. Oxford University Press, NY.

Robertson, G. P., P. Sollins, B. G. Ellis, and K. Lajtha. 1999. Exchangeable ions, pH, and cation exchange capacity. Pages 106-114 in G. P. Robertson, C. S. Bledsoe, D. C. Coleman, and P. Sollins, eds. *Standard Soil Methods for Long-Term Ecological Research*. Oxford University Press, NY.

Cavigelli, M. A., and **G. P. Robertson.** 2000. The functional significance of denitrifier community composition in a terrestrial ecosystem. *Ecology* 81:1402-1414.

Stoyan, H., H. De-Polli, S. Bohm, **G. P. Robertson**, and E. A. Paul. 2000. Spatial variability of soil respiration and related soil properties at the plant scale. *Plant and Soil* 222:203-214.

Robertson, G. P., E. A. Paul, and R. R. Harwood. 2000. Greenhouse gases in intensive agriculture: Contributions of individual gases to the radiative forcing of the atmosphere. *Science* 289:1922-1925.

Robertson, G.P. Denitrification. 2000. Pages C181-190 in M.E. Sumner et al., eds. *Handbook of Soil Science*. CRC Press, Boca Raton, FL.

Robertson, G. P., and E. A. Paul. 2000. Decomposition and soil organic matter dynamics. Pages 104-116 in E. S. Osvaldo, R. B. Jackson, H. A. Mooney, and R. W. Howarth, eds. *Methods in Ecosystem Science*. Springer Verlag, NY.

Ambus, P., E. S. Jensen, and **G. P. Robertson**. 2001. Nitrous oxide and N-leaching losses from agricultural soil: influence of crop residue particle size, quality and placement. *Phyton (Austria)* 41: 7-15.

Bergsma, T. T., N. E. Ostrom, M. Emmons, and **G. P. Robertson**. 2001. Measuring simultaneous fluxes from soil of N_2O and N_2 in the field using the ^{15}N-Gas "Nonequilibrium" technique. *Environmental Science and Technology* 35: 4307-4312.

Cavigelli, M. A., and **G. P. Robertson**. 2001. Role of denitrifier diversity in rates of nitrous oxide consumption in a terrestrial ecosystem. *Soil Biology and Biochemistry* 33:297-310.

Daroub, S., B. G. Ellis, and **G. P. Robertson**. 2001. Effect of cropping and low-chemical input systems on soil phosphorus fractions. *Soil Science* 166: 281-291.

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Bergsma, T. T., **G. P. Robertson**, and N. E. Ostrom. 2002. Influence of soil moisture and land use history on denitrification end-products. *Journal of Environmental Quality* 31:711-717.

Ostrom, N. E., L. O. Hedin, J. C. von Fischer, and **G. P. Robertson**. 2002. Nitrogen transformations and NO_3^- removal at a soil-stream interface: a stable isotope approach. *Ecological Applications* 12:1027-1043.

Dalal, R. C., W. Wang, **G. P. Robertson**, and W. J. Parton. 2003. Nitrous oxide emission from Australian agricultural lands and mitigation options. *Australian Journal of Soil Research* 41: 165-195.

Dazzo, F. B., A. R. Joseph, A. Gomaa, Y. G. Yanni, and **G. P. Robertson**. 2003. Quantitative indices for the autecological biogeography of a *Rhizobium* endophyte of rice at macro and micro spatial scales. *Symbiosis* 35:147-158.

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Grace, P. R., M. C. Jain, L. W. Harrington, and **G. P. Robertson**. 2003. Long-term sustainability of the tropical and subtropical rice and wheat system: An environmental perspective. Pages 27-43 in J. K. Ladha, J. E. Hill, J. M. Duxbury, R. K. Gupta, and R. J. Buresh, eds. *Improving the Productivity and Sustainability of Rice-Wheat System: Issues and Impacts*. American Society of Agronomy Special Publication 65, Madison, Wisconsin.

Kosola, K. R., D. M. Durall, **G. P. Robertson**, D. I. Dickmann, D. Parry, C. A. Russell, and E. A. Paul. 2004. Resilience of mycorrhizal fungi on defoliated and fertilized hybrid poplars. *Canadian Journal of Botany*, 82: 671.680.

Robertson, G. P., J. C. Broome, E. A. Chornesky, J. R. Frankenberger, P. Johnson, M. Lipson, J. A. Miranowski, E. D. Owens, D. Pimentel, and L. A. Thrupp. 2004. Rethinking the vision for environmental research in U.S. agriculture. *BioScience* 54:61-65.

Robertson, G. P., and P. R. Grace. 2004. Greenhouse gas fluxes in tropical and temperate agriculture: The need for a full-cost accounting of global warming potentials. *Environment, Development and Sustainability* 6:51-63.

Russell, C. A., K. R. Kosola, E. A. Paul, and **G. P. Robertson**. 2004. Nitrogen cycling in poplar stands defoliated by insects. *Biogeochemistry* 68:365-381.

Sanchez, J. E., R. R. Harwood, T. C. Willson, K. Kizilkaya, J. Smeenk, E. Parker, E. A. Paul, B. D. Knezek, and **G. P. Robertson**. 2004. Integrated agricultural systems: Managing soil carbon and nitrogen for productivity and environmental quality. *Agronomy Journal* 96:769-775.

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Robertson, G. P. 2004. Abatement of nitrous oxide, methane, and the other non-CO2 greenhouse gases: The need for a systems approach. Pages 493-506 in C. B. Field and M. R. Raupach, editors. *The Global Carbon Cycle*. Island Press, Washington, DC.

Robertson, G. P. and P. R. Grace. 2004. Greenhouse gas fluxes in tropical and temperate agriculture: The need for a full-cost accounting of global warming potentials. Pages 51-63 in R. Wassmann and P. L. G. Vlek, editors. *Tropical Agriculture in Transition - Opportunities for Mitigating Greenhouse Gas Emissions?* Kluwer, Dordrecht, The Netherlands. Also published in *Environment, Development, and Sustainability* 6:51-63.

Kravchenko, A. N., **G. P. Robertson**, K. D. Thelen, and R. R. Harwood. 2005. Management, topographical, and weather effects on spatial variability of crop grain yields. *Agronomy Journal* 97: 514-523.

McSwiney, C. P., and **G. P. Robertson**. 2005. Non-linear response of N_2O flux to incremental fertilizer addition in a continuous maize (*Zea mays* sp.) cropping system. *Global Change Biology* 11: 1712-1719.

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Robertson, G. P., and S. M. Swinton. 2005. Reconciling agricultural productivity and environmental integrity: A grand challenge for agriculture. *Frontiers in Ecology and the Environment* 3: 38-46.

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EXHIBIT B: LIST OF PUBLICATIONS (LAST TEN YEARS)

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Exhibit 4

CORRECTED EXPERT REPORT
OF
JAMES GUSTAVE ("GUS") SPETH

Kelsey Cascadia Rose Juliana; Xiuhtezcatl Tonatiuh M.,
through his Guardian Tamara Roske-Martinez; et al.,
Plaintiffs,

v.

The United States of America; Donald Trump,
in his official capacity as President of the United States; et al.,
Defendants.

IN THE UNITED STATES DISTRICT COURT
DISTRICT OF OREGON

(Case No.: 6:15-cv-01517-TC)

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TABLE OF ACRONYMS AND ABBREVIATIONS

ANWR:	Arctic National Wildlife Refuge
AR5:	Fifth Assessment Report
bbl/d:	barrels per day
BLM:	Bureau of Land Management
CAA:	Clean Air Act
CAFE:	Corporate Average Fuel Economy
CBO:	Congressional Budget Office
CCRI:	Climate Change Research Initiative
CCSP:	Climate Change Science Program
CEQ:	Council on Environmental Quality
CO_2:	Carbon dioxide
COP:	Conference of the Parties
CPP:	Clean Power Plan
CRS:	Congressional Research Service
DARPA:	Defense Advanced Research Projects Agency
DPC:	Domestic Policy Council
DOE:	Department of Energy
DOI:	Department of the Interior
DOT:	Department of Transportation
EIA:	Energy Information Administration
EO:	Executive Order
EPA:	Environmental Protection Agency
EPACT:	Energy Policy Act
FERC:	Federal Energy Regulatory Agency
GAO:	General Accountability Office
GARP:	Global Change Research Program
GCRP:	Global Change Research Program
GDP:	Gross domestic product
GFDL:	Geophysical Fluid Dynamic Laboratory
GHG:	Greenhouse Gas
HEW:	Department of Health, Education and Welfare
ICAS:	Interdepartmental Committee for Atmospheric Sciences
IPCC:	Intergovernmental Panel on Climate Change
NAS:	National Academy of Sciences
NASA:	National Aeronautics and Space Administration
NCAR:	National Center for Atmospheric Research
NCPO:	National Climate Program Office
NEPA:	National Environmental Policy Act
NGL:	Natural gas liquids
NOAA:	National Oceanic and Atmospheric Administration
NRC:	National Research Council
NSF:	National Science Foundation
OTA:	Congressional Office of Technological Assessment

OCS:	Outer Continental Shelf
OST:	Office of Science and Technology
OSTP:	Office of Science, Technology and Policy
ppm:	parts per million
PSAC:	President's Science Advisory Committee
Q&A:	Question and Answer
R&D:	Research and Development
SERI:	Solar Energy Research Institute
UNFCCC:	United Nations Framework Convention on Climate Change
USGS:	U.S. Geological Survey
WMO:	World Meteorological Organization
WRI:	World Resources Institute

QUALIFICATIONS

I, James Gustave Speth, am a retired Professor of Law at the Vermont Law School and a senior fellow at Vermont Law School, the Democracy Collaborative, and the Tellus Institute. During the Carter Administration I served as member and chairman of the U.S. Council on Environmental Quality. After leaving government, I founded and for a decade was president of the World Resources Institute. I also taught environmental and Constitutional law at Georgetown University Law Center. From 1993 to 1999, I was Administrator of the United Nations Development Programme and served as chair of the UN Development Group. I served as Dean of the Yale School of Forestry and Environmental Studies from 1999 to 2009.

I have a long career of working at the intersection of government and environmental protection, including providing leadership to many task forces and committees whose roles have been to combat environmental degradation, including the President's Task Force on Global Resources and Environment, the Western Hemisphere Dialogue on Environment and Development, and the National Commission on the Environment. Among my awards are the National Wildlife Federation's Resources Defense Award, the Natural Resources Council of America's Barbara Swain Award of Honor, a 1997 Special Recognition Award from the Society for International Development, Lifetime Achievement Awards from the Environmental Law Institute and the League of Conservation Voters, and the Blue Planet Prize. I hold honorary degrees from Clark University, the College of the Atlantic, the Vermont Law School, Middlebury College, the University of South Carolina, Unity College, and the University of Massachusetts/Boston.

A true and correct copy of my CV is attached as **Exhibit A** to my expert report in this action.

To the best of my recollection, I have not served as an expert at trial or by deposition in any case in the last four years.

A true and correct copy of a list of publications I authored within the last ten years is attached as **Exhibit B** to my expert report in this action. In preparing this expert report, in addition to relying upon my extensive experience and expertise, I have relied on a number of documents. My expert report contains a list of citations to the documents on which I relied in forming my opinions, listed in **Exhibit C** to my expert report in this action. **Exhibit D** is the list of **Exhibits E-1 to E-292**, which are documentary evidence underlying and supporting my expert opinions herein.

In preparing my expert report and testifying at trial, I am not receiving any compensation and am providing my expertise pro bono to Plaintiffs.

INTRODUCTION AND EXECUTIVE SUMMARY

I have been retained by Plaintiffs to provide expert testimony regarding the historic knowledge of the U.S. federal government (including Defendants) of climate change, climate science, and alternative pathways to power the nation's energy system other than fossil fuels. I will also testify about the decisions made by the U.S. federal government to devise and pursue energy policies and, in particular, to maintain a fossil fuel-based energy system.

By the end of the Carter Administration in January 1981, almost four decades ago, it was already very clear that:

1. Defendants knew the basic science of climate change and knew that the continued burning of high levels of fossil fuels would lead to climate danger;
2. Defendants knew of pathways recommended by experts within government and others to transition away from fossil fuels, including through conservation, efficiency and solar and other renewables; and
3. Notwithstanding 1 and 2, Defendants continued to plan for, support, invest in, permit and otherwise foster a national fossil fuel-based energy system.

In the first part of this report, through documentary evidence, I will present some important background information that preceded the Carter Administration to establish a foundation of knowledge by the federal government of climate change that existed when President Carter took office on January 20, 1977. I will then present the documentary evidence for my expert conclusions stated above as it existed at the end of the Carter Administration, and I will supplement this evidence drawing on my personal participation and observation. I will take up each of the three above points in turn. I used my contextual knowledge to present historical government evidence of the individual and institutional actors involved and the historical context of the events in question.

In the second part of this report, I will describe what transpired after President Carter left office with respect to the three conclusions just noted: that government had the basic information about climate science and the link between fossil fuels and climate change, that government also had abundant recommendations for reducing fossil fuel use as part of the national energy system, and that notwithstanding those reasonable and available alternatives, the federal government continued to foster a fossil fuel-based energy system. I will take up these matters in the context of each Administration following Carter, but in less depth than the Carter presentation. Because the science of climate change and the in-depth understanding of the danger of fossil fuels only increased after the Carter Administration, and are the subjects of other expert reports in this matter, I shall not attempt an exhaustive presentation.

One conclusion of this review stands out. The three-part pattern evident at the end of the Carter years continued through subsequent Administrations and through the various Congresses: knowledge of the climate science and the dangers of fossil fuel burning, knowledge of alternatives to fossil fuels, and continued full-throttle support for development and use of fossil fuels.

Finally, I briefly address the tragic actions of the current administration as well as my expert opinion on what it will take to redirect Defendants to abide their constitutional obligation to these children and Posterity in the very short time there is left.

For the year 1976, the year President Carter was elected, the United States relied on fossil fuels for 91 percent of primary energy consumption. In 2016, the year President Trump was elected, the United States was still overwhelmingly dependent on fossil fuels – 81 percent. During this 40-year period, the seeds planted during the Carter Administration regarding efficiency and renewable energy could have yielded a smooth transition toward an outstanding U.S. climate performance and global leadership in climate action. Instead, those years saw only negligible actual action to reduce U.S. fossil emissions and only modest actions to promote alternatives.

Defendants' actions on the national energy system over the past forty years are, in my view, the greatest dereliction of civic responsibility in the history of the Republic. And it is worse today than ever. This shocking historical conduct, government malfeasance on a grand scale, has left current and future generations enormously vulnerable to substantial danger.

EXPERT OPINION

I. The Federal Government Climate Science Knowledge that the Carter Administration Inherited in 1977

The 1930s through the early 1970s were a period of growing concern for scientists studying climate change. This period provides a prelude to the flowering forth of the climate change issue during the Carter Administration.

Particularly by the 1960s, with the advance of computer modeling, scientists were able to verify the changes that were happening and project what could happen in the future as the atmospheric CO_2 concentration increased. This period was marked by the work of scientists such as Guy S. Callendar, Roger Revelle, Gilbert Plass, and Charles D. Keeling. By the late 1950s and early 1960s, these scientists started sounding alarm bells. With federally-funded monitoring of the growing atmospheric CO_2 concentration, it was then possible to produce detailed charts showing the atmospheric CO_2 concentration. Early on, Keeling showed the seasonal variation in the concentration of atmospheric CO_2 in the Northern Hemisphere and that the CO_2 concentration in the late 1950s was around 315 ppm.[1] As the data was collected and charted year after year, the now famous "Keeling Curve" would become apparent, showing conclusively that the CO_2 concentration was on the rise (see Figure 1).

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[1] Rob Monroe, The History of the Keeling Curve, April 3, 2013, https://scripps.ucsd.edu/programs/keelingcurve/2013/04/03/the-history-of-the-keeling-curve/. Ex. E-1.

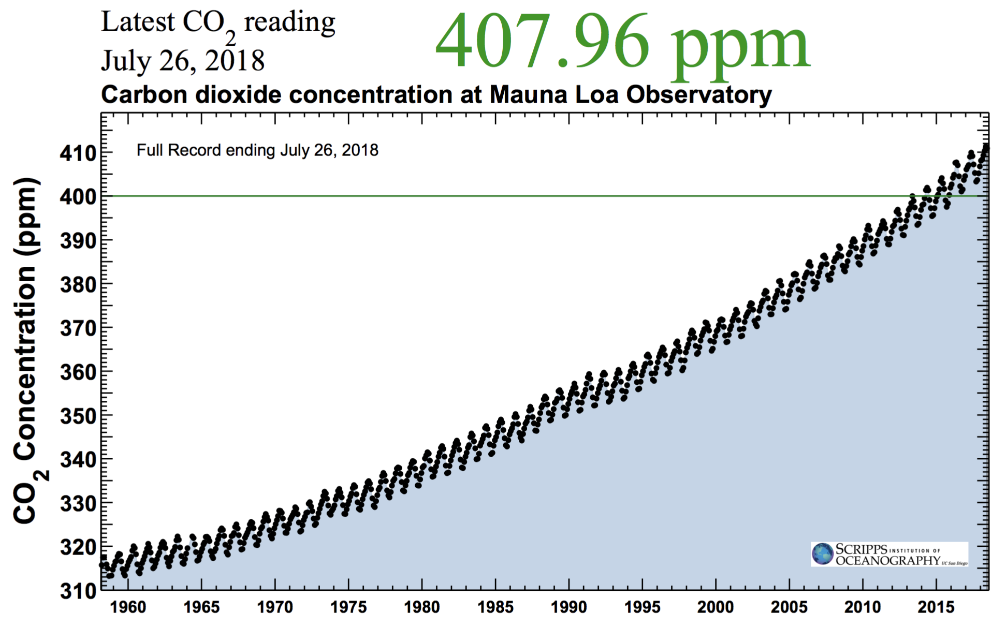

Figure 1: Carbon Dioxide Concentration at Mauna Loa Observatory, Showing the Keeling Curve.[2]

In 1955, the U.S. established the first major climate modeling center, the Geophysical Fluid Dynamic Laboratory (GFDL) of the National Oceanic and Atmospheric Administration (NOAA), now located at Princeton University (but still a NOAA lab). In 1960, another center was established by the National Science Foundation: the National Center for Atmospheric Research (NCAR) in Boulder, Colorado. Besides these government laboratories, UCLA established a modeling laboratory, as did the RAND Corporation, focused on possible military applications of climate modification. The RAND center was ultimately funded by the Defense Advanced Research Projects Agency (DARPA), which had been created in 1958 in response to the Soviet launching of Sputnik, with the mission of keeping U.S. military technology ahead of any potential enemy. These centers were focused on better understanding and developing atmosphere—ocean climate models and the response of the climate system to an increased concentration of CO_2.

The year 1965 was a pivotal year for the federal government recognizing climate change, with key reports issued late that year. In November 1965, the White House issued the Report of the Environmental Pollution Panel of the President's Science Advisory Committee, "Restoring the Quality of Our Environment," accompanied by Appendix Y4, Roger Revelle et al.'s work entitled "Atmospheric Carbon Dioxide."[3] The 1965 White House Report found that increasing CO_2 levels would be deleterious to humans by the year 2000, would cause ocean acidification,

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[2] Scripps Institution of Oceanography, The Keeling Curve, https://scripps.ucsd.edu/programs/keelingcurve/.
[3] The White House, Restoring the Quality of Our Environment: Report of the Environmental Pollution Panel of the President's Science Advisory Committee, November 1965. Ex. E-289.

sea level rise, and other adverse impacts, and that to burn all fossil fuels would cause a 200% increase in the atmospheric CO_2 concentration. The White House created a task force and ordered responses to the issues raised. By May 1967, the Office of Science and Technology (OST) (the predecessor to today's Office of Science, Technology and Policy (OSTP)) produced a report of agency responses to the 1965 White House Report, finding that most agencies failed to address CO_2 pollution at all.[4]

Also at the end of 1965, on December 20, the National Academy of Sciences (NAS) published the "Weather and Climate Modification: Report of the Special Commission on Weather Modification."[5] The "Weather and Climate Modification" report estimated that the CO_2 concentration in the atmosphere had increased 10-15% in the 20th century, causing significant changes in Earth's heat balance.[6] The report states that "the implications of this upon tropospheric stability cannot be ignored" and that there is a need for continuous monitoring of CO_2 content and of simulation of CO_2 effects "using the most sophisticated atmospheric models and numerical computers available" to assess the consequences.[7]

In a subsequent 1966 NAS Report on "Weather and Climate Modification Problems and Prospects, Vol. I, Summary and Recommendations," the NAS generally agreed that warming was occurring and stated that "to embark on any vast experiment in the atmosphere would amount to *gross irresponsibility*."[8] In 1967, the U.S. Department of Commerce released a report of the Panel on Electrically Powered Vehicles, "The Automobile & Air Pollution: A Program for Progress," which noted that temperatures could increase by 3-8 degrees F by the mid 2000s and included a recommendation that emissions standards be set for vehicles,[9] which was done during the Ford Administration through the nation's first CAFE standards.[10]

During the late 1960s and early 1970s, along with the enactment of the nation's seminal environmental statutes, Congress established the Council on Environmental Quality (CEQ) in part to develop and recommend policies that would promote environmental quality and meet the

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[4] Office of Science and Technology, Responses of the Federal Departments and Agencies to the President's Science Advisory Committee Report, "Restoring the Quality of Our Environment," May 1967. Ex. E-2.
[5] National Science Foundation, Weather and Climate Modification, Report of the Special Commission on Weather Modification, Washington, D.C., December 20, 1965. Ex. E-3.
[6] *Id.* at 42.
[7] *Id.*
[8] National Academy of Sciences, Weather and Climate Modification—Problems and Prospects, Vol. I: Summary and Recommendations, Final report of the Panel on Weather and Climate Modification to the Committee on Atmospheric Sciences, Washington, 1966. Ex. E-4 at 8 (emphasis added).
[9] U.S. Department of Commerce, Panel on Electrically Powered Vehicles, Commerce Technical Advisory Board, The Automobile and Air Pollution: A Program for Progress. Report to the Commerce Technical Advisory Board, 1967. Ex. E-5 at 5.
[10] Energy Policy and Conservation Act of 1975, Pub. L. 94–163, 89 Stat. 871, Sec. 502(a)(1), enacted December 22, 1975 (setting CAFE standards at 18 mpg for model 1978 passenger cars and 27.5 mpg for model 1985 passenger cars). Ex. E-6.

conservation, economic, health and environmental needs of the nation.[11] President Nixon was also advised in September 1969 that Seattle, New York, and Washington could all be lost to sea level rise if climate change was not addressed.[12] Two months later, President Nixon wrote to his Director of OST regarding the UNESCO Conference on the Environment, "Man and his Environment: A View Toward Survival," on the obligation and responsibility of government to protect future generations from global climate change and polluted oceans.[13] Director DuBridge subsequently directed John Erlichman to pursue the development of non-internal combustion engine vehicles so that they would be available when they were needed.[14]

The late 1960s and early 1970s were a period where the federal government acknowledged that climate policy is energy policy and what the nation did with fossil fuels and the energy system would impact the state of the climate system. NOAA and EPA were established during this period, and CEQ issued its first report in 1970.[15] CEQ called for worldwide recognition of the long-term significance of human alterations of the climate system.[16] President Nixon set the tone for CEQ's first report in his 1970 State of the Union Address, saying:

> Restoring nature to its natural state is a cause beyond party and beyond factions. It has become a common cause of all the people of this country. It is a cause of particular concern to young Americans, because they more than we will reap the grim consequences of our failure to act on programs which are needed now if we are to prevent disaster later.
>
> Clean air, clean water, open spaces-these should once again be the **birthright** of every American. If we act now, they can be.[17]

President Nixon similarly emphasized, in the United States' proposed participation in the Global Atmospheric Research Program (GARP), that: "In the longer term, *the quality of the atmosphere may well determine whether man survives or perishes*."[18]

Dr. Edward E. David, who later became the President of Research and Engineering at Exxon, was director of the OST under President Nixon, and helped draft the Administration's proposals on alternative energy and pollution control. On October 20, 1970, he wrote the following proposal to the White House: "The federal government must play a leadership role because these

[11] 42 U.S.C. §§ 4342, 4343.
[12] Daniel Moynihan, Memorandum to John Ehrlichman, September 17, 1969. Ex. E-7.
[13] Richard Nixon, letter to Lee DuBridge, Nov. 20, 1969. Ex. E-8.
[14] Lee DuBridge, Memorandum to John Erhlichman, Recommendation to Pursue Non-conventional Vehicle Development, Dec. 19, 1969. Ex. E-9.
[15] Council on Environmental Quality, The First Annual Report of the Council on Environmental Quality, August 1970. Ex. E-10.
[16] *Id.* at 104.
[17] Richard Nixon, Annual Message to the Congress on the State of the Union, January 22, 1970. Ex. E-11.
[18] U.S. Department of Commerce et al., World Weather Program, Plan for Fiscal Year 1971, April 1970. Ex. E-12 at 4 (emphasis added).

efforts are so large and so long-term that the fragmented power industry cannot be expected to do the job itself."[19] An OST memorandum made more detailed recommendations for research and development funding for new energy technology and stating: "[A]t present the funding and direction of most new pollution control technology and new methods of power generation must come from the Federal Government or not at all."[20]

In the latter months of 1970, Ehrlichman created the National Energy Subcommittee of the Domestic Council and the Council of Economic Advisors, together with the OST, "began to formulate a national energy policy."[21]

In my expert opinion, in the period shortly after President Carter took office in 1977, there was a growing sense of concern and indeed urgency within the federal government that fossil fuel burning was heating the planet and causing the climate to change in many ways that could be catastrophic, and that such climatic changes posed dangers to the lives and property of Americans, particularly its young people and future generations who would long live with the decisions made during the latter part of the twentieth century. This sense of concern deepened throughout the years of the Carter Administration, as I will now describe.

II. The Carter Administration, 1977-1981

Before taking up in detail the issues of the federal government's knowledge of both the climate danger and the opportunity to move away from fossil fuels, as well as its decision to continue pursuing fossil fuel energy, it is helpful to begin by recalling an important event in 1980 at which President Carter spoke. It illuminates these three conclusions well, in addition to my own personal engagement.

On Leap Day in 1980, President Carter's last full year in office, the President gave an important address at the Second Environmental Decade Celebration in the White House. Before the Celebration, I had an opportunity to brief the President on the forthcoming "Global 2000 Report," which would be released later in July of that year. In his remarks at the Celebration, President Carter noted:

> Just before lunch, Gus and I were discussing the long-term threats which just a few years ago were not even considered: the build-up of carbon dioxide; acid rain;

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[19] Edward W. David, Jr., Memorandum for Peter Flanigan, October 20, 1970. Ex. E-13 at 2. *See also,* Sam Roberts, Edward E. David Jr., Who Elevated Science Under Nixon, Dies at 92, https://www.nytimes.com/2017/02/28/science/edward-david-dead-science-adviser-to-nixon.html. Ex. E-14.

[20] Office of Science and Technology, Energy Policy Staff, Funding Energy Research and Development, August 26, 1970, Ex. E-291 at 1.

[21] Edward F. Hammel, Los Alamos Scientific Laboratory Energy-Related History, Research, Managerial Reorganization Proposals, Actions Taken, and Results, 1945-1979, p. 12, http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/28/077/28077313.pdf. Ex. E-15.

> the fact that 800 million human beings now suffer from lack of nourishment or disease; the fact that our population will increase 50 percent in the world by the end of this century . . . These kinds of concerns affect you and me, and on some of them we've hardly begun to work on corrective action that might be proposed, much less accepted and implemented. This last decade, however, has demonstrated that we can buck the trends.[22]

Later in his address, President Carter listed eight "preeminent environmental challenges of the next decade" and included on that list, "that we faced squarely such worldwide problems as the destruction of forests, acid rain, carbon dioxide buildup, and nuclear proliferation." President Carter also stressed the need for new energy directions. On his list of preeminent environmental challenges was: "that we put this nation on a path to a sustainable energy future, one based increasingly on renewable resources and on energy conservation." He urged that "energy conservation has got to become a way of life" and that we develop solar and renewable energy sources, noting that "[t]rue energy security can only come from solar and renewable energy technologies."[23]

President Carter was proud to remind the environmental leaders in attendance that day of the 1978 National Energy Act and hoped, he said, that future generations would recognize it as leading a "massive and fundamental shift toward energy efficiency." He noted that his proposed 1981 budget called for spending over $2 billion on energy conservation, double the 1980 level.[24]

All that said and done, President Carter's address that day also noted, "[i]t's important to pursue a broad range of alternative energy sources, including synthetic fuels," and he mentioned his "highly controversial" proposal for an Energy Mobilization Board to "eliminate unnecessary delays" in approving energy projects. Here, the President was referring in part to the energy development proposals in his famous "malaise" speech of July 15, 1979 where he proposed "the most massive peacetime commitment of funds and resources in our Nation's history to develop America's own alternative sources of fuel – from coal, from oil shale, from plant products for gasohol, from unconventional (natural) gas, from the Sun."[25] For instance, the federal synfuels program was created in 1980, had a rough life, and was terminated in 1985 as the oil market improved. The legislation to create the Mobilization Board never passed. Yet, in some respects, Carter's proposals were merely ahead of their time. As I will describe subsequently, oil and gas markets are today awash with unconventional oil and gas thanks in large part to federal support and facilitation.

Much had already happened in the Carter Administration before the President gave his Second Environmental Decade remarks in 1980. The White House, the Executive Office of the President, DOE, and several other agencies were certainly aware of the links and interactions

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[22] President Jimmy Carter, Remarks at the Second Environmental Decade Celebration, The White House East Room, February 29, 1980. Ex. E-20.
[23] *Id.*
[24] *Id.*
[25] President Jimmy Carter, Address to the Nation on Energy and National Goals, July 15, 1979. Ex. E-21.

among the three conclusions I list at the outset. Indeed, the preceding year, 1979, had been one of numerous reports flying about in the Administration, as well as interagency dialogue and debate linking these three points. It was well understood by Defendants DOE, the President, and the Executive Office of the President, for example, that to reduce carbon emissions to respond to the threat of climate change would require a new energy policy from the federal government. And, looking ahead, much regarding the climate issue was still to happen before the President's term ended. Still, it is notable that 38 years ago the basic outlines of the federal government's response to the climate issue were already plainly visible: knowledge of the climate science, knowledge of alternatives to fossil fuels, and continued full-throttle support for fossil fuel development and use. This pattern would persist through subsequent Administrations.

A. During the Carter Administration, the Federal Government's Awareness of Climate Science and the Link Between Fossil Fuel Use and Dangerous Global Warming and Climate Change Became Well Established

1. <u>The President and the Executive Branch</u>

In March 1977, in the early months of the Carter Administration, a climate science workshop was sponsored by what would subsequently become the newly formed Department of Energy.[26] The important conclusions of that workshop speak to the knowledge of climate science in the federal government at that time. The Preface to the DOE report of the workshop summarized the conclusions of the participants:[27]

> Implicit in all the panel reports is the acceptance of increasing atmospheric content, well documented since 1958 and most probably the case since the industrial era began. That this rise has paralleled the increase in fossil fuel usage and is roughly equal to half the CO_2 liberated by industrial activity was also accepted. That fossil fuel usage is the sole cause of the increase, however, is under dispute: some significant fraction may be attributable to a decrease in the size of the biosphere. It also seems certain that there is enough fossil fuel still available to raise manyfold the level of atmospheric CO_2, if the current models are anywhere near correct. . . It was also accepted that carbon dioxide's radiative properties are well enough known to say that its increase will warm the lower atmosphere. But the interactions and feedback mechanisms within the climate system are so complex that considerable uncertainty exists about the magnitude of the effects.

The President's science advisor during the Carter Administration was Frank Press, the Director of the Office of Science and Technology Policy. Press wrote the President about the climate

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[26] The Department of Energy became an official executive agency in August 1977. Department of Energy Organization Act of 1977, Pub. L. 95–91, 91 Stat. 565, enacted August 4, 1977. The report from these early conferences was ultimately published by DOE in May 1979.
[27] U.S. Department of Energy, Carbon Dioxide Effects Research and Assessment Program, Workshop on the Global Effects of Carbon Dioxide from Fossil Fuels, May 1979. Ex. E-22 at v.

threat on July 7, 1977, in a memorandum copied to James Schlesinger, who would soon become the first Secretary of Energy. Press' memorandum summarized the threat:

> Fossil fuel combustion has increased at an exponential rate over the last 100 years. As a result, the atmospheric concentration of CO_2 is now 12% above the pre-industrial revolution level and may grow 1.5 to 2 times that level within 60 years. Because of the greenhouse effect of atmospheric CO_2, the increased concentration will induce a global climatic warming of anywhere from .5 to 5 C. . . .
>
> The present state of knowledge does not justify emergency action to limit the consumption of fossil fuels in the near term. However, *I believe that we must now take the potential CO_2 hazard into account in developing our long-term energy strategy*. . .
>
> A rapid climatic change may result in large scale crop failures at a time when an increased world population taxes agricultural limits to productivity. *The urgency of the problem derives from our inability to shift rapidly to non-fossil fuel sources once the climatic effects become evident not long after the year 2000; the situation could grow out of control before alternate energy sources and other remedial actions become effective*.[28]

Barely six months into the new Administration, the President and his top energy advisor were apprised of the problem and its implications for the U.S. energy system.

A report on "The Long Term Impact of Atmospheric Carbon Dioxide on Climate" prepared for the Department of Energy in April 1979, known as the JASON Report, advised that the CO_2 influence on climate was "widely accepted" and predicted levels of temperature increase through the middle of the 21st century.[29] The JASON Report also predicted when atmospheric CO_2 levels would double for various rates of increase in fossil fuels (see Figure 2).

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[28] Frank Press, Memorandum to the President, Release of Fossil CO_2 and the Possibility of a Catastrophic Climate Change, July 7, 1977. Ex. E-23 (emphasis added).
[29] Gordon MacDonald, The Long Term Impact of Atmospheric Carbon Dioxide on Climate. Technical Report JSR-78-07, April 1979. Ex. E-24 at 2-3.

ASSUMED RATE OF INCREASE IN USE OF CARBON FUELS	DATE OF DOUBLING OF CARBON DIOXIDE CONTENT OF ATMOSPHERE
Constant 4.3%	2035
Constant 3%	2050
4.3% 1978 - 2000	
3% 2000-	2040
2% 2000-	2050
1% 2000-	2060

Figure 2: Approximate Date for Doubling the Carbon Dioxide Content of the Atmosphere.[30]

Even as early as the Carter Administration, there was not a debate over whether a clear climate threat existed, but there were uncertainties about how quickly different climate change harms would occur. One issue around which modeling results differed in the late 1970s was the amount of global average warming one could anticipate with a doubling of the CO_2 in the atmosphere. Carbon dioxide had been increasing as shown from measurements at Mauna Loa and was projected to increase (see Figure 3 from the JASON Report).

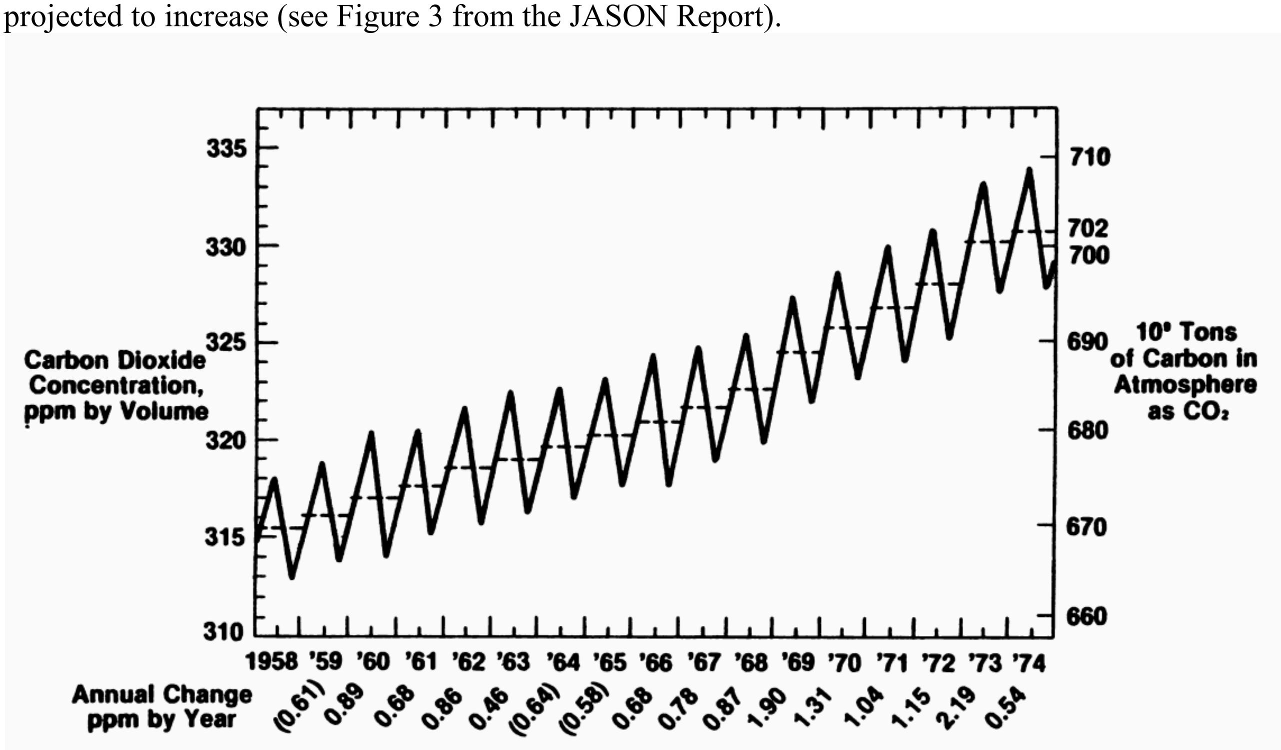

Figure 3: Atmospheric Carbon Dioxide Concentration at Mauna Loa Observatory.[31]

[30] *Id.* at 19.
[31] *Id.* at 6.

In May 1979, Frank Press asked the National Academy of Sciences to investigate this and related issues. The NAS convened a panel under the chair of MIT professor Jule Charney, and the panel met in July 1979. The concentration of CO_2 had risen that year to approximately 337 ppm.[32] The result was the famous Charney Report. The Charney Report was made widely available at the time both within and outside the Administration and used government sponsored and government produced scientific research to support its findings. The well-known technical finding of the Charney Report was as follows: "We believe, therefore, that the equilibrium surface global warming due to doubled CO_2 will be in the range 1.5° to 4.5° C with the most probable value near 3° C." This warming, the Charney Report concluded, "will be accompanied by significant changes in regional climatic patterns."[33]

The summary of the Charney Report findings was particularly telling in its warning:

> The conclusions of this brief but intense investigation may be comforting to scientists but disturbing to policymakers. If carbon dioxide continues to increase, the study group finds no reason to doubt that climate changes will result and no reason to believe that these changes will be negligible. The conclusions of prior studies have been generally reaffirmed. However, the study group points out that the ocean, the great and ponderous flywheel of the global climate system, may be expected to slow the course of observable climate change. ***A wait-and-see policy may mean waiting until it is too late***.[34]

The DOE released a report in July 1980 on its "Summary of the Carbon Dioxide Effects Research and Assessment Program," which also reflected the scientific consensus:

> It is the sense of the scientific community that carbon dioxide from the unrestrained combustion of fossil fuels is potentially ***the most important environmental issue facing mankind***. Current predictions call for a doubling of atmospheric carbon dioxide as early as the middle of the next century. Climate models, using these elevated levels, predict the possibility of significant dislocations in the global distribution of climate.[35]

This 1980 DOE report echoed the findings of the Charney Report, noting that a doubling of atmospheric CO_2 was predicted to occur in the middle of the next century. Although uncertainties regarding timing and severity of warming persisted, in part due to the role of the oceans, the DOE report reflected an understanding of the dangerous impacts of the doubling of CO_2.

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[32] Trends in Atmospheric Carbon Dioxide, Mean annual temperature from Mauna Loa, ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_annmean_mlo.txt. Ex. E-25.
[33] Climate Research Board, National Research Council, Carbon Dioxide and Climate: A Scientific Assessment, Washington, D.C., 1979. Ex. E-27 at 16-17.
[34] *Id*. at viii (emphasis added).
[35] U.S. Department of Energy, Summary of the Carbon Dioxide Effects Research and Assessment Program, July 1980. Ex. E-28 at 5 (emphasis added).

2. Congress

Congress was also aware of the climate and energy challenge during this early period. In a September 1977 report from the General Accounting Office (now General Accountability Office) on future U.S. coal development, the Comptroller General reported the following to Congress:

> [A] global warming of 1 degree to 2 degrees centigrade could cause serious repercussions on the earth's surface including shifting of wind circulation belts and redistributing temperature patterns and precipitation levels. Numerous secondary effects associated with these primary effects will also occur.
> . . .
>
> [T]he increased global temperature caused by rising concentrations of carbon dioxide may produce some melting of the polar ice caps, causing a sea level increase of tens of fee[t], gradually inundating coastal plains and lowlands, and perturbation of marine biology. With continued growth in the use of fossil fuels, the effect of increased coal combustion on climatic conditions may become an important problem during the next 50 years.[36]

Proposed legislation on climate issues was introduced in Congress just as the Carter Administration began. It became the National Climate Program Act of 1978 and its purpose was "to establish a national climate program that will assist the Nation and the world to understand and respond to natural and man-induced climate processes and their implications."[37] The Act noted the great importance of climate factors and found that "an ability to anticipate natural and man-induced changes in climate would contribute to the soundness of policy decisions."

The agency I led in the Executive Office of the President, the Council on Environmental Quality, was mandated by the National Environmental Policy Act of 1969 to provide an annual report to Congress on environmental conditions, trends, and policy actions and results. We always saw the report as a vehicle for informing the public as well as the Congress, and we viewed it, among other things, as a warning mechanism for environmental threats. We issued four of these reports while I was a member and then chair of CEQ, starting in December 1977. Each was widely distributed and included contributions from other agencies such as Office of Naval Research projections for atmospheric CO_2 increases that affirmed the work of climate scientists such as Charles Keeling.

In the CEQ's Eighth Annual Report to Congress in 1977, we wrote:

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[36] Elmer B. Staats, Controller General, Report to Congress, U.S. Coal Development – Promise, Uncertainties. EMD-77-43, Sept. 22, 1977. Ex. E-29 at 6.19.
[37] 15 U.S.C. section 2901(3).

> If carbon dioxide levels increase, the amount of energy leaving the earth may decrease, resulting in higher temperatures in the lower atmosphere. The potential environmental consequences are many.
>
> Deforestation, on the other hand, provides fuel, increases biological decay, and disturbs the soil – all of which increase CO_2 emissions. Deforestation also reduces the rate at which CO_2 is removed from the air.
>
> If we use up the world's stores of fossil fuels at a rapid rate, the predicted CO_2 level will double by 2025 and reach a maximum of seven to eight times today's level by the year 2100. A doubling of CO_2 level could cause a 2-3 degrees C increase in average atmospheric temperatures. The most warming would occur at the poles. . . .
>
> A possible 2-3 degrees C average temperature increase must be looked upon as a major global environmental threat – global temperatures over the past several thousand years have never fluctuated by more than 1 degree C . . . .
>
> The global CO_2 problem is an issue which must be addressed in terms of its relevance to national energy policies. If further research confirms the hypothesis just described, then a programmed switch from fossil fuels to energy sources with no associated CO_2 emissions – such as solar power – may be imperative in order to limit global temperatures.[38]

The Eighth Annual CEQ Report also included a graph (Figure 4 below) showing the steady increase in CO_2 emissions, beginning in 1860.

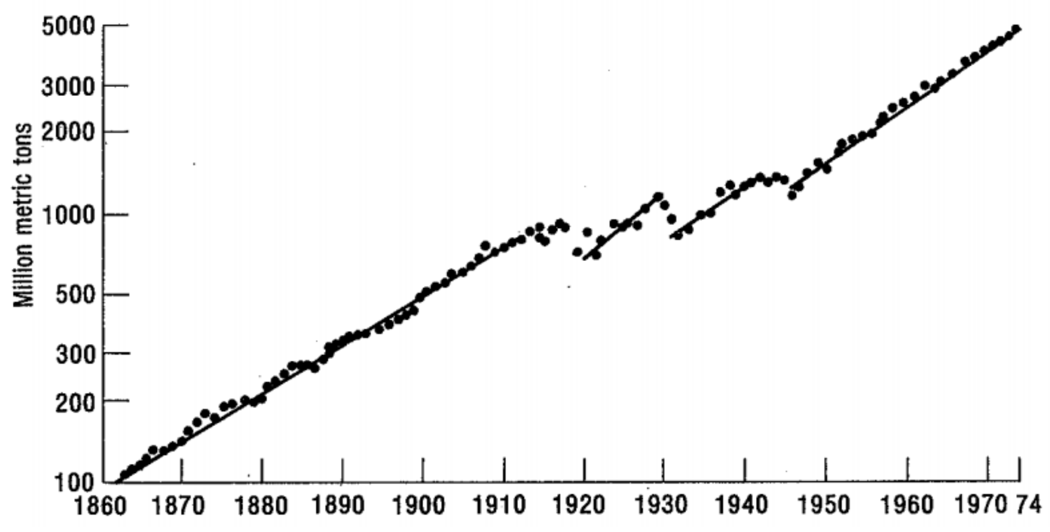

Figure 4: Estimated CO_2 Global Emission Trends, 1860-1974.[39]

[38] Council on Environmental Quality, Environmental quality 1977: The Eighth Annual Report of the Council on Environmental Quality, Washington, D.C., 1977. Ex. E-30 at 188-190, 192.
[39] *Id.* at 190.

In CEQ's Ninth Annual Report to Congress in 1978, we wrote to Congress:

> Global effects of carbon dioxide in the atmosphere – Combustion of fossil fuels, and especially coal, is increasing global atmospheric CO2. This could induce climatic changes with potential for generating global sociopolitical disruption after 2025. It is urgent that we continue a strong research program to provide a sound basis for action no later than 1985. Because this problem is global in character, the United States should initiate a continuing international dialogue immediately.[40]

Building from the work we had done since the 1977 CEQ report, in CEQ's Eleventh Annual Report to Congress in 1980, we strengthened our findings to Congress that the ongoing rising concentration of CO_2 from fossil fuel burning and deforestation would be disastrous for our natural systems and for humanity, particularly later generations of Americans. We wrote:

> Further, added to the major effects of fossil fuel burning, extensive loss of forests might aggravate the rising concentrations of CO_2 in the earth's atmosphere and thus eventually contribute to unprecedented human-caused changes in world climate.
>
> There is a growing realization that the earth's atmosphere could be permanently and disastrously altered by human actions. The burning of fossil fuels and perhaps the cutting of forests without compensatory replanting are causing a steady, measurable buildup of carbon dioxide in the atmosphere that threatens widespread climate change.
>
> A World Meteorological Organization (WMO) study group recently concluded that there is now little doubt that rising concentrations of carbon dioxide in the atmosphere will cause global warming.
>
> A major contributor of CO_2 to the atmosphere is the combustion of fossil fuels. Most estimates of global energy use suggest that CO_2 concentrations could reach twice the pre-industrial level around the middle of the 21st century.
>
> Possible climatic effects include changes in wind direction and speed, in ocean currents, and in precipitation patterns. If these large-scale climatic changes occurred, the socioeconomic impacts would be significant. If the warming continued long enough, polar ice could melt and sea levels would rise, forcing a gradual evacuation of heavily populated coastal areas. Agricultural patterns would

[40] Council on Environmental Quality, Environmental quality: The Ninth Annual Report of the Council on Environmental Quality, Washington, D.C., 1978. Ex. E-31 at 86.

change as well. In some regions existing agricultural infrastructure could become obsolete.[41]

In sum, based on my personal experience in the White House, these CEQ reports, and other historical evidence, by 1980, the U.S. government was both well aware of the scientific findings that anthropogenic buildup of greenhouse gases in the atmosphere, principally carbon dioxide from the burning of fossil fuels, was occurring and that the projected and possible consequences of this buildup, if unabated, would be catastrophic.

3. A Key Energy and Policy Question Posed Early On Was What the CO_2 Target Should Be.

In the 1977 NAS Report "Energy and Climate: Studies in Geophysics," NAS explained "[t]he principal conclusion of this study is that the primary limiting factor on energy production from fossil fuels over the next few centuries may turn out to be the climatic effects of the release of carbon dioxide."[42] NAS explained that their "best understanding of the relation between an increase in carbon dioxide in the atmosphere and change in global temperature suggests a corresponding increase in average world temperature of more than 6°C, with polar temperature increases of as much as three times this figure."[43] Consequently, NAS advised that "[i]n the light of a rapidly expanding knowledge and interest in natural climatic change, perhaps the question that should be addressed soon is, '**What *should* the atmospheric carbon dioxide content be over the next century or two to achieve an optimum global climate?' Sooner or later, we are likely to be confronted by that issue.**'"[44] That key question posed in 1977 has been answered by scientists many times since (e.g., James Hansen[45]), and, indeed, we at CEQ offered an estimate as early as January 1981 (see below), but the federal government has never adopted a ceiling for CO_2 build-up in the atmosphere

B. During the Carter Administration, the Federal Government Was Well Aware of the Need to Shift U.S. Energy Policy Away from Fossil Fuels to Renewables, Efficiency Gains, and Conservation.

1. The Federal Government's National Energy Policy Included a Preliminary Push for Clean Energy

As early as the Frank Press memorandum to the President in July 1977 (a memorandum that reflected views widely held in the scientific community), there were calls for a new energy

[41] Council on Environmental Quality, Environmental quality: The Eleventh Annual Report of the Council on Environmental Quality, Washington, D.C., 1980. Ex. E-32 at 8, 12, 265-266.
[42] National Academy of Sciences, Energy and Climate: Studies in Geophysics, Washington, D.C., 1977. Ex. E-33 at viii.
[43] *Id*.
[44] *Id*. at ix (emphasis added).
[45] *See, e.g.,* James Hansen et al. Target Atmospheric CO_2: Where Should Humanity Aim? Open Atmospheric Science Journal, 2: 217-231, 2008.

pathway that went straight to the White House.[46] Although Press did not call for "emergency action," he advised President Carter that "we must now take the potential CO_2 hazard into account in developing our long-term [energy] strategy."[47]

The need to shift to non-fossil resources was not surprising news to President Carter or the federal government generally. Three years previously in 1974, Congress had passed the Solar Energy Research, Development, and Demonstration Act, which *inter alia* called for the creation of the Solar Energy Research Institute. In this legislation, Congress found that "dependence on nonrenewable energy resources cannot continue indefinitely" and that "it is in the Nation's interest to expedite the long-term development of renewable and nonpolluting energy resources, such as solar energy."[48] Congress accordingly declared that it is "the policy of the Federal Government to pursue a vigorous and viable program of research and resource assessment of solar energy for our national needs."[49] Congress in 1974 was aware of the need for early commercialization of renewable technologies. The legislation notes that some solar technologies were "already near the stage of commercial application," and it called for "the demonstration of practicable means to employ solar energy on a commercial scale."[50]

President Carter moved fast in his first year in office to build on this legislation. In 1977 he created the Solar Energy Research Institute and provided it with strong leadership and significant funding. (SERI was renamed in 1991 as the National Renewable Energy Laboratory.)

In April 1977, just a few months in office, the Carter Administration released the National Energy Plan, much of which would find its way into the National Energy Act of 1978. The official Fact Sheet on the President's program said: "[t]he cornerstone of our policy is to reduce demand through conservation"; and added the following statement: "Our energy problems have the same cause as our environmental problems—wasteful use of resources. Conservation helps us solve both at once."[51]

The National Energy Act of 1978 launched many of the energy efficiency initiatives needed to reduce fossil fuel use and foreshadowed others. It eliminated electricity rate structures that encouraged power use and, similarly, began the process of deregulating natural gas prices. It placed a tax on new gas guzzling automobiles, created incentives for energy saving investments, and imposed requirements for demand side management by electric utilities, among other measures.[52]

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[46] Frank Press, Memorandum to the President, Release of Fossil CO_2 and the Possibility of a Catastrophic Climate Change, July 7, 1977. Ex. E-23.
[47] *Id.*
[48] Solar Energy Research, Development, and Demonstration Act, Publ. L. 93-473, §2, Oct. 26, 1974, 42 USC § 5551 at 1431.
[49] *Id.*
[50] *Id.*
[51] President Jimmy Carter, National Energy Program Fact Sheet on the President's Program, April 20, 1977. Ex. E-34.
[52] Auto fuel economy standards and building energy standards were enacted earlier in 1975.

At CEQ, we saw a need to share with the public what government knew about the near and long-term potential for solar and renewable energy. By April 1978 we had completed a report, "Solar Energy: Progress and Promise," which we made widely available within and outside of the federal government.[53]

The CEQ solar report defined "solar" to include renewables broadly and stated its goal on the first page of the Preface:

> Despite the great potential of energy conservation, it alone will not be sufficient. We must also shift from oil and gas to other sources of supply. Yet, the two most readily available, coal and nuclear power, are constrained by environmental and social problems.
>
> It should not be surprising then that many of us in government and elsewhere are returning again to the questions: What can we reasonably expect of solar energy? And how soon?[54]

The CEQ solar report noted that, "[u]nlike coal, solar poses little risk to climate and creates little direct air pollution."[55]

Our conclusions at CEQ about the solar potential were more positive than we anticipated:

> Based on our review, the Council on Environmental Quality has reached some tentative conclusions about what would be reasonable goals for the United States in this vital area. No one's crystal ball works very well in examining energy futures, but based on available information and recognizing the uncertainties, we view the following goals as optimistic but achievable if we commit the necessary resources to them:
>
> - To make economically competitive over the remainder of the century a variety of solar technologies for the production of heat, electricity and biofuels.
>
> - To meet, by the turn of the century, a significant portion of our energy needs with solar energy. Although the actual contribution of solar energy will depend on an enormous number of decisions by the public and private sectors, we believe that under conditions of accelerated development and with a serious effort to conserve energy, solar technology could meet a quarter of our energy needs by the year 2000.[56]

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[53] Council on Environmental Quality, Solar Energy: Progress and Promise, Government Printing Office, April 1978. Ex. E-35.
[54] *Id.* at iii.
[55] *Id*. at 2.
[56] *Id.* at iv.

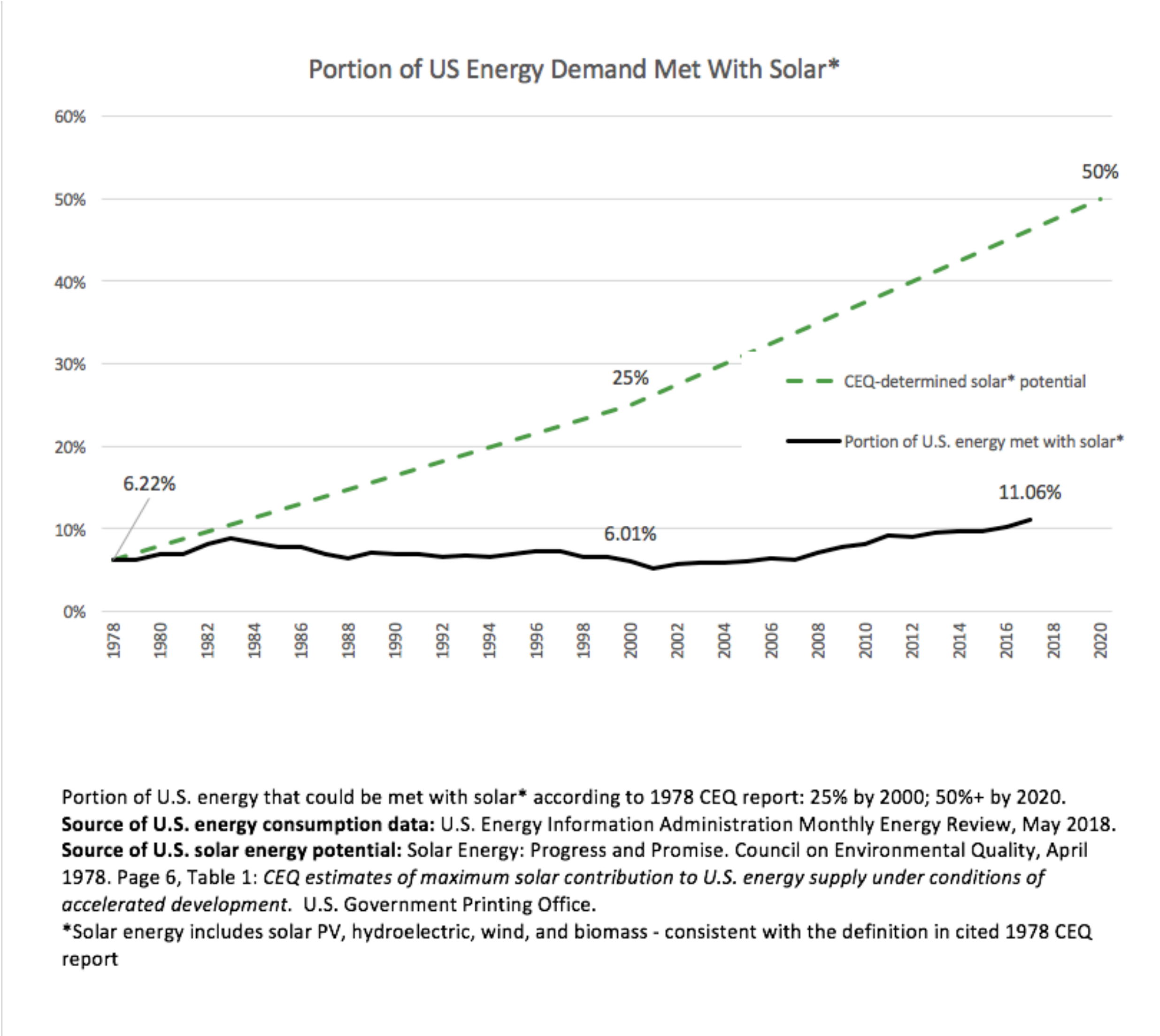

Figure 5: Portion of U.S. Energy Demand Met with Solar between 1978 and 2017.[57]

The CEQ solar report in April was followed by President Carter's well-known Sun Day speech on May 3, 1978, in Golden, Colorado, the future home of SERI. President Carter began his remarks by noting that his energy proposals to Congress in 1977 had declared: "America's hope for energy to sustain economic growth beyond the year 2000 rests in large measure on the development of renewable and essentially inexhaustible sources of energy."[58]

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[57] Source of U.S. energy consumption data: U.S. Energy Information Administration, Monthly Energy Review, May 2018, 2018. Ex. E-36. Source of U.S. solar energy potential: Council on Environmental Quality, Solar Energy: Progress and Promise, April 1978. Ex. E-35 at 6.
[58] President Jimmy Carter, Remarks at the Solar Energy Research Institute, Golden, Colorado, May 3, 1978. Ex. E-37

He continued, citing our CEQ solar report in the process:

> We must begin the long, slow job of winning back our economic independence. Nobody can embargo sunlight. No cartel controls the Sun. Its energy will not run out. It will not pollute the air; it will not poison our waters. It's free from stench and smog. . . .
>
> The question is no longer whether solar energy works. We know it works. The only question is how to cut costs so that solar power can be used more widely and so that it will set a cap on rising oil prices. . . .
>
> The Council on Environmental Quality recently estimated that we could meet as much as one-fourth of our energy demands for solar sources by the end of this century, and perhaps more than half by the year 2020. We must continue to make progress toward these goals.
>
> The Department of Energy believes that photovoltaic cells can be competitive with conventional energy sources, perhaps as early as 1990. The Energy Department is working on many projects throughout this country, indeed throughout the world.[59]

President Carter announced major new funding for solar that day, but his major proposals for action came in his June 20, 1979 Solar Energy Message to the Congress where he outlined, as the message says, "the major elements of a national solar strategy."[60]

After making the case to Congress for major coal use to replace oil, President Carter made an equally powerful case for solar and renewables. The goal President Carter announced of 20% renewables by the year 2000 was slightly below our recommended 25% target but reflected the CEQ's conclusions that a large shift to renewables was entirely possible with federal leadership.

In short, as early as 1978, the federal government was fully aware of and had begun acting on energy conservation and efficiency policies, both in response to the oil crises that persisted through the 1970s, including the OPEC oil embargo of 1973-74, and because alternatives to fossil fuels provided greater security and would have avoided the looming threat of catastrophic climate change. Notwithstanding Carter's and later recommendations regarding solar energy potential, U.S. energy demand met with solar has consistently lagged far behind, as shown in the above Figure 5.

We at CEQ turned attention to the energy efficiency issue in 1979, releasing our report, *The Good News About Energy*. We undertook this energy efficiency report to explore the potential for achieving low energy growth in the United States and the implications of alternative energy growth paths for the economy and the environment. We ultimately found that energy consumption did not need to expand significantly in order to continue a healthy, expanding

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[59] *Id.*

[60] President Jimmy Carter, Solar Energy Message to the Congress, June 20, 1979. Ex. E-38.

economy. We showed that by improving energy productivity and efficiency, we could keep energy consumption from increasing by only 10-15 percent by the year 2000. We also found that "unforeseen developments [in technological improvements] seem far more likely to reduce energy growth than to increase it."[61]

In assessing the benefits of a low energy growth alternative, we noted that coal production could be about 50 percent less than business-as-usual and thus avoid the associated climate risks:

> Other longer-term environmental threats—equally difficult to quantify—will also be exacerbated by increasing energy use. The buildup of carbon dioxide, whose release is directly proportional to the amount of fossil fuels burned, is one. By absorbing a portion of the earth's outgoing radiation, carbon dioxide could lead to a long-term warming trend with potentially disastrous effects on the world's climate.[62]

Our report, which was made widely available to the Executive Branch, the Congress, and the media, presented a long list of potential energy efficiency measures beyond those already enacted.

2. Climate Enters the Policy Arena: 1979-81

In 1979, the clash between the White House's call for climate protection and the federal government's fossil fuel energy policies became stark. As mentioned above, it was the year the oft-cited Charney report was released and also the year President Carter gave his "malaise" address to the nation with its emphasis on a massive new synfuels, a coal to liquids energy initiative. I was personally involved in bringing public and government attention to this entrenched conflict.

In May 1979 I met at CEQ with Gordon MacDonald, one of the U.S.'s top atmospheric scientists, and Rafe Pomerance, then-president of Friends of the Earth. They were seeking a stronger government response to the problem of global climate disruption. I promised to take the matter to the President and requested a reliable, scientifically credible memorandum on the problem from top scientists. The resulting July 1979 report, now almost four decades old, connected policy with scientific understanding of climate change, and was signed by four of our most distinguished American scientists – David Keeling, Roger Revelle, George Woodwell (lead author), and MacDonald.[63]

The contents of the 1979 report were alarming. The report predicted, "a warming that will probably be conspicuous within the next twenty years," and it called for early action:

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[61] Council on Environmental Quality, The Good News About Energy, Government Printing Office, 1979. Ex. E-39 at v.

[62] *Id.* at 27.

[63] George M. Woodwell, Gordon J. MacDonald, Roger Revelle, and C. David Keeling, The Carbon Dioxide Problem: Implications for Policy in the Management of Energy and Other Resources, A Report to the Council on Environmental Quality, July 1979. Ex. E-40.

"Enlightened policies in the management of fossil fuels and forests can delay or avoid these changes, but the time for implementing the policies is fast passing."[64]

Here are some further important excerpts from the 1979 report:

- Man is setting in motion a series of events that seem certain to cause a significant warming of world climates over the next decades unless mitigating steps are taken immediately. The cause is the accumulation of CO_2 and other heat-absorbing gases in the atmosphere.

- If we wait to prove that the climate is warming before we take steps to alleviate the CO_2 build-up, the effects will be well underway and still more difficult to control. . . . The potential disruptions are sufficiently great to warrant the incorporation of the CO_2 problem into all considerations of policy in the development of energy.

- The first element of any policy that offers the hope of being effective is conservation. Limitation of the rate of exploitation of fuels is possible. The rate is controlled currently by price, taxation, and regulation. It can be controlled as a matter of policy. All actions of government should be reviewed to determine effects on the total use of carbon-based fuels.

- Steps toward control are necessary now and should be a part of the national policy in management of sources of energy.

- It is our conviction that an appropriate reaction to the mounting worldwide squeeze on supplies of energy requires consideration of the CO_2 problem as an intrinsic part of any proposed policy on energy.[65]

The report was very clear on the urgency of bringing the climate issue into the formulation of national energy policy generally and the future of fossil fuels particularly. Unfortunately, later that same July the President would call for a major program to develop synthetic fuels (oil and gas) from coal and other hydrocarbons. The Woodwell-MacDonald-Revelle-Keeling report to CEQ contained a major warning about this policy. It strongly criticized the President's programs to increase coal production, stressing that synthetic fuels from coal and other hydrocarbons would release an estimated 2.3 times the amount of carbon dioxide per Btu as natural gas. The report made clear that the new synfuels policy the Department of Energy had developed for the President was inconsistent with protecting the climate system.[66]

[64] *Id.* at 1.
[65] *Id.* at 7, 11, 12, 13.
[66] Our 1979 CEQ Report echoed these recommendations saying: "Conceivably, scientific proof of the warming of the earth might come after the time has passed when action could be taken to reverse the trend. 'If we wait until there is absolute proof that the increase in CO_2 is causing a warming of the earth,' says Dr. George Woodwell of Woods Hole Marine Biological Laboratory, 'it will be 20 years too late to do anything about it.'" Council on Environmental Quality,

This shot across the bow of the Administration's plan to greatly expand domestic fossil fuel production was covered well in the press. *The New York Times* reported on July 10, 1979 that CEQ found the report to be historic and an important policy guiding document to bring energy policy in line with climate protection policy.[67] According to *The New York Times*:

> The new report has been sent to the President and other Administration leaders. Gus Speth of the Council of Environmental Quality, a White House advisory group, said, 'The report is an extremely important perhaps historic statement.' He added that he expected the report to be 'very influential in government decision making.' Mr. Speth also said that the report had shown that 'the country needs to address the carbon dioxide issue squarely before going down the synfuels road.' . . . Environmentalists have warned of potentially harmful effects from the rapid development of synthetic fuels, such as the release of toxics into the air and water, the rapid consumption of scarce water resources and devastation of the land for coal and shale mining. But little attention has been paid in the past by environmentalists and policy makers to carbon dioxide, which is odorless, colorless and poses no immediate threat to human health.[68]

Nonetheless, the 1979 report, the media coverage, and our efforts at CEQ did not deter the Administration from announcing the synfuels program a few days later. Nonetheless, the central policy issue—climate protection vs. fossil fuel development—was joined in the policy arena for the first time. DOE pushed back hard against CEQ and the climate scientists' 1979 report. As part of their push back, I recall that DOE produced a graph showing U.S. fossil fuel use and CO_2 emissions growing so rapidly in future decades that the increment from synfuels development was simply dwarfed.

We were determined at CEQ to continue to press the matter of aligning energy policy with what the climate scientists were telling us was necessary to control climate change. We issued three subsequent reports to that end. Each received considerable media attention.

The first report, "The Global 2000 Report to the President," which CEQ produced over several years jointly with the State Department, was, as previously noted, released in 1980.[69] It was a

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Environmental quality: The Tenth Annual Report of the Council on Environmental Quality, Washington, D.C., 1979. Ex. E-41 at 622.

[67] Philip Shabecoff, Scientists Warn U.S. of Carbon Dioxide Peril, *The New York Times*, July 10, 1979. Ex. E-26.

[68] *Id.*

[69] A different 1980 report by the National Academy of Sciences, conveyed to President Carter in a memorandum by Frank Press, made clear that the Carter Administration understood the connection between energy policy and climate change. The 1980 report noted that, "[p]reventing or delaying the increase of carbon dioxide would have to be done mainly by restricting the use of fossil fuels, although management of land and forests could also contribute." And, "increases in energy consumption using fossil fuels will have increasingly undesirable climate effects. . . . We and the main energy-consuming countries must keep open a number of options for energy and

"base case" analysis, looking twenty years ahead at future environmental and other conditions in 2000 if societies continued business-as-usual approaches. In its summary, the "Global 2000" report concluded that, "[a]tmospheric concentrations of carbon dioxide . . . are expected to increase at rates that could alter the world's climate . . . significantly by 2050."[70] Commenting generally on climate and other global-scale threats, the "Global 2000" report observed:

> Prompt and vigorous changes in public policy around the world are needed to avoid or minimize these problems before they become unmanageable. Long lead times are required for effective action. If decisions are delayed until the problems become worse, options for effective action will be severely reduced.[71]

The several volumes of the "Global 2000" report described the climate challenge and its links to fossil fuels and made a strong plea to prepare now for needed actions.

CEQ and the State Department also collaborated on a follow-up action plan to the "Global 2000" report, called "Global Future: Time To Act." Its recommendations for government action on energy and climate were forceful:

- An interagency task force should be established to chart a realistic path for achieving the goal of getting 20 percent of our energy from renewable energy by the year 2000. A national energy conservation plan, with near- and long-term sectoral goals, should be developed as part of the integrated strategy.

- The United States should ensure that full consideration of the CO_2 problem is given in the development of energy policy. Efforts should be begun immediately to develop and examine alternative global energy futures, with special emphasis on regional analyses and the implications for CO_2 buildup. The analyses should examine the environmental, economic, and social implications of alternative energy futures that involve varying reliance on fossil fuels, and they should examine alternative mechanisms and approaches, international and domestic, for controlling CO_2 buildup. Special attention should also be devoted to determining what would be a prudent upper bound on global CO_2 concentrations.[72]

In its coverage of "Global Future: Time to Act," on January 15, 1981, *The New York Times* noted that the report "followed the 'Global 2000 Report to the President,' which was issued last

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not become committed to an extended period of unrestricted fossil-fuel use." Frank Press, Memorandum to the President, Carbon Dioxide Increases, May 5, 1980. Ex. E-42 at 6, 8.

[70] Council on Environmental Quality and Department of State, The Global 2000 Report to the President: Entering the Twenty-First Century, Government Printing Office, 3 (1980). Ex. E-43 at 3.

[71] *Id.* at 5.

[72] Council on Environmental Quality and Department of State, Global Future: Time To Act, Government Printing Office, January 1981. Ex. E-44 at 63, 138.

summer and warned that, without action to reverse them, current trends would lead 'to a more crowded, more polluted, less stable world' by the beginning of the next century."[73]

Our third, and most extensive, effort at CEQ to force a successful integration of energy and climate policy was not completed until around the time that President Carter unexpectedly lost the 1980 election. In, "Global Energy Futures and the Carbon Dioxide Problem," we presented rigorously developed computer models of alternative energy futures and the climate risks associated with them. Based on this analysis, our recommendations to the federal government echoed the "Global 2000" report and were as follows:

- Assign a high priority to incorporating the CO_2 issue into U.S. energy policy planning
- Increase reliance on energy conservation and renewable sources of energy
- Undertake new and expanded cooperative international efforts to address CO_2 issues.[74]

I summarized these conclusions in my foreword to the "Global Energy Futures and the Carbon Dioxide Problem" report:

> The CO_2 problem should be taken seriously in new ways: it should become a factor in making energy policy and not simply be the subject of scientific investigation. Every effort should be made to ensure that nations are not compelled to choose between the risks of energy shortages and the risks of CO_2. This goal requires making a priority commitment here and abroad to energy efficiency and to renewable energy resources; it also requires avoiding a commitment to fossil fuels that would preclude holding CO_2 to tolerable levels.[75]

Though the "Global Energy Futures and the Carbon Dioxide Problem" report was issued by a lame duck White House, it was widely distributed in Washington and elsewhere and garnered considerable media attention. I was quoted commenting on the report as follows in an article in *The New York Times* about the report:

> Gus Speth, chairman of the council, conceded that there was still some scientific uncertainty about the timing and effects of the carbon dioxide buildup in the atmosphere. But Mr. Speth said that, given the magnitude of the risks and the fact that industrial countries were now formulating long-range energy plans, the carbon dioxide buildup must be considered in energy policy decisions. He said it

[73] Philip Shabecoff, "U.S. Calls for Efforts To Combat Global Environmental Problems," *The New York Times*, January 15, 1981. Ex. E-45.
[74] Council on Environmental Quality, Global Energy Futures and the Carbon Dioxide Problem, Government Printing Office, January 1981. Ex. E-46 at 65-73.
[75] *Id.* at vi.

> would be too late to change course once the impact of the buildup began to be felt.[76]

The CEQ report recommended that a safe maximum level (or cap) for carbon dioxide in the atmosphere be established. In the late 1970s, it was thought that the CO_2 cap could be 50% higher than preindustrial levels, which would be approximately 420 ppm. Today, climate scientists say that level is too high and that we have already exceeded safe bounds. The CEQ report addressed favorably a scenario that capped the buildup of CO_2 in the atmosphere at 50 percent above the pre-industrial level. On this matter, *The New York Times* article said as follows:

> The level of carbon dioxide is currently estimated at 15 to 25 percent above pre-industrial levels existing around the year 1800. One recommendation of the report is that agreement be reached by industrialized nations on a safe maximum level for carbon dioxide in the air. It suggested a level 50 percent higher than that of pre-industrial times as an upper limit.

The CO_2 pre-industrial concentration is generally taken to be 280 ppm. A 50 percent increase would be 420 ppm. In February 2018, the atmosphere's CO_2 concentration reached 408 ppm, and atmospheric CO_2 will likely reach 420 ppm, the 50 percent increase mark, in about five years. Many, perhaps most, climate scientists now believe a 50 percent increase is too risky and would want the CO_2 buildup to stay below 25 percent. But it is noteworthy that the CEQ analysts were able to suggest an upper bound that was off only by a factor of two almost four decades ago.

President Carter was, I believe, prepared to tackle the climate issue in some meaningful way had he been re-elected. But that was not to be. I think he would have asked his agencies for their ideas and plans on how to reduce U.S. CO_2 emissions and would have led the U.S. on a very different path. It was not to be.

C. Despite the Emergence of Climate Concern and the Pursuit of Alternative Policies to Fossil Fuels, Fossil Fuel Use and its Expansion Were Consistently Promoted in Many Ways During the Carter Years

In parallel with its strong actions on energy conservation and its first-of-a-kind initiatives on renewables, and despite repeated warnings about the climate risks of fossil fuels, the Carter Administration vigorously supported not only continued, deep U.S. reliance on fossil fuels but also a much larger reliance on coal in particular.

Coal use in the United States did indeed grow dramatically during and immediately after the Carter Administration, while oil imports declined equally dramatically for a variety of reasons.

When Carter came into office in 1977, the country was still experiencing "gas lines" shock and stinging from its international oil vulnerability. In the decade before 1977, U.S. oil imports had

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[76] Philip Shabecoff, U.S. Study Warns of Extensive Problems from Carbon Dioxide Pollution, *The New York Times*, January 14, 1981. Ex. E-47.

increased an astounding six-fold, and the OPEC oil embargo of 1973-74 had deeply shaken American consumers and their politicians alike. The oil embargo gave rise to a major push to reduce oil imports by promoting "fuel switching" – shifting electricity generation from oil and natural gas to coal – and, some hoped, by using "synthetic" liquid fuels based on coal, tar sands, and oil shale. These heavier hydrocarbons produce more CO_2 per Btu when burned and are thus more harmful to climate. The key policy initiative in Carter's National Energy Program, a program put forth early in his first year in office, was, as the April 20, 1977 Fact Sheet said: "We must reduce our vulnerability to potentially devastating embargoes. We can protect ourselves from uncertain supplies by reducing our demand for oil, making the most of our abundant resources such as coal, and developing a strategic petroleum reserve."[77] The Administration and the Congress pursued this objective with many policy initiatives, central to which was "fuel switching"—the shift in electrical power generation from oil and natural gas to coal. Fuel switching was among the policies strongly encouraged in the 1978 National Energy Act.

In addition to expanding coal leasing on federal lands, the Carter Administration also joined with the Congress in promoting oil leases on the outer continental shelf. In signing the then Outer Continental Shelf Lands Act Amendments of 1978, Carter said, "this legislation will provide the needed framework for moving forward once again with a balanced and well-coordinated leasing program to assure that OCS energy resources contribute even more to our Nation's domestic energy supplies."[78]

At the end of his Administration, Carter gathered information from throughout the federal government on what had been accomplished over the four years past. I recall working with CEQ staff to prepare our Memorandum to the President responding to this White House request. The result was Carter's January 16, 1981, State of the Union Annual Message to the Congress. It was an amazingly comprehensive 80-page document delivered to the Congress only in writing. In summarizing the Administration's accomplishments, the first one listed by the President was: "almost all of our comprehensive energy program have been enacted, and the Department of Energy has been established to administer the program."[79] Here, regarding legislative enactments, Carter was referring mainly to the National Energy Act of 1978 and the National Energy Security Act of 1980.

President Carter offered an overall summary of U.S. energy policy that illustrates the power and control of the federal government over the national energy system, and the push for fossil fuel development notwithstanding the dire warning on climate change from ongoing fossil dependence.

> Since I took office, my highest legislative priorities have involved the reorientation and redirection of U.S. energy activities and, for the first time, to

[77] Jimmy Carter, National Energy Program Fact Sheet on the President's Program, April 20, 1977. Ex. E-34.
[78] President Jimmy Carter, Outer Continental Shelf Lands Act Amendments of 1978 Statement on Signing S.9 Into Law, September 18, 1978. Ex. E-48.
[79] President Jimmy Carter, The State of the Union Annual Message to the Congress, January 16, 1981. Ex. E-49.

> establish a coordinated national energy policy. The struggle to achieve that policy has been long and difficult, but the accomplishments of the past four years make clear that our country is finally serious about the problems caused by our overdependence on foreign oil. Our progress should not be lost. We must rely on and encourage multiple forms of energy production—coal, crude oil, natural gas, solar, nuclear, synthetics—and energy conservation. The framework put in place over the last four years will enable us to do this.[80]

He then listed a number of specific accomplishments that underscore the commitment to fossil fuels both by the Administration and by the Congress:

- Under my program of phased decontrol, domestic, crude oil price controls will end September 20, 1981. As a result exploratory drilling activities have reached an all-time high.
- Prices for new natural gas are being decontrolled under the Natural Gas Policy Act—and natural gas production is now at an all time high; the supply shortages of several years ago have been eliminated.
- The Synthetic Fuels Corporation has been established to help private companies build the facilities to produce energy from synthetic fuels.
- Coal production and consumption incentives have been increased, and coal production is now at its highest level in history.
- In 1979 the Interior Department held six OCS (outer continental shelf) lease sales, the greatest number ever.
- The first general competitive federal coal lease sale in ten years will be held this month.[81]

The United States was about 90 percent dependent on fossil energy at the beginning of the Carter Administration and close to 90 percent at the end; there was only a slight decline in fossil dependency of 2-3 percent. Meanwhile, the fossil fuel mix was shifting toward coal and away from oil imports. Total U.S. energy use had declined slightly, and GDP had grown about 10 percent in real terms, so the overall energy efficiency of the economy had improved. A slow shift to renewables had started. It can be said that the energy policy of the Carter years was for the first time truly "all of the above" – and that included fossil fuels as the vast majority of our energy supply.

D. Reflections

It is clear looking back that, notwithstanding the unsupported climate denialism that has pervaded American politics off and on since the Carter years, and especially now, it is impressive how much was understood about climate change and the role of fossil fuels in causing it by the late 1970s, four decades ago. Enough was known, for example, to suggest a prudent upper bound for the buildup in the atmosphere of the principal greenhouse gas, CO_2, a limit that many reasonable people would fall on their knees to achieve today. For President

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[80] *Id.*
[81] *Id.*

Carter, as he said repeatedly, and for many of us inside the federal government, the path ahead was clear for our climate system and our nation's security and independence: energy efficiency, conservation, and renewables.

On Ronald Reagan's Inauguration Day, John Oakes, a member of *The New York Times*' editorial board, penned a warning for the incoming president in an article entitled "For Reagan, a Ticking Ecological 'Time Bomb.'" *The New York Times* piece accurately reflected the pivotal moment for our nation's energy and climate systems and the need to act swiftly to address the looming crisis. In it Oakes wrote:[82]

> The rapid environmental degradation of this planet is a time bomb, as great a threat to both our national and our global survival as is the threat of nuclear annihilation. . . . The environmental crisis alluded to by Mr. Carter and described by a recent Government report, 'Global 2000,' is different in quality and degree from anything that has gone before in the history of the human race.[83]

Oakes went on to stress the climate threat: "the mad rush from oil to coal means more poisoned lakes from coal-produced acid rain, fouler air, and a prospective rise in world temperature (from accumulated carbon dioxide) that could dangerously raise the level of the seas." He pointed out that these threats "cannot be long ignored by the Reagan Administration." Oakes said this about solutions:

> What can we do about all this? In a sequel to 'Global 2000,' called 'Global Future: A Time To Act,' a Government task force headed by Gus Speth, chairman of the Council on Environmental Quality, has just proposed a string of recommendations to halt the slide into the environmental disaster that is sure to come if the new President and the new Congress fail to give it their urgent attention. This is a crucial issue—today. Like human life itself, once ecological systems are destroyed, they can never be recovered.[84]

Sadly, we know now that the Reagan Administration and the Congress did indeed fail to give these issues their urgent attention.

E. Every Subsequent Administration Knowingly Continued Down the Fossil Fuel Energy Road, Further Endangering the Climate System.

For the remainder of this expert report, I will describe how the federal government, under each Presidential Administration: (a) was made aware of the best and most current climate science; (b) had access to but largely ignored alternative policy pathways towards renewable energy development and energy efficiency; and (c) proceeded to pursue policies and take actions at the

[82] John B. Oakes, "For Reagan, a Ticking Ecological 'Time Bomb,'" *The New York Times*, January 20, 1981. Ex. E-50.
[83] *Id.*
[84] *Id.*

federal level that promoted the development and combustion of fossil fuels, thereby increasing carbon dioxide emissions and exacerbating the global warming crisis.

In 1976, the year President Carter was elected, the United States relied on fossil fuels for 91 percent of primary energy consumption. During the past 40 years, the seeds planted during the Carter Administration regarding efficiency and renewables could have yielded a smooth transition toward an outstanding U.S. climate performance and global leadership in climate action, which would have changed the trajectory of the atmospheric CO_2 levels. Instead, those decades saw only negligible actual action to reduce U.S. emissions, leaving fossil fuels at 81 percent of primary energy consumption today and total fossil fuel consumption is 8 percent higher than it was 40 years ago.[85]

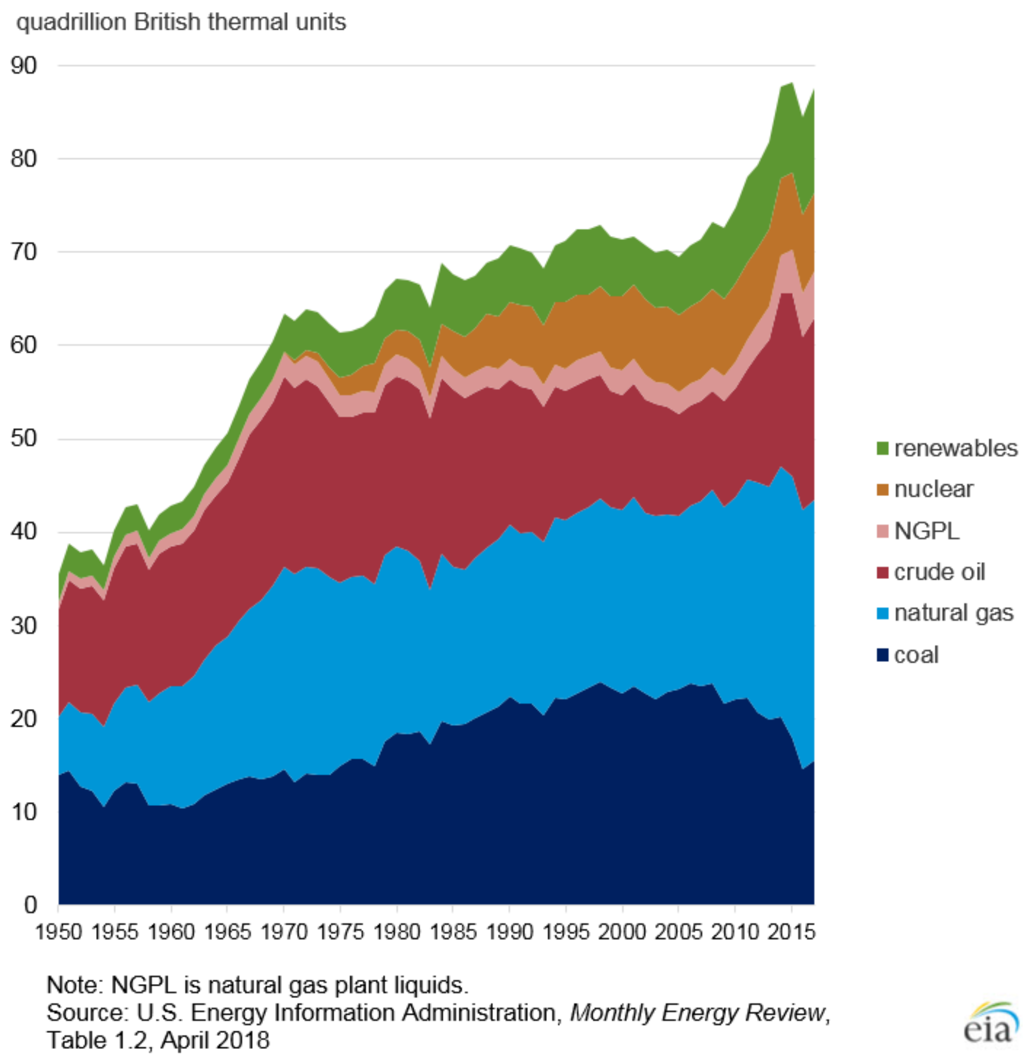

Figure 6: U.S. Primary Energy Production by Major Sources, 1950-2017.[86]

[85] U.S. EIA, Monthly Energy Review: May 2018, 2018. Ex. E-36 at Table 1.3.
[86] EIA, U.S. Energy Facts Explained, available at https://www.eia.gov/energyexplained/?page=us_energy_home. Ex. E-51.

This national energy policy of the last four decades is, in my view, the greatest dereliction of civic responsibility in the history of the Republic. And it is worse today than ever.

Though I did not serve in subsequent Administrations as I had under President Carter, through my work at the World Resources Institute, at the United Nations Development Programme, and as Dean of the Yale School of Forestry and Environmental Studies, I have closely followed the federal government's positions and policies on global warming, climate change, and energy. What follows is my expert evaluation on what each Administration knew about the science of global warming and their respective policy responses.

As the field of climate science and policy has evolved, the number of reports and testimonies provided to and by the federal government has grown exponentially. These reports have been produced, and testimonies have been delivered, by scientists and others representing the federal government, research institutions, academia, and even private companies. There have been so many studies and reports over the past four decades that I couldn't possibly reference or discuss them all in this expert report. However, over the past four decades since leaving the Carter Administration, I have kept apprised of and read hundreds of climate related reports. I have also closely followed the escalating policy-related deliberations and actions on energy and climate. Accordingly, herein I reference some of the most important documents, testimonies, and events that illustrate how much the federal government truly did understand the risks of global warming. Similarly, my evaluation of policies and policy proposals will focus on what seem to me the most illustrative, representative, and impactful since President Reagan was inaugurated.

III. The Reagan Administration, 1981-1989, Disregarded Climate Science and Committed the U.S. to a Fossil Fuel Future Where Perceived Economic Factors Trumped Urgently Needed Energy and Climate Policy.

During the period of the Reagan administration, the field of climate science continued to mature and reveal ever-more confidence about the reality of potential impacts. Despite the dire warnings of scientists, warnings which were presented to and even promoted by the federal government, the federal policies enacted during Reagan's eight years in office pivoted away from any real pursuit of renewable energy resources or efficiency programs and redoubled the U.S. commitment to unrestrained fossil fuel development.

The commonly observed symbol of that pivot was when the Reagan Administration removed from the White House roof the solar collectors put there by President Carter. *Scientific American* described the Reagan pivot in a nutshell:

> By 1986, the Reagan administration had gutted the research and development budgets for renewable energy at the then-fledgling U.S. Department of Energy (DoE) and eliminated tax breaks for the deployment of wind turbines and solar technologies—recommitting the nation to reliance on cheap but polluting fossil fuels, often from foreign suppliers. . . . And in 1986 the Reagan administration

quietly dismantled the White House solar panel installation while resurfacing the roof.[87]

A. Government Knowledge

During the Reagan administration, the Executive Branch and Congress were both clearly aware of the link between fossil fuel combustion and the enhanced greenhouse effect, as well as the potential for catastrophic economic and human impacts of the resulting global warming and climate change. Between 1981-1988, research by governmental and non-governmental scientists built upon and reaffirmed the early warnings issued by scientists in the 1970s. During these years, there was groundbreaking testimony before Congress by Dr. James Hansen and others, and their dire warnings about potential climate impacts were heard by the federal government and the American public. Meanwhile, President Reagan's own agencies produced a number of reports about global warming and developed strategic climate research plans, all while their budgets were slashed and resources drained.

1. Research and Reports on Climate Impacts

In June 1981, less than six months after President Reagan took office, the DOE convened a Workshop on First Detection of Carbon Dioxide Effects through its Carbon Dioxide Effects Research and Assessment Program.[88] The preeminent climatologists and meteorologists that attended and presented were described in the DOE's report on the workshop as "the best available scientists."[89] The purpose of the workshop was "to develop a research strategy that would provide the basis for early identification of the expected CO_2-induced response so that model projections of a warmer climate and of impacts on the biosphere can either be confirmed, rejected, or modified."[90] In its report on the workshop, the DOE noted the history of climate science awareness in the federal government, citing the 1965 Report of the Environmental Pollution Panel of the President's Science Advisory Committee (PSAC), and the 1977 report Energy and Climate by the National Research Council that refined estimates of expected global temperature increases. The DOE was attempting to ensure that scientists and the government were prepared to identify the physical evidence of global warming as early as possible, "with the recognition that atmospheric CO_2 concentrations are increasing and that the consequent warming may have significant potential impacts on other climate elements and on important aspects of society, including the continued expansion of fossil fuel combustion." It is clear that President Reagan's DOE recognized the best available climate science projections at the time and considered the detection of impacts to be a priority supported by the federal government.

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[87] David Biello, "Where Did the White House Solar Panels Go?" *Scientific American*, August 6, 2010.
[88] Proceedings of the Workshop on First Detection of Carbon Dioxide Effects, Harpers Ferry, West Virginia, June 8-10, 1981, prepared by the Institute for Energy Analysis, Oak Ridge Associated Universities, Washington, D.C., 1982. Ex. E-52.
[89] *Id*. at vii.
[90] *Id.* at 3.

A year later, the DOE's Carbon Dioxide Effects Research and Assessment Program acknowledged the catastrophic risk of sea level rise while examining the extensive research on the potential collapse of the West Antarctic Ice Sheet. The DOE's 1982 report stated:

> The serious consequences of the ~ 6 [meter] sea level rise that would occur in the event of a major shrinkage of the West Antarctic ice sheet would include flooding of all existing port facilities and other low-lying coastal structures, most of the world's beaches, extensive sections of the heavily farmed and densely populated river deltas of the world, and large areas of many of the major cities of the world, which are concentrated along coast lines.[91]

At the time, the DOE was the main federal agency researching CO_2, through the Assessment Program described above and DOE's Carbon Dioxide Research Division. For the first two years of the Reagan administration, DOE was producing and coordinating critical research on CO_2 emissions and potential climate impacts. However, in 1982, President Reagan cut the budgets of many of DOE's research offices, ignoring the recommendation of DOE's own Energy Research Advisory Board, which had recommended increasing funding for CO_2 research.[92]

In addition to the DOE, other agencies and councils linked to the federal government were conducting important research on CO_2 and climate change. For example, in 1982 the National Research Council issued a comprehensive report, affirming the government's the longstanding knowledge of global warming, discussing the success of climate modeling, and explaining the role that the oceans play in absorbing most of the heat trapped by the excess CO_2 in the atmosphere.[93] The very first sentence of the report noted: "For *over a century*, concern has been expressed that increases in atmospheric carbon dioxide (CO_2) concentration could affect global climate by changing the heat balance of the atmosphere and Earth."[94] The report also stated:

> [D]espite the admitted existence of numerous uncertainties, the consensus on the nature and magnitude of the problem has remained remarkably constant throughout this long worldwide process of study and deliberation. Burning of fossil fuels releases to the atmosphere carbon that was extracted by ancient plants many millions of years ago. . . . Although questions have been raised about the magnitude of climatic effects, no one denies that changes in atmospheric CO_2 concentration have the potential to influence the heat balance of the Earth and atmosphere. Finally, although possibly beneficial effects on biological photosynthetic productivity have been recognized, no one denies that an altered

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[91] U.S. Department of Energy, Carbon Dioxide Effects Research and Assessment Program, Societal Consequences of a Possible CO_2-Induced Climate Change: Response of the West Antarctic Ice Sheet to CO_2-Induced Climatic Warming, Vol. 11, Part I, Apr. 1982. Ex. E-53 at 1.

[92] David Narum, A troublesome legacy: The Reagan Administration's conservation and renewable energy policy, Energy Policy, Volume 20, Issue 1, 1992, pages 40-53, http://www.sciencedirect.com/science/article/pii/030142159290146S.

[93] National Research Council, Carbon Dioxide and Climate: A Second Assessment, 1982. Ex. E-54.

[94] *Id.* at 1 (emphasis added).

> climate would to some extent influence how humanity secures its continuing welfare.[95]

In 1983, President Reagan's EPA issued two seminal reports. In the first, Can We Delay a Greenhouse Warming?, EPA projected an increase in temperatures of 2°C by 2040, a temperature increase that, in EPA's assessment, was guaranteed to produce substantial climatic consequences, including disastrous flooding.[96] The Report found that fossil fuels were responsible for most of the growth in the atmospheric concentration of CO_2 and thus stated that eliminating coal combustion by 2000 and banning shale oil as the best policy options for delaying a 2°C temperature increase. EPA made clear that the risks are high with a "wait and see" policy.[97] Importantly, the report did not endorse a 2°C warming target. On the contrary, it stated: "A 2 degrees C temperature rise was selected because it represents a global warming significantly beyond the historical change for any 120 year period, and one guaranteed to produce substantial climatic consequences."[98]

The second EPA report, Projecting Future Sea Level Rise: Methodology, Estimates to the Year 2100, and Research Needs, predicted 7 feet of sea level rise by 2100, but said 11 feet could not be ruled out.[99] It found that CO_2 emissions were primarily caused by the combustion of oil, gas, and coal and that those emissions were consistently increasing.[100] EPA found that "[f]uture energy use and fuel selection will thus be the primary determinants of the rate of CO_2 emissions."[101] EPA also rejected a "wait and see" approach and found that "forthcoming decisions cannot be postponed the several decades" that a transition away from fossil fuels would require.[102]

In 1984, William Ruckelshaus, then-EPA Administrator made a powerful speech in Paris at the Organization for Economic Cooperation and Development. He acknowledged that the combustion of fossil fuels "has the potential for creating major climate changes," and that the failure to make a long-term commitment to address climate change and other environmental threat would lead to "a succession of unexpected and shattering crises."[103] In another 1984 speech, Ruckelshaus referred to "the need to preserve our life support systems," and said

> I don't think our liberties are threatened in the next 90 days, but if we fail to improve our record in the realm of risk management, both within our societies and

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[95] *Id.* at 14.
[96] U.S. Environmental Protection Agency, Can We Delay A Greenhouse Warming? Sept. 1983. Ex E-55 at 1-16 to 1-17.
[97] *Id.* at i, 1-2, 2-8.
[98] *Id.* at 1-16 to 1-17.
[99] U.S. Environmental Protection Agency, Projecting Future Sea Level Rise: Methodology, Estimates to the Year 2100, and Research Needs, Oct. 1983. Ex. E-56 at vi.
[100] *Id.* at 8.
[101] *Id.*
[102] *Id.* at 51.
[103] William D. Ruckelshaus, Remarks at Organization for Economic Cooperation and Development, June 21, 1984. Ex. E-57 at 6-7.

> in the world as a whole, we will at least waste precious time and resources and at worst threaten all we hold dear.[104]

While the DOE's CO_2 research was hampered by President Reagan's budget cuts, its research did still continue. In 1985, two scientists at DOE's Lawrence Livermore National Laboratory edited and published a major five-volume series for the Carbon Dioxide Research Division on the current state of carbon dioxide research. This series included volumes on "Projecting the Climatic Effects of Increasing Carbon Dioxide" and "Detecting the Climatic Effects of Increasing Carbon Dioxide," and was described by the editors as "an accounting" of what had been learned over the past eight years since the 1977 workshop described above (in Section II, a, 1). One of the volumes, "Atmospheric CO_2 and Global Carbon Cycle," noted that CO_2 levels had varied in the last million years with a *high* point, during warm, interglacial phases, of 350 ppm.[105] An enormous amount had been learned; the first volume alone was over 400 pages long, and is full of hard evidence of how much the federal government knew about the impacts of burning fossil fuels. For instance, in the preface of "Projecting the Climatic Effects of Increasing Carbon Dioxide," Michael R. Riches, Program Manager for the Carbon Dioxide Research Division at DOE, wrote:

> There is little doubt that the increasing concentration of atmospheric carbon dioxide (CO_2) has the potential to modify the Earth's climate. Increased global surface temperatures, altered precipitation patterns, and changes in other climatic variables could have substantial economic and social consequences. . . . Virtually all studies suggest that the increasing CO_2 concentration will significantly increase the global average temperature.[106]

Later in the volume, T. Webb III and T.M.L. Wigley, in their article, "What Past Climates Can Indicate About a Warmer World," wrote:

> The most significant effects of increased atmospheric CO_2 on climate will be manifest in regional changes of moisture and temperature patterns. . . . Changes in pressure patterns, both geographical and seasonal, will in turn affect rainfall, temperatures, and winds: all the meteorological variables that contribute to the overall climate at a given place.[107]

In the volume summary, Michael C. McCracken and Frederick M. Luther offer some dramatic conclusions:

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[104] William D. Ruckelshaus, The Role of the Private Sector in Environmental Action, November, 14, 1984. Ex. E-58 at 4, 24.
[105] U.S. Department of Energy, Atmospheric Carbon Dioxide and the Global Carbon Cycle, Dec. 1985. Ex. E-59 at xvi. The other volumes were "Characterization of Information Requirements for Studies of CO_2 Effects: Water Resources, Agriculture, Fisheries, Forests and Human Health" and "Direct Effects of Increasing CO_2 on Vegetation."
[106] Michael C. MacCracken and Frederick M. Luther, eds., Projecting the Climatic Effects of Increasing Carbon Dioxide, Dec. 1985. Ex. E-60 at ix.
[107] *Id*. at 241.

> As the climate warms, the amount of sea ice and the extent of snow cover will generally be reduced. . . . Feedbacks and interactions of many other types can also occur among elements of the climate system. . . . These model results suggest that global average temperatures will warm by 1.5 to 4.5°C once equilibrium is achieved after the CO_2 concentration has doubled. Continuing increases in the CO_2 concentration above those levels would warm the Earth still further. Such changes would be large in comparison to the decadal average temperature changes of the last 10,000 years, during which prolonged, global-scale variations have probably only rarely been more than about 1°C. . . . In summary, we have a sound qualitative understanding of the causes of the warming that is occurring and is projected to occur as a result of the increasing CO_2 and trace gas concentrations.[108]

In 1986, the National Oceanic and Atmospheric Administration published a report for the White House's Domestic Policy Council, the opening sentence of which read: "We have become involved in a global climate experiment in which human activities . . . act as agents of inadvertent global change. . . . Recent and continuing increases in atmospheric carbon dioxide (CO_2) due to burning of fossil fuels can be thought of as a global climate experiment."[109] The report added, "We are reaching a technological threshold from which progress in understanding can be proportional to the investment of our effort. This conclusion, combined with the need to formulate policy regarding current climate modification activities, deserves the attention of scientific and *governmental leaders who must determine and muster the needed resources*."[110]

It was also in 1986 that eight senators sent a letter to Lee Thomas, administrator of the EPA, asking the EPA to conduct two studies on climate change.[111] The first study would examine the health and environmental impacts of climate change. The second study "should include an examination of the policy options that, if implemented, would *stabilize current levels of atmospheric greenhouse gas emissions*. This study should address the need for and implications of significant changes in energy policy, including energy efficiency and development of alternatives to fossil fuels."[112]

In a separate letter, also in 1986, a group of Senators asked the Office of Technology Assessment to come up with policy options that would stabilize and minimize GHGs in the atmosphere adding that they were "deeply troubled by the prospect of such a rapid and unprecedented change in the composition of the atmosphere and its implications for the human and natural worlds."[113]

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[108] *Id*. at 271-272.
[109] NOAA, Global Climate, A Variable and Vulnerable Natural Resource, Oct. 1, 1986. Ex. E-61 at 1.
[110] *Id.* at 36.
[111] Senators George J. Mitchell at el., Letter to Lee Thomas, Sept. 12, 1986. Ex. E-62.
[112] *Id.* at 2.
[113] Letter from Sens. Stafford et al. to John Gibbons, Executive Director of U.S. Congress Office of Technology Assessment, December 23, 1986. Ex. 292 at 1.

It is noteworthy that the atmospheric concentration of CO_2 at the time these senators were asking the EPA and OTA to come up with concrete policy option to stabilize CO_2 at current levels was 347 ppm, just below the level where observations indicate that such significant impacts as loss of mass from ice sheets started accelerating. All three reports (two by EPA and one by OTA) were eventually prepared and submitted to Congress during the George H.W. Bush presidency (see Section IV below discussing the reports).

DOE, EPA, NOAA, and other agencies had delivered an exhaustive, comprehensive accounting of the contemporary understanding of climate science during President Reagan's time in office. They had also explained that CO_2 wasn't the only greenhouse gas, but that other trace gas concentrations could contribute to the greenhouse effect and create a unified Greenhouse Gas Index.[114] DOE's Carbon Dioxide Research Division would add to this body of knowledge, officially publishing a new Master Index in 1987 that again included dire warnings about the constantly-updated state of climate science. The reports were conclusive that humans caused climate change and temperature increases would be beyond anything seen in recent geological times.[115]

2. Groundbreaking Congressional Testimony by Dr. James Hansen and Others

Congress had heard from climate scientists before 1982, but earlier testimonies had largely covered what researchers knew about levels of carbon dioxide and predictions of future impacts. However, during a landmark hearing before the House Committee on Science and Technology on March 25, 1982, Dr. James Hansen and Dr. George Kukla first presented Congress with evidence of impacts. Hansen and Kukla had recently correlated increased CO_2 levels in the atmosphere with the shrinking of Antarctic ice and increases in worldwide sea levels. Thus, in spring of 1982, Congress was alerted of precise and observable physical impacts of global warming resulting largely from the combustion of fossil fuels.

These observable impacts made modeling more accurate, and Hansen offered this projection related to sea level rise:

> I would like to note that a smaller but still significant sea level rise is likely to occur in the coming decades even without collapse of the West Antarctic ice sheet. Just the thermal expansion of ocean water and the slow ice sheet melting, that we have evidence to be occurring, will probably raise sea level between 1 and 2 feet in the next 70 years, if the climate sensitivity is approximately of the magnitude estimated by the National Academy of Sciences committee chaired by Charney.

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[114] U.S. Environmental Protection Agency, Climate Change Indicators: Climate Forcing. Ex. E-63.

[115] U.S. Department of Energy, Office of Energy Research, Office of Basic Energy Sciences, Carbon Dioxide Research Division, Master Index for the Carbon Dioxide Research State-of-the-Art Report Series, March 1987. Ex. E-64 at 1, 13.

> A sea level rise of 1 to 2 feet is sufficient to cause large-scale beach erosion, intrusion of salt water into low-lying freshwater regions, and a large increase of damaging storm surges in coastal areas.[116]

Later in the hearing, Dr. Hansen warned, "Mr. Chairman, it is becoming increasingly clear that we should anticipate substantial climate change during the next several decades as a result of man's impact on the composition of the atmosphere."[117]

We know that the White House was aware of the testimonies at the hearings. A DOE report on the hearings and copies of testimonies were found in the Reagan Library files of Danny Boggs, who was a special assistant to the President at the time. Boggs' report on the hearing stated on the first page:

> The first witness, Professor Calvin, said that recent new evidence is giving us early warning signals that the greenhouse effect is, in fact, taking place, and we must not wait too long to act or it will be too late. The best way to avoid the problem is NOT put CO_2 in the air.[118]

In June 1986, Dr. Hansen testified again before Congress, along with other climate scientists. Senator John Chafee asked three scientists the question: "Do any of you believe that we need more scientific data before we could reach the conclusion that what is taking place now, if continued, will increase the temperature on the globe?" Dr. Hansen responded, "I don't think we need more evidence to say that." Dr. Rowland responded, "The fact that the greenhouse effect is working on the Earth, it seems to me, is perfectly straightforward." Dr. Watson responded, "No; I believe global warming is inevitable."[119] In his written statement, Dr. Hansen also stated, "Evidence confirming the essence of the greenhouse theory is already overwhelming from a scientific point of view."[120]

Two years later, in the summer of 1988, Congress would again hear from Dr. James Hansen during the Senate Committee on Energy and Natural Resource's First Session on the Greenhouse Effect and Global Climate Change. Dr. Hansen testified about the startling discoveries that had been made since his groundbreaking 1982 testimony.

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[116] U.S. House of Representatives, Hearing before the Subcommittee on Natural Resources, Agricultural Resources and Environment and the Subcommittee on Investigations and Oversight of the Committee on Science and Technology, Carbon Dioxide and Climate: The Greenhouse Effect, 97th Cong. 2-45, Mar. 25, 1982. Ex. E-65 at 39.
[117] *Id.* at 48.
[118] Dotty Curles, Department of Energy Action Officer, Report on Hearing, Joint Hearing on Carbon Dioxide and the Greenhouse Effect, Mar. 25, 1982. Ex. E-66 at 70 (emphasis in original).
[119] U.S. Senate, Hearing before the Subcommittee on Environmental Pollution of the Committee on Environment and Public Works, Ozone Depletion, the Greenhouse Effect, and Climate Change, June 10 and 11, 1986. Ex. E-67 at 22.
[120] *Id.* at 97.

> I would like to draw three main conclusions. Number one, the earth is warmer in 1988 than at any time in the history of instrumental measurements. Number two, the global warming is now large enough that we can ascribe with a high degree of confidence a cause and effect relationship to the greenhouse affect. And number three, our computer climate simulations indicate that the greenhouse effect is already large enough to begin to effect the probability of extreme events such as summer heat waves.[121]

In addition to Dr. Hansen's testimony, the hearing included discussion of specific potential impacts, particularly droughts in western states and sea level rise in coastal regions. It also included specific recommendations to Congress to promptly reduce fossil fuel use. According to Dr. Woodwell, then-Director of Woods Hole Research Center:

> What has to be done? There isn't any question . . . . We must reduce the use of fossil fuels on a global basis, a reduction of the order of 50 to 60 percent is probably appropriate, and the sooner the better. It is also true that cessation of deforestation on a global basis is completely appropriate to solve the climatic change problem and for many other reasons. . . . I'm not at all doubtful that such an objective is realistic. If we could establish that as a signal step in the process of reducing reliance on fossil fuel globally, I would think that we would have done one of the strongest and wisest things possible.[122]

As one might imagine, Hansen's 1988 testimony created waves in the media and elsewhere. *The New York Times* story was page one news: "Global Warming Has Begun, Expert Tells Senate."[123]

In September 1988, Donna Fitzpatrick, Undersecretary of DOE, testified before Congress that:

> Evidence available from research to date from the Department's activities, from that of many other agencies and from other nations is sufficient cause for serious concern, even at the most optimistic end of the range of predicted results. This is of particular interest to the Department of Energy because U.S. fossil fuel use accounts for approximately 23 percent of the global total emissions of CO_2 resulting from combustion.
>
> The prospects for future growth in the use of renewable technology appear especially promising as research continues to improve their efficiency, economics, and reliability. Renewable energy use can reduce carbon emissions

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[121] U.S. Senate, Committee on Energy and Natural Resources, First Session on the Greenhouse Effect and Global Climate Change, June 23, 1988. Ex. E-68 at 39.
[122] *Id.* at 93-94.
[123] Philip Shabecoff, "Global Warming Has Begun, Expert Tells Senate," *The New York Times*, June 24, 1988, at 1. Ex. E-69.

> and give developing countries attractive alternatives to the use of fossil fuels and further depletion of forests.[124]

At the same September 1988 hearing, Office of Technology Assessment Director, John Gibbons, discussed the urgency of developing policy responses to climate change. He stated:

> In global climate . . . . the time constant is long – requiring decades to cause effects and almost indefinitely long for effects to reverse. And that's why it seems to me it may be foolhardy to procrastinate and apply Disney's law to the issue. That is, Disney's law says that wishing will make it so. I don't think we have a basis for wishing that this problem will fix itself. Therefore, what do we do? Well, one option is to cut back on our emissions. Another is to slow down the emissions and buy some time to understand things better. The third would be to offset the effects.[125]

3. The Reagan White House Council on Environmental Quality Warned of CO_2 Risks, Then Goes Silent on Global Warming

In 1982, my successor at CEQ, Alan Hill, filed CEQ's 12th Annual Report to the Congress (for 1981), detailing the current state of the environment and spelling out the President's recommendations for dealing with environmental issues. The CEQ Report recognized the recent research, acknowledging that anthropogenic warming had been detected by NASA studies and that mean global temperature could increase "between 2.5 and 4.5 degrees Celsius by the end of the 21st century."[126]

However, the White House's recognition of climate science was short-lived, and the same report described President Reagan's plan to increase production of domestic fossil fuel resources. The next year, CEQ's Annual Report for 1982 omitted any discussion of CO_2 and climate change, focusing almost exclusively on a blueprint for increased fossil fuel development. The 1983 CEQ Annual Report did not reference climate change, and the 1984 report only included a chart recognizing the increase in CO_2 emissions since 1958.[127]

In 1986, President Reagan received a letter from Senator Al Gore discussing the current climate change science and warning that, "[o]ne of the most serious and long-term environmental

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[124] U.S. House of Representatives, Hearings before the Subcommittee on Energy and Power of the Committee on Energy and Commerce, Energy Policy Implications of Global Warming, Sept. 22, 1988. Ex. E-70 at 85, 100.
[125] *Id.* at 192.
[126] Council on Environmental Quality, 12th Annual Report of the Council on Environmental Quality, 1982. Ex. E-71 at 191.
[127] Council on Environmental Quality, Environmental Quality 1983, 14th Annual Report of the Council on Environmental Quality. Ex. E-72; Council on Environmental Quality, Environmental Quality 1984, 15th Annual Report of the Council on Environmental Quality. Ex. E-290 at 714.

problem facing the United States and the world is the greenhouse effect."[128] The Assistant to the President responded to Senator Gore, "[y]our concern over the seriousness of this problem is being conveyed to the President . . ." and "we will be pleased to review the option which you suggested to coordinate efforts to deal with this phenomenon."[129] Nevertheless, as discussed in the following section, the actions of President Reagan's administration indicate that inaction on climate change was not addressed.

B. Government Action

Through President Reagan's time in office, while his own administration was producing and publishing groundbreaking research on the growing threat of greenhouse gas emissions from fossil fuels, his administration firmly committed the country on a path of further extensive coal, oil, and gas development.

The President's first term was marked by rapid deregulation of fossil fuel energy markets and the opening up of lands for fossil fuel production, especially oil and gas. In 1981, President Reagan first introduced the elements that would form his national energy policy through the National Energy Policy Plan, which included dismantling environmental regulations and removing restrictions on production and leasing policies.[130]

The 12th Annual Report of the CEQ made clear the government's focus on expanding fossil fuel development, notwithstanding the threats posed by climate change. The report stated:

> Energy and minerals on public lands – both onshore and offshore – have been the focus of intense interest since the 1973-74 oil crisis. The Administration has placed these resources in central position in its energy policy . . . . 'The Federal role in national energy production is to bring these resources into the energy marketplace, while simultaneously protecting the environment' . . . . To carry out the President's program, the BLM Director announced a reorganization of the Bureau's functions . . . stating 'One of our primary objectives is to increase the availability of federal lands and resources for energy and mineral development.' . . . High priority is to be given to streamlining existing energy and mineral leasing programs; accelerating the development and implementation of new programs for leasing oil shale, tar sands, and Alaskan onshore oil and gas; increasing the availability of federal lands for exploration and development activities, particularly for oil and gas and strategic minerals. . . .[131]

[128] Al Gore, Letter to President Reagan, May 21, 1986. Ex. E-73 at 3.
[129] William L Ball, Letter to Al Gore, May 28, 1986. Ex. E-73 at 2.
[130] Ronald Reagan: "Message to the Congress Transmitting the National Energy Policy Plan," July 17, 1981. Ex. E-74.
[131] Council on Environmental Quality, 12th Annual Report of the Council on Environmental Quality, 1982. Ex. E-71 at 148 (quoting 1981 National Energy Plan).

The report also states that the Interior Department increased oil and gas leases in 1981 by 36 percent, increased the acreage leased in 1981 by 152 percent, and ended the moratorium on oil and gas leasing on military lands.[132]

The Reagan administration opened up more federal lands for oil and gas development, and sped up the sale of offshore oil and gas leases. In its 13th Annual Report, CEQ noted that "[d]espite the presence in the offshore area of approximately two-thirds of America's oil and gas resources, over the past 30 years little effort was expended to develop that potential."[133]

The figure that CEQ included in the report is telling:

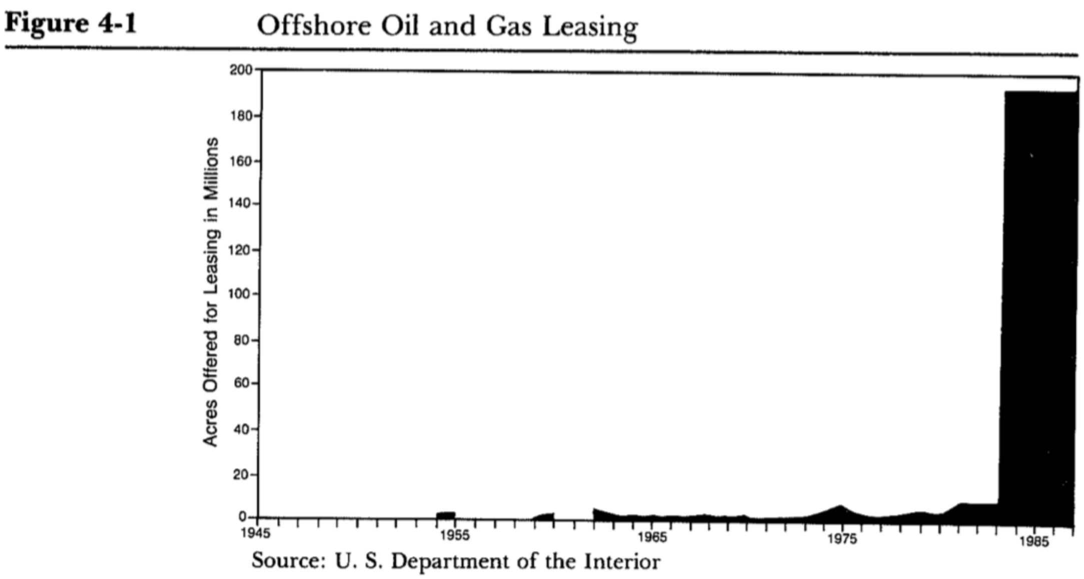

Figure 7: Offshore Oil and Gas Leasing.[134]

Not only was the federal government opening up vast new acreage to potential oil and gas development, it spent hundreds of millions of dollars in research necessary to open these offshore areas to oil and gas exploration and development.[135] Between 1954 and 1980, the federal government had never offered more than 7.2 million acres of offshore land for oil and gas development, or leased more than 1.9 million acres, in any one year.[136] However, by President Reagan's third year in office, the number of acres offered surpassed 119 million acres and the number of acres leased surpassed 6.5 million acres. By his fourth year, 154 million acres were

[132] *Id.* at 149.
[133] Council on Environmental Quality, 13th Annual Report of the Council on Environmental Quality, 1982. Ex. E-75 at 156.
[134] *Id.*
[135] *Id.*
[136] Rolando A. Gachter, Federal Offshore Statistics: 1995, U.S. Department of Interior, 1997. Ex. E-76 at 6.

offered, a 21-fold increase from the previous peak in acres leased, and almost 7.4 million acres were leased, nearly a four-fold increase.[137]

The Reagan administration's work pertaining to onshore oil and gas development followed a similar trend. As CEQ noted: "In 1981, BLM [Bureau of Land Management] leased 150 percent more onshore acres than were leased in 1980. In 1982, leased acres nearly doubled again, thus equaling in 1982 alone the number of acres leased for the entire period of 1977-1980."[138]

In his second term, President Reagan continued to maintain support for almost unrestrained fossil fuel development.[139] Reagan's anti-regulation policies and price decontrol for oil and gas was executed by the heads of various federal agencies including James Watt and Dan Hodel and DOI.[140] It was also supported by the EPA, which among other things, eased regulatory burdens for wastes from the exploration, development, and extraction of oil and natural gas and specifically exempted such wastes from the Resource Conservation and Recovery Act.[141]

A 1985 OSTP report, "Biennial Science and Technology Report to Congress: 1983-1984," emphasized science and technology that enhance fossil fuel recovery, for example through hydraulic fracturing (fracking) but did not discuss the need for electric vehicles, high-speed rail or the need to increase the Corporate Average Fuel Economy (CAFE) standard. While noting some improvements in wind and solar energy, it focused on government research that would increase fossil fuels and largely left the research and development of renewable energy sources to the private sector.[142] Subsequently, the Reagan Administration actually *increased* national auto emissions by undoing the fuel economy standards that had been put in place by prior administrations. President Reagan's Department of Transportation reduced the CAFE standard from 27.5 mpg to 26 mpg for 1986.[143]

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[137] *Id.*
[138] Council on Environmental Quality, 13th Annual Report of the Council on Environmental Quality, 1982. Ex. E-75 at 160.
[139] *See, e.g.,* John Herrington, DOE Secretary, Letter to the President, March 16, 1987. Ex. E-77 (describing an impending oil shortage and what "has already been done during this Administration to strengthen the domestic oil industry and remove impediments to the exploration for oil and gas").
[140] *See, e.g.,* George Cameron Coggins, "Nothing Beside Remains": The Legal Legacy of James G. Watt's Tenure as a Secretary of the Interior on Federal Land and Law Policy, Boston College Envtl. Affairs L. Rev., Vol. 17(3), 473, 521-22, 1990, (describing Watt's efforts to accelerate leasing of oil and gas from public lands "in the face of powerful reasons to proceed more cautiously").
[141] U.S. Environmental Protection Agency, Regulatory Determination for Oil and Gas and Geothermal Exploration, Development and Production Wastes, July 6, 1988. Ex. E-78.
[142] Office of Science and Technology Policy, Biennial Science and Technology Report to Congress: 1983-1984, 1985. Ex. E-79 at 81, 87.
[143] U.S. Department of Transportation, Summary of Fuel Economy Performance, Dec. 15, 2014. Ex. E-80; PEW, Driving to 54.5 mpg: A History of Fuel Efficiency in the United States, 2, Sept. 2012, http://www.pewtrusts.org/-/media/assets/2014/06/02/factsheet-graphic-fuel-effiency-timeline-finalsept-2012.pdf. Ex. E-81 at 3.

1. <u>Climate Concern Goes Global</u>

Meanwhile, as researchers in the federal government continued to sound the alarm about the threat of carbon emissions, momentum was building internationally for a cooperative response to climate change. As the longtime leader among the well-to-do countries, the United States was inevitably drawn into the climate issue internationally.

By the mid-1980s, the intellectual and policy leadership of the scientific community, the environmental community, and the UN Environment Programme had paid off: a new and international environmental agenda had emerged – one that governments would be compelled to address collectively, or seem to address. The international pressure for major action on climate and other global-scale issues was becoming too strong to ignore.

The idea of an international climate convention entered international discourse at the important climate science conference held in Villach, Austria in 1985. The Villach conference was the third of a series of meetings starting in 1980 that examined the impacts of CO_2. The conclusions and recommendations from the conferences included:

- Climate change and sea level rises due to greenhouse gases are closely linked with other major environmental issues, such as acid deposition and threats to the Earth's ozone shield, mostly due to changes in the composition of the atmosphere by man's activities. Reduction of coal and oil use and energy conservation undertaken to reduce acid deposition will also reduce emissions of greenhouse gases . . .
- While some warming of climate now appears inevitable due to past actions, the rate and degree of future warming could be profoundly affected by governmental policies on energy conservation, use of fossil fuels, and the emission of some greenhouse gases.[144]

The Villach results then fed quickly into the famous Brundtland Commission Report – moving them from a scientific arena to a policy one. The 1986 Brundtland Report, written by a United Nations-sponsored international commission, called for action to "minimize damage and cope with the climate changes and rising sea level."[145] It urged international cooperation to achieve these ends "backed by a global convention if necessary." Over the ensuing few years "if necessary" would become "as is essential." The United States participated as a member of the Brundtland Commission, and the organization I led at the time, the World Resources Institute, had a role in shaping the report.

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[144] World Climate Programme, Report of the International Conference on the Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts, Oct. 1985. Ex. E-82 at 1.
[145] World Commission on Environment and Development, Our Common Future, Oxford: Oxford University Press, 1987. Ex. E-83 at 124.

The Villach conference and the Brundtland Report led to the International Conference on the Changing Atmosphere convened in Toronto in 1988. (WRI also participated in the Toronto conference.) The delegates at the conference suggested that global CO_2 emission should be reduced by 20 percent below 1988 levels by 2005.

In addition to starting the ball rolling on an international convention, the Villach and Toronto conferences had another major upshot, this one quite unintended. Many governments, including the United States, did not like the scientific community taking the reins on policy entrepreneurship. Thus, the Intergovernmental Panel on Climate Change (IPCC), an international body established in 1988 under the auspices of the United Nations Environment Programme and the World Meteorological Organization, was created (with U.S. backing) for governments to assess anthropogenic climate change based on the latest science.

By the last year of Reagan's second term, advisors within his administration, including at the State Department, were advising Reagan to develop national climate policies and engage in international diplomatic efforts that were forming, such as the IPCC.[146] However, at the first IPCC meeting, the State Department made clear that, while it was not refuting climate science, it was "premature" to negotiate any international agreement that "sets targets for greenhouse gases."[147]

Similarly to the Administration's approach internationally, on the national front, the Reagan administration called for more research as opposed to taking action to confront the threats. In 1987, Congress passed the Global Climate Protection Act, directing the President "to establish a Task Force on the Global Climate to research, develop, and implement a coordinated national strategy on global climate."[148] However, as one 1987 memorandum from the White House stated, "OSTP has strongly opposed the Global Protection Act and consideration of policy actions on global climate change, arguing that the science is not understood well enough to formulate meaningful policies. Although the statute requires policy consideration of this issue, DPC [Domestic Policy Council] action now could be premature before the science 'is ready.'"[149] In a January 1988 report to Congress on the greenhouse effect, President Reagan again emphasized the need for further research and interagency coordination, but offered no prescriptions for policy actions to reduce greenhouse gas emissions.[150]

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[146] Richard Smith, Acting Administrator U.S. State Department, Memo to Ralph Bledsoe, White House Domestic Policy Council, Jan 15, 1988. Ex. E-84 (discussing President's obligation under the Global Climate Protection Act to develop a national policy on climate change).
[147] J. Edward Fox (Assistant Secretary Legislative Affairs), Letter to Senator Chafee, July 29, 1988. Ex. E-85 at 10; *see also* Richard J. Smith, Letter to Richard Hallgren, January 27, 1988. Ex. E-86 at 4.
[148] S. 420 – 100th Congress: Global Climate Protection Act of 1987.
[149] Robert E. Johnson, Memorandum through Ralph C. Bledsoe for Nancy J. Risque, The Global Climate Protection Act, Dec. 29, 1987. Ex. E-87 at 1.
[150] President Reagan, Report to Congress, United States Activities Related to the Greenhouse Effect, Jan. 26, 1988. Ex. E-88.

Such was the political and social backdrop to the 1988 Presidential elections—a growing global call for international climate action, a Congress that was hearing repeated testimonies by Dr. Hansen and others on the forefront of climate research, and even agencies within the Reagan administration suggesting action to plan for and mitigate the potential impacts of warming. All the while, the federal government's policies were encouraging the enhanced production and combustion of fossil fuels.

IV. The George H.W. Bush Administration, 1989-1993: Outwardly Recognizing the Threat of Dangerous Anthropogenic Climate Change, While Entrenching Fossil Fuel Dependency, Dragging its Feet on Global Action and Undermining Scientific Consensus Behind-The-Scenes.

During his presidential campaign, George H.W. Bush famously acknowledged the threat of global warming and promised action: "Those who think we are powerless to do anything about the greenhouse effect forget about the 'White House effect'; as President, I intend to do something about it."[151]

The Bush administration's acknowledgement of the fundamental facts and implications of climate change is aptly summed up by comments made by Secretary of State James A. Baker III, a mere ten days after inauguration. Speaking to the Response Strategies Working Group of the Intergovernmental Panel on Climate Change (IPCC), Baker said:

> we can probably not afford to wait until all the uncertainties regarding climate change have been resolved before we act . . . [W]hile scientists refine the state of our knowledge, we should focus immediately on prudent steps that are already justified on grounds other than climate change . . . . [S]olutions will be most effective if they transcend the great fault line of our times, the need to reconcile the transcendent requirements for both economic development and a safe environment.[152]

Not long after his election, however, the actions of President Bush and his administration – both at home and, increasingly, abroad – began to undermine both these statements and the long-accumulating body of knowledge within the federal government and international community regarding the robustness of climate science and the risks of climate change. For the next four years, the Bush Administration would outwardly and quite vocally recognize the threat of climate change, the risks of ongoing high levels of greenhouse gas emissions, and the necessity of at least some action to counteract these risks. Yet the Bush Administration continued to act in ways that would deepen U.S. dependence on fossil fuels, foster high U.S. greenhouse gas emissions, politically interfere with scientific research, appeal to alleged short-term "economic" justifications for inaction, downplay the significant short- and long-term consequences (economic or otherwise) of irreversible climate change, and slow international collective action

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[151] *See* "The Whitehouse and the Greenhouse," *The New York Times*, May 9, 1989. Ex. E-89.
[152] James A. Baker III, Remarks before the Response Strategies Working Group, Intergovernmental Panel on Climate Change, Jan. 30, 1989. Ex. E-90 at 4.

to reduce greenhouse gas emissions. Federal Defendants deeply understood the gravity of the emerging climate crisis and yet, when presented with pathways to decarbonization, continued to promote fossil fuel development and consumption.

A. Government Knowledge

1. The Administration Acknowledged Specific, Foreseeable Impacts from Climate Change and Sea Level Rise

In his speech to the IPCC, quoted above, Secretary Baker channeled the advice of Frederick M. Bernthal, who was then the Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs and the Chair of the IPCC's Third Working Group, but did weave in some doubt. Bernthal had written in a memo to the White House, in advance of Baker's speech, saying "[w]hile it is clear we need to know more about climate change, prudence dictates that we also begin to weigh impacts and possible responses. We simply cannot wait – the costs of inaction will be too high."[153]

This wasn't the first warning of its kind to the federal government or the last of the warnings from Bernthal, who would be appointed by President Bush to lead the National Science Foundation (NSF) in 1990. Bernthal wrote to the Secretary of State, also in February 1989: "If climate change within the range of current predictions (1.5 to 4.5 degrees centigrade by the middle of next century) actually occurs, the consequences for every nation and every aspect of human activity will be profound."[154]

The EPA under the Bush administration, with William Reilly as agency head, was in the process of recognizing and evaluating the great advances in climate modeling that had occurred in previous years, which introduced a new level of clarity as to the specific potential physical impacts of the greenhouse effect. Following a series of Congressional hearings on climate science in 1986, the Subcommittee on Pollution of the Senate Environment and Public Works Committee requested the EPA to conduct a study examining the potential health and environmental impacts of greenhouse gas-induced global warming. The resulting "The Potential Effects of Global Climate Chang on the United States" report, published in 1989, provided an unprecedented and comprehensive evaluation of anticipated climate impacts, including on: water resources, sea level rise, agriculture, aquatic resources, air quality, and more.[155]

The language of the "Potential Effects" report regarding the broad climate situation was unequivocal:

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[153] Frederick M. Bernthal, Memorandum to Richard T. McCormack Under Secretary-Designate for Economic Affairs, Feb. 9, 1989. Ex. E-91 at 4.
[154] Frederick M. Bernthal, Memorandum to the Secretary of the Department of State, Review of Key Foreign Policy Issues: The Environment, Feb. 27, 1989. Ex. E-92 at 2.
[155] U.S. Environmental Protection Agency, The Potential Effects of Global Climate Change on the United States, Dec. 1989. Ex. E-93.

> Recently, we have come to realize that human activity may, in the near future, produce effects powerful enough to overwhelm [] natural mechanisms and dominate the changes of climate. By early in the next century, the planet's temperature may rise to a range never before experienced by our species, at a rate faster and to temperatures warmer than the Earth has experienced in the past million years. This anticipated temperature increase would be caused by an enhancement of the greenhouse effect.[156]

While the "Potential Effects" report language concerning the macro-level risks of anthropogenic climate change largely reflected that of previous government reports, the report is significant for the very high degree of confidence with which it described specific harms to specific regions from sea level rise:

> A rise in sea level is one of the more probable impacts of climate change. Higher global temperatures will expand ocean water and melt some mountain glaciers, and may eventually cause polar ice sheets to discharge ice. Over the last century, global sea level has risen 10 to 15 cm (4 to 6 inches), and along the U.S. coastline, relative sea level rise (which includes land subsidence) has averaged about 30 cm (1 foot). Published estimates of sea level rise due to global warming generally range from 0.5 to 2.0 meters (1.5 to 7 feet) by 2100 . . . .
>
> Although some wetlands can survive by migrating inland, a study on coastal wetlands estimated that for a 1-meter rise, 26 to 66% of wetlands would be lost, even if wetland migration were not blocked . . . .[157]

Notably, the EPA also projected a timeframe on the potential impacts, warning that "[c]hanges may begin in 30 to 80 years."[158] And, indeed, the impacts have begun, on the short end of the expected timeframe.

2. <u>Other Federal Agency Reports Demonstrated Increasingly Sophisticated Knowledge of Climate Risks</u>

During the first Bush administration, EPA was not the only agency to comment on climate risks. The Council on Environmental Quality discussed climate change in its annual reports. The Twentieth Annual Report, for instance, equivocated on the issue, stating that "[e]missions released to the atmosphere from fossil fuel combustion contribute to atmospheric degradation" but also that "the possible extent of climate change and its likely effects on the environment are both complex and controversial."[159] The CEQ's Twenty-Third Annual Report similarly sought to highlight uncertainties in the science, while noting that the U.S.'s National Climate Change Action Plan was expected to reduce greenhouse emissions by 6-11% below business-as-usual

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[156] *Id.* at 9.
[157] *Id.* at xxxiv.
[158] *Id.* at xxxii.
[159] Council on Environmental Quality, Environmental Quality 1989, 20th Annual Report of the Council on Environmental Quality. Ex. E-94 at 227, 278.

levels by the year 2000 (U.S. greenhouse gas emissions would in fact still increase in real terms over the period 1994-2000).[160]

The DOE also published a report in March 1990, in which it explained all the ongoing research that DOE is conducting, including across 24 different programs and stated in its "Policy on Global Warming" section that "DOE has concluded that currently available information about the warming increase of carbon dioxide in the atmosphere is cause for serious concern even at the most optimistic end of the range of predicted impacts."[161] Later in the year, the General Accountability Office published a report, requested by Congress, that laid out what was currently known about climate change and greenhouse gas emissions, and identified possible policy responses. "[T]he average global temperature will increase by 3 to 9 degrees Fahrenheit over the next century, assuming a doubling of the effect of greenhouse gases," the GAO wrote.[162] "Even the lower of these estimates could be the most rapid temperature increase the earth has ever experienced."[163]

Two years later, in September 1992, the National Oceanic and Atmospheric Administration also published a public-facing report on "The Climate System," that spelled out the hard truths of climate science and the increasing probability for adverse impacts on society.[164] A chapter of the report titled "Water, water everywhere," stated:

> Rising ocean levels also threaten to flood low-lying areas and could create millions of refugees in Bangladesh and other countries. Urban centers like New Orleans, Bangkok and Venice may be unable to afford the costs of protecting themselves against the surge of high waves during storms.[165]

In (correctly) identifying that "[n]o need could be more pressing, no mission of greater import to future generations" than "to anticipate future climate change and develop a rational program for protecting the environment," the report also showed an acute awareness of the particular temporal challenges inherent in responding to the climate crisis:

> The buildup of these and other gases has already strengthened Earth's greenhouse effect. But it may take several decades to feel the warming because atmospheric temperatures will rise significantly only after the oceans of the world have slowly warmed.

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[160] Council on Environmental Quality, Environmental Quality 1992, 23rd Annual Report of the Council on Environmental Quality, 1993. Ex. E-95 at 144; U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks (1990-2016). Ex. E-96.
[161] U.S. General Accounting Office, Greenhouse Effect: DOE's Programs and Activities Relevant to the Global Warming Phenomenon, March 1990. Ex. E-97 at 14.
[162] U.S. General Accounting Office, Global Warming: Emission Reductions Possible as Scientific Uncertainties are Resolved, Sept. 1990. Ex. E-98 at 4.
[163] *Id.*
[164] National Oceanic and Atmospheric Administration, Reports to the Nation on Our Changing Planet: The Climate System, Sept. 1992. Ex. E-99
[165] *Id.* at 10-11.

> The postponement may seem like an advantage, in that it gives us more time to prepare. However, the time lag could lead us to underemphasize the importance of the problem while we still have a chance to avert drastic climate change. In truth, we have already committed ourselves to some degree of warming, even if we could instantly halt the buildup of greenhouse gases in the atmosphere.
>
> Whatever lies ahead, the world is accelerating its pace toward that unknown end. In the last three decades, the annual global release of carbon dioxide has doubled, reflecting a climb in the rate of fossil fuel burning and deforestation. As human population and economic activities continue to grow, carbon dioxide emissions could double again in the next three decades unless the nations of the world limit their consumption of fossil fuels.[166]

It is also worth noting that in 1990 the Global Change Research Act was passed into law requiring research on climate change and requiring the preparation of a report to Congress every four years on various climate change issues, including the environmental, economic, health, and safety impacts of climate change. The Act stated that:

> human activities, coupled with an expanding world population, are contributing to processes of global change that may significantly alter the Earth habitat within a few human generations. Such human-induced changes, in conjunction with natural fluctuations, may lead to significant global warming and thus alter world climate patterns and increase global sea levels. Over the next century, these consequences could adversely affect world agricultural and marine production, coastal habitability, biological diversity, human health, and global economic and social well-being.[167]

The Act brought together the research efforts of all the various federal agencies researching climate change under a single umbrella and coordinated effort that continues to this day.

3. The Bush Administration Recognized Alternative Policy Pathways to Reduce Climate Risk

In addition to the widespread and sophisticated knowledge of climate change held by multiple federal agencies during this first Bush Administration, for at least a brief period federal agencies and Congress also seriously considered specific and comprehensive U.S. policies for mitigating greenhouse gas emissions and reducing the risk of climate change.

Early recognition of the need to implement policies to mitigate the risks of climate change can be found in a 1989 memoranda from Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs Frederick M. Bernthal to Secretary of State James Baker. In a February 9, 1989 memorandum, Assistant Secretary Bernthal stated:

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[166] *Id.* at 17-18.
[167] 15 U.S.C. § 2931(a)(1)-(2).

> While it is clear we need to know more about climate change, prudence dictates that we also begin to weigh impacts and possible responses. We simply cannot wait – the costs of inaction will be too high. . . . Will focus on emissions reductions and encouraging reforestation for example.[168]

The memo went on to state that "the U.S. must take the lead in international efforts to address global climate change. Others look to us to do so because we are best equipped to understand the problem and develop solutions. We also contribute substantially to the problem."[169]

Assistant Secretary Bernthal reaffirmed this position – that policies to reduce greenhouse gas emission could be implemented right away and justified in their own right, and the benefits of which would far outweigh the costs of inaction on climate change – in a February 27, 1989 memorandum to Secretary Baker:

> But a number of prudent measures could be taken that we would never regret, whether or not global warming ever occurs e.g., increased efficiency in energy use, global reforestation, and phasing out CFC production and use.[170]

Reflecting Assistant Secretary Bernthal's reasoning, the Department of Energy released a report in May 1990 titled, "CO_2 Emissions from Coal-Fired and Solar Electric Power Plants."[171] The report found that "[r]eplac[ing] fossil fuels with renewable energy sources . . . is the only viable long-term strategy to provide power without curtailing growth" and that "[a]ppropriate technology" was then available to begin this transition.[172] The report went on to note that:

> In view of the long lead time required for conservation and renewable technologies to be brought into the energy infrastructure on a large scale, policies that can be justified on their own merit and also reduce greenhouse-gas emissions should be initiated as soon as possible. There is a risk in delaying such actions since the costs of reducing CO_2 emissions are likely to increase if the urgency for their implementation should grow.[173]

These findings were reinforced in a September 1990 report entitled, "The Economics of Long-Term Global Climate Change: A Preliminary Assessment: Report of an Interagency Task

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[168] Frederick M. Bernthal, Memorandum to Richard T. McCormack, Feb. 9, 1989, Ex E-91 at 4.
[169] *Id.* at 5.
[170] Frederick M. Bernthal, Memorandum to The Secretary, Review of Key Foreign Policy Issues: The Environment, Feb. 27, 1989. Ex. E-92 at 2.
[171] Solar Energy Research Institute, CO_2 Emissions from Coal-Fired and Solar Electric Power Plants, May 1990. Ex. E-100.
[172] *Id.* at 3.
[173] *Id.* at 28.

Force."[174] The Task Force included representatives from Council of Economic Advisors, the Departments of State, Treasury, Commerce, Interior, Agriculture, and Energy, the Environmental Protection Agency, the Office of Management and Budget, and the Office of Science and Technology. The Task Force's report made a number of findings in support of immediate, sector-specific policies to reduce greenhouse emissions and transition the U.S. energy system to renewables, including:

- [E]limination of coal-mining jobs gradually over time does not necessarily imply increased general unemployment . . . . A shift to other energy sources would create jobs.

- Further increases in the CAFE standards are technically feasible and would likely reduce CO_2 emissions . . . .

- A number of changes in agricultural programs that would have other benefits can be expected to assist in reducing emission of greenhouse gases. These include reducing commodity price support levels, encouraging additional tree planting, and conservation cross compliance.[175]

Additionally, a 1992 GAO report, "Energy Policy: Options to Reduce Environmental and Other Costs of Gasoline Consumption," discussed how a tailpipe tax, subsidies for alternative fuel, a higher CAFE standard, and other programs could be used to increase fuel efficiency and encourage the use of electric vehicles.[176]

While the first Bush Administration's enthusiasm for concrete actions to address climate change would soon waiver, federal agencies did develop comprehensive policy proposals for addressing greenhouse gases and stabilizing the climate in a way that would benefit the climate system and U.S. economy. A major effort to assess policy alternatives was conducted by the EPA, as requested by the Subcommittee on Pollution of the Senate Environment and Public Works Committee. The EPA's "Policy Options for Stabilizing Global Climate" report, released in December 1990, "present[ed] possible future scenarios of greenhouse gas emissions to the year 2100 depending on the level of response as well as many other independent factors," ultimately finding that "[t]he results demonstrate that greenhouse gas emissions can be effectively

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[174] U.S. Department of Energy, The Economics of Long-Term Global Climate Change: A Preliminary Assessment, Sept. 1990. Ex. E-101.
[175] *Id.* at 29, 31.
[176] U.S. General Accounting Office, Energy Policy: Options to Reduce Environmental and Other Costs of Gasoline Consumption, Sept. 1992. Ex. E-102 at 2.

reduced."[177] Per the Congressional Committee's request,[178] EPA considered energy and emission pathways that would keep CO_2 levels at 350 ppm.[179]

The EPA modeled a number of different scenarios and evaluated the technological and economic feasibility of many emissions reductions efforts. The findings are summarized nicely in the Executive Summary:

> The adoption of policies to limit emissions on a global basis, such as simultaneous pursuit of energy efficiency, non-fossil energy sources, reforestation, the elimination of CFCs [chlorofluorocarbons] and other measures, could reduce the rate of warming during the 21st century by 60% or more. Even under these assumptions, the Earth could ultimately warm by 1-4°C or more relative to pre-industrial times. Extremely aggressive policies to reduce emissions would be necessary to ensure that total warming is less than 2°C.[180]

The EPA identified some of these policies and even evaluated their feasibility. For example, this report, 28 years ago, said: "50 mile per gallon automobiles are technically feasible with *currently available technology*. Further improvements could increase fuel efficiency to more than *80 miles per gallon* . . . ."[181]

The EPA was not the only entity in the federal government to map out alternative scenarios during the Bush years. The Congressional Office of Technological Assessment (OTA) produced a report in 1991, as requested by Congress in 1988, that described policy options for reducing greenhouse gas emissions. The Director of OTA, wrote in the foreword that, "this assessment focuses principally on ways to cut carbon dioxide emissions both in the United States and in other countries as well, although it does examine all greenhouse gases . . . major reductions of carbon dioxide and other greenhouse gases will require significant new initiatives by the Federal Government, by the private sector, and by individual citizens."[182]

The OTA report identified the United States as the single largest contributor to carbon pollution and developed "an energy conservation, energy-supply, and forest-management package that can achieve a 20- to 35-percent emissions reduction."[183] The report identifies "Technical Options" for lessening greenhouse gas emissions, and then spells out specific "Policy Instruments"

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[177] U.S. Environmental Protection Agency, Policy Options for Stabilizing Global Climate, Dec. 1990. Ex. E-103 at xxiii.
[178] *See, e.g.,* Senators George J. Mitchell at el., Letter to Lee Thomas, Sept. 12, 1986. Ex. E-62 (asking the EPA to consider policy options that would stabilize atmospheric GHG emissions at current levels, which were right around 350 ppm).
[179] U.S. Environmental Protection Agency, Policy Options for Stabilizing Global Climate, Dec. 1990. Ex. E-103 at 8, I-5, IV-19.
[180] *Id.* at VI-I.
[181] *Id.* at V-I (emphasis added).
[182] U.S. Congress, Office of Technology Assessment, Changing by Degrees: Steps To Reduce Greenhouse Gases, OTA-O-482, 1991. Ex. E-104 at Foreword.
[183] *Id.* at 5.

available to government "to require or encourage a desired technical or behavioral response" (see Figure 8 below).[184]

Unfortunately, the Bush Administration and Congress failed to act seriously on either the EPA or OTA plan, instead committing the nation to become even more dependent on fossil fuels.

Table 1-2—Policy Instruments To Reduce CO_2

	Taxes			Financial incentives			Marketable permits	Regulations		RD & D		Information	
	Energy tax	Carbon tax	Purchase tax	Tax incentive	Low cost loans	Direct payments		Performance standards	Building codes	R&D	Demonstration	Labels/ rating	Audits
Commercial buildings													
Thermal integrity	√	√	—	√	√	√	—	—	√	√	√	√	√
Appliance/lighting	√	√	√	√	—	√	—	√	—	√	—	√	√
Usage patterns	√	√	—	—	—	—	—	—	—	—	—	—	√
Residential buildings													
Thermal integrity	√	√	—	√	√	√	—	—	√	√	√	√	√
Appliance/lighting	√	√	√	√	√	√	—	√	—	—	—	√	√
Usage patterns	√	√	—	—	—	—	—	—	—	—	—	—	√
Transportation													
Small car/truck efficiency	√	√	√	√	√	√	—	√	—	√	√	√	—
Alternate fuels	—	√	—	√	√	√	—	—	—	√	√	—	—
Off highway[a]	√	√	—	—	—	—	—	√	√	—	—	—	—
Vehicle miles traveled	√	√	—	—	—	—	—	—	—	—	—	—	—
Manufacturing													
Efficiency	√	√	—	—	—	—	√	—	√	√	—	—	—
Recycling	√	√	—	√	—	√	—	—	—	—	—	—	√
Energy supply													
High to low carbon fuels	—	√	—	—	—	—	√	—	—	√	√	—	—
Renewable	√	√	—	√	—	√	√	—	√	√	—	—	—
Cogeneration	√	√	—	√	—	—	√	—	—	—	—	—	—
Efficiency, existing plants	√	√	—	—	—	—	√	—	—	—	—	—	√
Forests													
Recycling	—	—	—	√	—	√	—	√	—	—	—	√	—
Increased productivity	—	√	—	√	—	√	—	—	—	√	—	—	—
Afforestation	—	√	—	√	—	√	—	—	—	—	—	—	—
Biomass	√	√	—	√	—	—	—	—	√	√	—	—	
Food													
Farm inputs	—	√	—	—	—	√	—	√	—	—	√	√	√
Farm operation & efficiency	—	√	—	√	—	√		√	—	√	—	—	—
Food processing	—	√	—	—	—	—	=	—	√	—	√	—	√

[a]Heavy equipment, aircraft.

SOURCE: Office of Technology Assessment, 1991.

Figure 8: Policy Instruments to Reduce CO_2.[185]

B. Government Action

Despite the growing body of climate science and increasingly honed modeling which allowed for predicting specific impacts regionally, and despite the clear recognition of both the need for and feasibility of policies to reduce climate impacts, the federal government under George H.W. Bush continued to enact policies that would worsen greenhouse gas pollution, and worked against the growing international scientific consensus and political momentum to take meaningful action, including international action, on climate change.

[184] *Id.* at 13.
[185] *Id.* at 14.

1. The Federal Government Kept Consideration of Climate Impacts Out of Federal Decision-making

On June 21, 1989, CEQ Director Alan Hill circulated a Draft Guidance to the heads of federal agencies, concluding that global warming was "reasonably foreseeable" and instructing agencies how to prepare environmental impact statements and assessments that account for a projects' impact on climate change, as well as how climate change could later impact the federal project, suggesting that this is required under the National Environmental Policy Act (NEPA).[186] Hill had previously attempted to circulate a similar guidance at the end of the Reagan administration, but was prevented from doing so by intervention from the White House Counsel and the Domestic Policy Council.[187]

This time around, Hill again faced stiff opposition within the administration. In a June 23, 1989 memo, Acting Assistant Attorney General Donald A. Carr expressed concern about the effects of Hill's proposal on "litigation about the adequacy of environmental impact statements for continuing activities such as oil and gas development, timber sales, highways and coastal projects."[188] Carr "strongly urge[d] as a first step further deferral of the CEQ directive before things get out on the street, in the press and out of hand."[189] Hill was soon relieved of his position as head of CEQ, and David Bates, then Secretary to the Cabinet, issued a one-page memorandum on July 14, 1989 that purported to "undo Hill's mischief" by advising agencies to abandon any efforts to address CEQ's draft guidance.[190] (Note that in 2010 the CEQ finally issued draft guidance on NEPA guidelines on how agencies must consider the impacts of their actions on global climate change. In 2014, after extensive public comment, revised draft guidance was issued, and in 2016, final guidance. However, this guidance was revoked by the Trump Administration in March 2017.)

A 1990 GAO report subsequently confirmed that, notwithstanding campaign promises or the looming crisis, President Bush would not coordinate federal action on energy and climate policy to stop climate change:

> The President announced in February 1989 that he would issue an executive order on global climate change that would clearly define responsibility of federal departments and agencies, as well as establishing effective coordination mechanisms. However, as of November 1989, the order had not been issued and

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[186] Alan Hill, Memorandum to Heads of Federal Agencies regarding Draft of Guidance Regarding Consideration of Global Climate Change in Preparation of Environmental Documents, June 21, 1989. Ex. E-105.
[187] *See* Donald Carr, Memorandum to Kenneth Vale, CEQ Global Climate Change Directive, June 23, 1989. Ex. E-106.
[188] *Id.* at 1.
[189] *Id.* at 2-3.
[190] David Bates, Assistant to the President and Secretary to the Cabinet, Memorandum to Heads of Agencies (Hill's Mischief), July 14, 1989. Ex. E-107.

> its status was uncertain. Agency officials told us that they had not received clear guidance to direct the course of climate change activity.[191]

The GAO report further stated: "The administration has not tasked any agency with providing overall policy direction or leadership, nor has any agency acted as the administration's voice on global climate change" and that "NCPO's [National Climate Program Office] low placement in the department's executive echelon and a comparatively modest budget have hindered its effectiveness."[192] The Bush Administration never issued the referred to guidance or direction to federal agencies.

2. Administration Officials Undermined Agency Scientists and Domestic Confidence in Climate Science

As I have detailed in previous sections, the first Bush Administration inherited decades of federal agency research, knowledge, and output in the area of climate science. Numerous agency reports and instances of congressional testimony by agency scientists had confirmed that warming of the atmosphere and resultant climate change was already occurring; that the cause was anthropogenic greenhouse gas emissions, foremost CO_2 emissions; that the adverse impacts from climate change would be numerous and potentially extreme; and that these impacts could be predicted with increasing accuracy and certainty. Given the implications of the evidence before it, it is saddening to observe that several prominent individuals within the first Bush Administration rejected taking action and instead chose to undermine public confidence in the certainty of climate science, foster skepticism, promote contrarian viewpoints and interfere with the work of government scientists.

One of the earliest examples of the first Bush Administration running counter to the work of government climate scientists is the attempt by the White House Office of Management and Budget to alter testimony by then Director of the NASA Goddard Institute for Space Studies, Dr. James Hansen, before a Senate Committee chaired by then Senator Al Gore.[193] As Dr. Hansen stated in response to questioning during the Senate Committee hearing, the effect of the Office of Management and Budget alterations was to create confusion and internal contradictions in his testimony, and cast doubt on the underlying science of climate change:

> Senator Gore [to Hansen]: In your statement you respond to our request for information on our scientific understanding of global climate models and our effort to determine which effects are pretty well understood and which effects are subject to change as we learn more about the models.

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[191] U.S. General Accounting Office, Global Warming: Administration Approach Cautious Pending Validation of Threat, Jan. 1990. Ex. E-108 at 17.
[192] *Id*. at 3, 21.
[193] Hearing before the Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science, and Transportation, Climate Surprises, May 8, 1989. Ex. E-109 at 5; *see also* Philip Shabecoff, "Scientist Says Budget Office Altered His Testimony," *The New York Times*, May 8, 1989. Ex. E-110.; J. Hansen, Storms of My Grandchildren, Bloomsbury, New York, p. 304, 2009.

You respond by saying, among other things, that as the models improve and more evidence becomes available, it is not very likely that scientists will change their conclusion that increases in greenhouse gases will intensify drought in the middle and low latitude land areas, like the Midwest of the United States.

I am puzzled that you also say on that same point on page 4 of your statement that you want to stress that you do not really believe that and that as the computer models evolve, that conclusion will very likely evolve and should not be regarded as reliable.

I think I know the answer to the question I am about to ask you, but why do you directly contradict yourself in the testimony you are giving about this scientific question?

Dr. Hansen: Let me first rephrase exactly what we said in that regard because when I discussed this with my scientific colleagues, the slight rephrasing makes a difference.

What I said was we believe it is very unlikely that this overall conclusion [sic] drought intensification at most middle and low latitude land areas if greenhouse gases increase rapidly, will be modified by improved models. Now, that is what I believe, and that is what I wrote.

The last paragraph in that section which seems to be in contradiction to that was not a paragraph which I wrote. It was added to my testimony in the process of review by OMB, and I did object to the addition of that paragraph because in essence it says that I believe that all the scientific conclusions that I just discussed are not reliable, and I certainly do not agree with that. . . .

Senator Gore: Well, were there other parts of your testimony which they forced you to change?

Dr. Hansen: The number of changes as these things go is actually not that large, but there was at least one other one which I think is worth mentioning. That was concerned with the-they added a sentence which says one point that remains scientifically unknown is the relative contribution of natural processes and human activities to the growth of trace gas climate forcings.

Now, I was able to get them to change the last part of that sentence to say “non-CFC climate forcings,” because it is very clear that CFCs have no natural source. But, you know, even in the case of the growth of carbon dioxide and methane, it is pretty clear to scientists that in fact they are rising because of anthropogenic emissions.

> I agree that the sentence is a scientifically correct sentence, but I would not have added that myself if I had not had it put in there for me. . . .
>
> Senator Gore: Dr. Hansen, were there scientists in OMB who ordered the change in your testimony?
>
> Dr. Hansen: I do not know them personally, so I really cannot say.
>
> Senator Gore: These are nameless, faceless individuals with whom you are dealing, is that correct?
>
> Dr. Hansen: Yes.
>
> Senator Gore: Sort of like members of the Science Politburo of the Bush administration. Well, I think this is an outrage of the first order of magnitude. I think that is evident.[194]

A magazine interview with then-National Center for Atmospheric Research scientist Stephen Schneider[195] provided further indication that officials with the first Bush Administration were interfering with government climate scientists and gatekeeping access to President Bush when he was asked to comment on President Bush's position:

> I suspect that his Chief of Staff John Sununu doesn't let a representative spectrum of climate scientists get near the Oval Office. The president apparently only hears unknowledgeable or extreme people. Neither [Bert] Bolin nor [James] Hansen nor myself have spoken with him. I doubt he gets balanced information on global warming or he'd join the (sic.) Margaret Thatcher, and other "conservative" leaders, who counsel at least some immediate action to counter the greenhouse effect.[196]

Indeed, the first Bush Administration's efforts to muddy the waters around the science of climate change were not limited to political interference with and censoring of government scientists. Another strategy, in concert with sympathetic members of the fossil fuel industry, was to foster support for climate science deniers, skeptics and contrarians. For instance, in February 1991, President Bush received a letter from a group of scientists detailing a recent conference they had held, the purpose of which was to cast doubt on the consensus understanding of climate change and its risks.[197] By April 1991, Director of the Office of Science and Technology Policy D. Allan

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[194] *Id.* at 143-147.

[195] Schneider would later serve as a consultant to the first Bush Administration, and holds the rare distinction of having at one point served in a consulting or advisory capacity for every administration from Richard Nixon to Barack Obama. *See* https://www2.ucar.edu/atmosnews/in-brief/2270/stephen-schneider-extraordinary-life. Ex. E-111.

[196] Briefing for Governor Sununu, Preparations for the First Framework Convention Negotiating Session, Washington, DC, Feb. 4, 1991, Nov. 7, 1990. Ex. E-112 at 58.

[197] Patrick Michaels and Robert Balling, Letter to George H. Bush, Feb. 1. 1991. Ex. E-113.

Bromley and White House Chief of Staff John Sununu had decided to invite several members to a meeting at the White House, with the apparent motive of seeking out and supporting scientists who "have been actively participating in the public debate on global warming from the point of view that perhaps the popular view – 'The Popular Vision' – (IPCC science and/or potentially very negative effects) is wrong."[198] Bromley and Sununu appear to have convened the meeting in order to foster opposition to a soon-to-be released report, "Policy Implications of a Greenhouse Warming," which Bromley and Sununu were concerned called for a more "activist" approach than was supported by the administration.[199]

White House Chief of Staff Sununu also appears to have been involved in soliciting support from the fossil fuel industry in undermining public consensus around climate science. On July 30, 1991, David Loer of the Minnkota Power Cooperative, Inc. wrote to Sununu as follows:

> Dear Mr. Sununu:
>
> On behalf of the 80,000 customers served by our rural electric power system, I want to thank you for the strong position you have taken on the global warming issue.
>
> Your skepticism regarding carbon dioxide as a cause of global warming is a "breath of fresh air" to those of us who are very concerned about the consequences of adverse action or legislations dealing with this issue.
>
> In our research, we have also found a number of credible climatologists who are not agreeing with the catastrophic global warming theory. We need to find ways for them to be more involved in dealing with this important issue.
>
> We know there is an extreme amount of pressure on you and other staff in the Administration to convince you that there needs to be limits placed on carbon dioxide emissions. We appreciate your recognizing the severe economic impact of such action.
>
> Minnkota Power Cooperative, Inc., owns and operates only North Dakota coal-fired electric generating plants. Not surprisingly, we are hoping that your position on this issue prevails.

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[198] D. Allen Bromley, Memorandum to John H. Sununu, Possible Group from Whom to Obtain Reaction to the NAS/Evans Report, April 18, 1991. Ex. E-114 at 2.

[199] *See* National Academy of Sciences, Policy Implications of Greenhouse Warming, Committee on Science, Engineering, and Public Policy, 1991. Ex. E-115.; D. Allen Bromley, Memorandum to John H. Sununu, Possible Group from Whom to Obtain Reaction to the NAS/Evans Report, April 18, 1991. Ex. E-114.; D. Allen Bromley, Memorandum to Governor Sununu, The NRC Evans Report, April 8, 1991. Ex. E-116.; Nancy G. Maynard, Memorandum to D. Allen Bromley and J. Thomas Ratchford, Environment Update – Week of May 26 and June 3, 1991, June 3, 1991. Ex. E-117.

> Is there anything that we can do to assist you or your position on the global warming issue? Please call us – we would like to help.[200]

Sununu's response was brief, but telling of his support for the industry position:

> Dear David,
>
> Thank you very much for your note. My only suggestion to you on how you might assist us on the global warming issue is to encourage your colleagues in the industry to provide assistance and support to a credible climatologist who understands the complexities of the issue.
>
> We really *do* need your help in getting this important message out.[201]

3. <u>The Federal Government Undermined and Watered-down International Climate Science Assessments</u>

During the first Bush Administration, the U.S. exercised heavy influence over the shape and content of international scientific assessments. It largely did this behind-the-scenes while continuing to take a cooperative and comparatively positive stance in international fora. Thus, President Bush in his 1990 address to the IPCC stated:

> We all know that human activities are changing the atmosphere in unexpected and unprecedented ways. Much remains to be done. Many questions remain to be answered. Together, we have a responsibility to ourselves and the generations to come, to fulfill our stewardship obligations.[202]

As the main liaison from the Bush administration to the IPCC, Assistant Secretary Frederick M. Bernthal helped craft the policy section of the Panel's first report, "Climate Change: The IPCC Scientific Assessment," which was published in August 1990.[203] A particularly conservative block of White House advisors – including chief of staff John Sununu and science advisor Allan Bromley – insisted on highlighting uncertainties in climate science, introducing the purported benefits of global warming while downplaying the central dangers of fossil fuel emissions and CO_2.[204] This same group of advisors also took the extraordinary step of directly writing to Bert Bolin, chair of the IPCC, and repeatedly demanding that changes be made to drafts of the IPCC

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[200] David W. Loer, Letter to John Sununu, July 30, 1991. Ex. E-118 at 1.
[201] John Sununu, Letter to David W. Loer, Aug. 20, 1991. Ex. E-118 at 2 (emphasis in original).
[202] George Bush, Presidential Address to Intergovernmental Panel on Climate Change, Georgetown University, Feb. 5, 1990. Ex. E-119 at 5.
[203] IPCC, Climate Change: The IPCC Scientific Assessment, 1990.
[204] *See* D. Allan Bromley and Stephen Danzansky, Memorandum to Members of Global Change Strategy Task Force, May 21, 1990. Ex. E-120; D. Allan Bromley and Bob Grady, Memorandum to John Sununu, Update on First Session of Framework Convention Negotiations, Jan. 24, 1991. Ex. E-121. Policy decisions on climate change came from John Sununu. *See* Michael Weisskopf, Bush Was Aloof in Warming Debate, Washington Post, Oct. 31, 1992. Ex. E-122.

First Assessment Report's "executive summary" and "overview and conclusions" sections and threatening to withhold U.S. support for the report if the changes were not made.[205]

Bush's White House advisors, often adversaries of EPA's Reilly, knew that if they accepted the international consensus on climate science, they would be forced to accept needed remedial action. As Bromley stated in a memo to Sununu on June 14, 1990:

> I am also concerned that if we appear to accept IPCC [Working Group I: Scientific Assessment of Climate Change] as ultimate truth then to some extent we have been effectively coopted into accepting the recommendations of the IPCC [Working Group II: Impacts Assessment of Climate Change] and [Working Group III: The IPCC Response Strategies] which may well be substantially different from what we had in mind.[206]

Indeed, as explained below, the U.S. would use its successes in watering down the conclusions of the IPCC First Assessment Report as a negotiating tactic in weakening the commitments and language of the 1992 framework convention.

4. <u>The Federal Government Weakened the Language of, and Resisted the Inclusion of Targets and Timetables in the United Nations Framework Convention on Climate Change</u>

During his presidential campaign, then-Presidential candidate George H.W. Bush announced his plans for his administration to spearhead international action on climate change and other environmental issues of global concern. A State Department memorandum quoted candidate-Bush stating:

> [I]n my first year in office, I will convene a global conference on the environment at the White House. All nations will be welcome – and indeed, all nations will be needed. . . . The agenda will be clear. We will talk about global warming. We will talk about acid rain. We will talk about saving our oceans and preventing the loss of tropical forests. And we will act.[207]

International developments over the previous years – including the 1985 Villach and 1988 Toronto conferences (in which WRI participated) and the Brundtland Report,– laid the groundwork for a climate convention, and by late 1990, the United Nations General Assembly had approved the start of negotiations leading to such a convention.

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[205] Frederick Bernthal, Letter to Bert Bolin, July 5, 1990. Ex. E-123; Steve Danzansky, Memorandum to Chris Dawson et al., Aug. 7, 1990. Ex. E-124.
[206] D. Allen Bromley, Memorandum to John Sununu, Sea level change and environmental matters, June 14, 1990. Ex. E-125 at 3.
[207] OES – Richard J. Smith, Confidential Memorandum to The Secretary, United States Department of State, Preparations for an International Conference on the Environment, May 16, 1989. Ex. E-126 at 1.

Yet, in spite of Bush's early call for action, his Administration set about using the United States' influence to weaken international action on climate change. Even before formal negotiations began, the Bush administration worked to limit the strength of any agreement. While other nations, including most of Europe, argued for binding targets to protect the climate system, the U.S. would not commit to firm targets or timetables.[208] This opposition, based on "a volatile mixture of ideology and politics" rather than a "rational assessment of the national interest," was instrumental in ensuring that no binding targets were agreed to in the 1992 climate convention, a major setback.[209]

The U.S. was largely isolated in several other negotiating areas, including whether to incorporate the "precautionary principle" in the language of the convention, the level of financial assistance provided to developing countries to offset the costs of reducing greenhouse gas emissions, and the degree of technology transfer between parties on non-commercial terms.[210]

Despite successful U.S. efforts to weaken the content of the UN Framework Convention on Climate Change (UNFCCC), the convention was adopted on May 9, 1992, signed by Bush Administration in June 1992 at the Earth Summit in Rio de Janeiro, and later ratified by the United States Senate in October 1992. I was there at Rio, saw it happen, and recall being quite proud with, at last, a feeling of hope for the future.

In ratifying the climate convention, the federal government was not on auto-pilot. Two aspects of the U.S. adoption of the climate convention in particular underscore the seriousness of the U.S.'s undertaking. Simultaneous with signing the climate convention, the U.S. rejected a parallel, but less far-reaching, convention aimed at protecting global biological diversity. And, second, the Senate's ratification of the agreement has proven a rarity indeed. The U.S. Senate is a veritable graveyard of unratified multilateral environmental agreements going back at least to the 1982 Law of the Sea. The potential import of the 1992 climate convention was therefore unmistakable,

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[208] In U.S. Dept. of State Memorandum entitled PRD-12/Global Climate Change Policy Decision Paper, the Department of State made the following statement: "While many nations sought to set firm 'targets and timetables' for reducing greenhouse gas emissions, U.S. objection to firm commitments resulted in an agreement that sets a non-binding goal for developed countries to return emissions to 1990 levels by the end of the decade." Ex. E-127 at 1. *See also* Roger B. Porter, Memorandum for the President, The Second World Climate Conference, Oct. 23, 1990. Ex. E-128 at 2; Global Change Working Group, Memorandum for the Domestic Policy Council, Framework Convention on Climate Change, Jan. 22, 1991. Ex. E-129 at 7; U.S. Department of State, PRD-12 Global Climate Change Policy Decision Paper. Ex. E-127 at 1. Internal memos from the time period also show resistance to targets and timetables in the White House. *See, e.g.,* Allan Bromley and Stephen Dazansky, Memorandum to Bernthal et al., May 21, 1990. Ex. E-120 at 4 ("Targets and Timetables: We do not believe there is sufficient evidence at this time to warrant stringent measures, with potentially serious negative economic consequences, to limit greenhouse gas emissions.").

[209] William A. Nitze*, A Failure of Presidential Leadership,* in Negotiating Climate Change 187, 1994 at 189.

[210] *See also, id.* at 194.

as was its meaning for U.S. action. In the end, despite the serious omissions, much of the language of the convention was quite promising.

The preamble to the UNFCCC states that the parties to the convention are: "*Determined* to protect the climate system for present and future generations."[211] The parties, comprising now essentially every nation on earth (including the United States), expressed their concern:

> that human activities have been substantially increasing the atmospheric concentrations of greenhouse gases, that these increases enhance the natural greenhouse effect, and that this will result on average in an additional warming of the Earth's surface and atmosphere and may adversely affect natural ecosystems and humankind.[212]

The UNFCCC recognized: "the need for developed countries to take immediate action in a flexible manner on the basis of clear priorities, as a first step towards comprehensive response strategies at the global, national and, where agreed, regional levels."[213] It also noted remaining scientific uncertainties, stating, "there are many uncertainties in predictions of climate change, particularly with regard to the timing, magnitude and regional patterns thereof."[214]

The most cited language in the convention comes in stating the convention's overall objective, "to achieve, in accordance with the relevant provisions of the Convention, **stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system**."[215]

All parties further committed to: "Formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to mitigate climate change by addressing anthropogenic emissions . . . ."[216] Specifically, the developed country signatories committed to: "adopt national . . . policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of greenhouse gases and protecting and enhancing its greenhouse gas sinks and reservoirs."[217]

Throughout, the treaty stresses the need to base decisions on the best science. For example, parties agree to:

> Promote and cooperate in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system and intended to further the understanding and to reduce or

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[211] United Nations, United Nations Framework Convention on Climate Change, 1992. Ex. E-130 at Preamble.
[212] *Id.*
[213] *Id.*
[214] *Id.*
[215] *Id.* at Article 2 (emphasis added).
[216] *Id.* at Article 4.
[217] *Id.*

> eliminate the remaining uncertainties [and] . . . Promote and cooperate in the full, open and prompt exchange of relevant scientific, technological, technical, socio-economic and legal information.[218]

This history and these treaty commitments underscore the full awareness by the federal government of: (1) the climate threat to current and future generations, and (2) the need to take concrete actions to "prevent dangerous anthropogenic interference," especially action by the developed countries such as the United States. Actions by the Bush Administration in signing and ratifying the UNFCCC, and the language of the UNFCCC itself, should have signaled the beginning of ongoing federal leadership at home and abroad to reduce GHG emissions, for the quoted treaty language endorsed by the Executive Branch and Congress was strong indeed in many respects. But the commitments the federal government made in 1992 in fact were not honored.

5. The Federal Government Introduces a New National Energy Strategy that Encourages More Fossil Fuel Development

In contrast to the optimism embodied by its signing of the UNFCCC, the energy policy legacy of the first Bush Administration was instead a cause of further endangerment of the climate system.

During his first year in office, at the signing of the Natural Gas Wellhead Decontrol Act of 1989, President Bush announced that the DOE would develop a new National Energy Strategy.[219] The Strategy, which was ultimately released in February 1991, openly acknowledged the risks of global warming, even claiming that the plan would reduce greenhouse gas emissions. However, as implemented, emissions continued to rise, and the Strategy encouraged such a build-out of infrastructure for oil and gas that it ensured a longer future of greenhouse gas pollution.[220]

Although the National Energy Strategy included a broad focus on using energy more efficiently, it supported increases in domestic production of oil, gas and coal,[221] and made "little effort to reflect in energy prices all the costs to society of obtaining and using energy, such as the adverse environmental costs of relying on fossil fuels."[222] Specifically, it called for opening the Arctic National Wildlife Refuge (ANWR) and other areas of the Outer Continental Shelf (OCS) to oil production, to "implement oil and gas incentives," to "deregulate pipelines," and to "increase production of California Heavy Oil."[223] It also set out to "provide regulatory incentives to offset financial risks in commercial deployment of new clean coal technology" and "reduce the cost,

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[218] *Id.*
[219] President George H.W. Bush, Remarks on Signing the Natural Gas Wellhead Decontrol Act of 1989, Jul. 26, 1989. Ex. E-131.
[220] U.S. Department of Energy, National Energy Strategy, February 1991. Ex. E-132 at 19, 74-106.
[221] *Id.* at 10-11, 74-106.
[222] *Id.* at 1-7; U.S. General Accounting Office, Energy Conservation: DOE's Efforts to Promote Energy Conservation and Efficiency, April 1992. Ex. E-133 at 5.
[223] U.S. Department of Energy, National Energy Strategy, Feb. 1991. Ex. E-132 at 10-11.

investment risks, and environmental impacts of producing liquid fuels from coal."[224] DOE had already sought large increases in funding for so-called "clean coal" research and development as early as 1989.[225] The DOE was prioritizing research and development that would allow for more fossil fuel production rather than the development of needed renewable energy sources. For example, for the 1990 fiscal year, DOE requested $575 million, a 242 percent increase over the fiscal year 1989, for clean coal technology. Meanwhile, DOE's funding request for conservation and renewable programs were reduced for fiscal year 1990.[226]

Just four months after signing the framework convention on climate change and promising the world at the Rio Earth Summit "forceful action" on climate change and international cooperation,[227] on October 24, 1992, President Bush signed the Energy Policy Act (EPACT) of 1992 beneath an oil derrick in Maurice, LA (see Figure 9 below), declaring "a new era in which Government acts not as a master, but as a partner and a servant" to the fossil fuel energy industry.[228] Many of the most climate-adverse elements of the 1991 National Energy Strategy were converted into law with the signing of the EPACT of 1992. The statute guaranteed free trade of natural gas, effectively mandated natural gas export to nations with whom the U.S. had a free-trade agreement, provided financial incentives to oil and gas drillers, committed funds for the research and development of new "clean coal" and natural gas technologies, and promised to export fossil fuel technologies to other nations.[229]

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[224] *Id.* at 12.
[225] *See* U.S. General Accounting Office, Greenhouse Effect: DOE's Programs and Activities Relevant to the Global Warming Phenomenon, March 1990. Ex. E-97 at 17.
[226] *Id.* at 15.
[227] The Earth Summit, Excerpts From Speech By Bush on 'Action Plan', *The New York Times*, June 13, 1992, available at https://www.nytimes.com/1992/06/13/world/the-earth-summit-excerpts-from-speech-by-bush-on-action-plan.html. Ex. E-134.
[228] President George H. W. Bush, Remarks on Signing the Energy Policy Act of 1992 in Maurice, Louisiana, Oct. 24, 1992. Ex. E-135.
[229] Energy Policy Act of 1992. Ex. E-136.

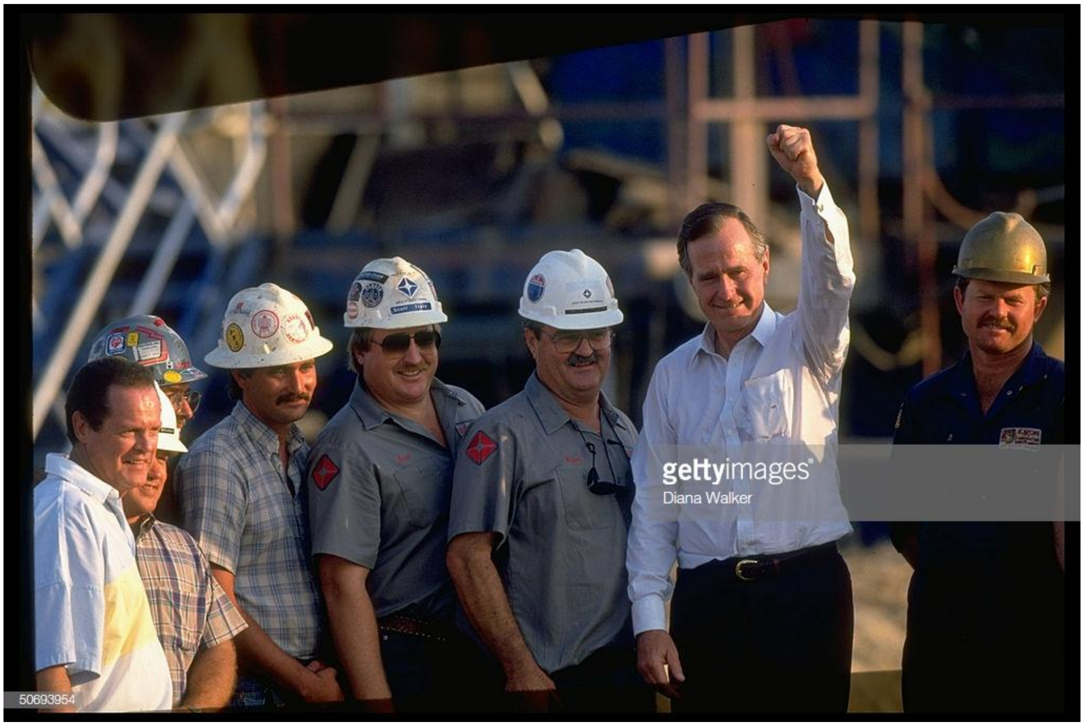

Figure 9: President George Bush at Energy Policy Act Bill Signing In Front of Oil Rig.[230]

At a signing ceremony for the EPACT of 1992, President Bush said:

> Two years ago our administration proposed a national energy strategy. It was a blueprint to promote economic growth and make the country more secure . . . . But now our efforts have borne fruit, and this afternoon, right here, and it's fitting it happens in the shadow of a drilling rig, we're going to sign the Energy Policy Act of 1992.[231]

Finally, the Bush Administration, despite knowing that vehicles could get up to 50 mpg with then-current technology, and up to 80 mpg with continued improvements in technology,[232] made only a modest improvement in the CAFE standards, raising them to the previous level of 27.5

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[230] Photo by Diana Walker, Time Life Pictures/Getty Images, available at https://www.gettyimages.com/detail/news-photo/pres-george-bush-raising-fist-w-hardhats-combining-duties-news-photo/50693954#pres-george-bush-raising-fist-w-hardhats-combining-duties-of-office-w-picture-id50693954.
[231] George Bush: Remarks on Signing the Energy Policy Act of 1992 in Maurice, Louisiana, October 24, 1992. Ex. E-135.
[232] U.S. Environmental Protection Agency, Policy Options for Stabilizing Global Climate, December 1990. Ex. E-103 at V-15, V-22.

mpg from 26 mpg. The requirements for light trucks, however, were actually lowered to 20 mpg.[233]

In sum, just four months after signing the framework convention on climate change and promising the world at the Rio Earth Summit "forceful action" on climate change and international cooperation, President Bush signed the Energy Policy Act of 1992 that would further a generation-long dependence on fossil fuels and growth in greenhouse gas emissions. This aptly captures the Bush Administration's position on climate change: admit that it's happening on the one hand, but at the same time, cast doubt on the science while supporting the fossil fuel industry and expanding fossil fuel development on the other hand.

V. Clinton Administration (1993 – 2001)

The Clinton Administration came into office in 1993 with a clear understanding of the dangers of climate change and with stated determination to act to meet that challenge. Vice President Al Gore had years before established himself as a national and international leader on the climate issue, and his 1992 book, *Earth in the Balance*, focused attention on the need for far-reaching climate action and became a best seller. In a very pertinent passage in the book, Gore wrote: "We can believe in the future and work to achieve it and preserve it, or we can whirl blindly on, behaving as if one day there will be no children to inherit our legacy."[234] Moreover, the responsibility to move forward on the UNFCCC, give substance to its ultimate objective, and breathe life to its commitments had fallen to the Clinton Administration.

President Clinton consistently acknowledged the threat and the necessity of taking action, starting just after taking office with his Earth Day address on April 21, 1993: "Unless we act now, we face a future . . . where our children's children will inherit a planet far less hospitable than the world in which we came of age."[235] During that address, he announced his pledge to cut emissions to 1990 levels by 2000.[236]

Members of the new administration also spoke of the need to address climate change, with Vice President Gore leading the way. Agencies such as EPA and DOI continued to issue reports consistent with the scientific consensus on climate change and anticipating severe impacts. The IPCC, meanwhile, issued its Second Assessment Report in 1995.[237] Undersecretary of State Timothy E. Wirth heralded the Second Assessment Report and said that, "the world's scientists

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[233] Pew, History of Fuel Economy, April 2011, available at http://www.pewtrusts.org/~/media/assets/2011/04/history-of-fuel-economy-clean-energy-factsheet.pdf. Ex. E-137.
[234] Al Gore, Earth in the Balance: Ecology and the Human Spirit, 1992.
[235] William Clinton, Remarks on Earth Day, April 21, 1993. Ex. E-138.
[236] *Id*.
[237] Intergovernmental Panel on Climate Change, IPCC Second Assessment, Climate Change 1995, A Report of the Intergovernmental Panel on Climate Change, 1995. https://www.ipcc.ch/pdf/climate-changes-1995/ipcc-2nd-assessment/2nd-assessment-en.pdf.

have reached the conclusion that the world's changing climatic conditions are more than the natural variability of weather. Human beings are altering the Earth's natural climate system."[238]

Though the U.S. participated importantly in the international negotiations leading to the signing of the Kyoto Protocol in 1998, indeed Vice President Gore participated personally, Congress never ratified that treaty. The prospects for ratification were so bleak, the agreement was never sent to the Senate. The federal government, taken as a whole, effectively abandoned the promises it had just made, thus pushing the growing burden of climate impacts onto the children who, in Vice President Gore's words, would inherit our "environmental legacy."[239] These actions thus presented a stark juxtaposition between the U.S. commitment to an international climate convention steeped in the concrete promises just reviewed, and the default on those commitments in favor of the fossil fuel status quo. This historical moment embodies the reckless and knowing disregard not merely of knowledge that could prevent great harm but also of clear legal commitment to act on that knowledge. Meanwhile, carbon emissions rose steadily throughout the 1990s as fossil fuel growth and consumption continued during the Clinton years.

A. Government Knowledge

1. <u>The Clinton Administration Understood Climate Science and Recognized the Growing Domestic and International Consensus as to the Causes and Projected Impacts of Climate Change.</u>

Knowledge of climate science continued to solidify and strengthen both within and outside the Administration. The Clinton Administration oversaw the release of multiple climate scientific assessments by federal agencies.[240] Several examples are worth mentioning. A 1993 EPA report noted that, "the atmospheric concentration of CO_2 is increasing at the rate of about 1.8ppm/year (0.5%/year)," and that "[t]he current concentration is higher than at any time in the last 160,000 years."[241] The 1993 EPA Report further recognized that drastic reductions in anthropogenic greenhouse gas emissions were needed to stabilize atmospheric CO_2 concentrations, otherwise "CO_2 concentrations [of] (450 to 500 ppm) . . . will be reached within a reasonably short time (assuming current emissions rates) . . . ."[242]

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[238] Timothy E. Wirth, Statement at the Second Conference of the Parties, Framework Convention on Climate Change, July 17, 1996. Ex. E-139 p. 2.
[239] Al Gore, Remarks at the SE Regional Climate Change Impacts Meeting, Vanderbilt University, Nashville, Tennessee, June 25, 1997. Ex. E-140 at 2.
[240] *See, also,* U.S. Congress, Office of Technology Assessment, Preparing for an Uncertain Climate: Volume 1, OTA-0-567, Washington D.C., October 1, 1993. Ex. E-141; White House Domestic Policy Council, Climate Change: State of Knowledge. Ex. E-142; National Science and Technology Council and the Institute of Medicine/National Academy of Sciences, Conference on Human Health and Global Climate Change: Summary of Proceedings, Washington, D.C., 1996. Ex. E-143.
[241] U.S. Environmental Protection Agency, Effects of CO_2 and Climate Change on Forest Trees, April 1993. Ex. E-144 at 22-23.
[242] *Id.* at 24.

A February 1993 State Department "policy decision paper" recognized: "The best scientific evidence indicates that the continued increase in greenhouse gas concentrations will cause the global climate to change."[243] Importantly, the document recognized that, in the context of achieving the UNFCCC's "ultimate objective," *stabilizing* atmospheric greenhouse gas concentrations "would require dramatic (60 percent) reductions in current greenhouse gas emissions," and this could only be achieved within the United States through additional policy measures.[244]

In October 1993, Katie McGinty, from CEQ, circulated a memorandum on the President's Climate Action Plan. The memorandum included a suite of other documents; one was titled "State of Scientific Understanding of Climate Change."[245] This document outlined what climate scientists understood "very well" and "reasonably well" by that time, which was consistent with what prior administrations understood, as reviewed here.[246] President Clinton clearly grasped the gravity of climate change. In his October 1993 remarks at the unveiling of his Climate Action Plan, President Clinton stated that climate change "is a threat to our health, to our ecology, and to our economy."[247]

CEQ continued to issue clear warnings and acknowledgment of the threat. In its 1996 report (issued in 1997), CEQ noted: "The average global temperature is projected to rise 2 to 6 degrees over the next century, leading to increased flood and drought, rising sea levels, agricultural disruption, the spread of infectious disease and other health effects. The longer we wait to reduce our emissions, the more difficult the job, and the greater the risks."[248] In its 1997 annual report (issued in 1998) CEQ stated: "Within a span of just 100 years, the United States became the world's largest producer and consumer of fossil fuels," and, "[s]ince 1860, it is estimated that global CO_2 concentrations have increased from about 280 parts per million to about 360 parts per million today, or about 30 percent. Roughly half of that increase has occurred since 1970."[249]

Internationally, the Second IPCC report in 1995 warned of a worsening problem presented by continued atmospheric CO_2 buildup: "With the growth in atmospheric concentrations of greenhouse gases, interference with the climate system will grow in magnitude and the likelihood of adverse impacts from climate change that could be judged dangerous will become

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243 U.S. Department of State, PRD-12/Global Climate Change Policy Decision Paper. Ex. E-127 at 1.
244 *Id.* at 1-2.
245 Katie McGinty, Memorandum to the President and Vice President, Climate Change Action Plan, October 18, 1993. Ex. E-145 at 18.
246 J.D. Mahlman, D. Albritton, and R.T. Watson, State of Scientific Understanding of Climate Change, included in Katie McGinty, Memorandum to the President and Vice President, Climate Change Action Plan, October 8, 1993. Ex. E-146.
247 William J. Clinton, Remarks at the White House Conference on Climate Change, Unveiling of President Clinton's Climate Action Plan, October 19, 1993. Ex. E-147.
248 Council on Environmental Quality, Along the American River: The 1996 Report of the Council on Environmental Quality, 1997. Ex. E-148 at xi.
249 Council on Environmental Quality, The 1997 Report of the Council on Environmental Quality, 1998. Ex. E-149 at 163, 194.

greater."[250] In an October 22, 1997 speech to the National Geographic Society, President Clinton endorsed the IPCC's findings, saying: "Average temperatures are rising. Glacial formations are receding. Clinton also stated: "make no mistake, the problem is real. And if we do not change our course now, the consequences sooner or later will be destructive for America and for the world."[251]

2. Clinton Administration Officials Understood the Risks Climate Change Posed to the Nation's Youth and Future Generations, and Their Responsibility to Protect Future Generations from These Risks.

As early as his April 1993 Earth Day speech, President Clinton issued a stark warning about the threat of climate change and said that "the bounty of nature is not ours to waste. It is a gift from God that we hold in trust for future generations. Preserving our heritage, enhancing it, and passing it along is a great purpose worthy of a great people."[252] Two years later on Earth Day 1995, President Clinton remarked: "This continent is our home, and we must preserve it for our children, their children, and all generations beyond."[253]

President Clinton acknowledged the necessity of acting on climate for the sake of our children on multiple other occasions. In remarks to the Business Roundtable, on June 12, 1997, he said: "Let's find a way to preserve the environment, to meet our international responsibilities, to meet our responsibilities to our children, and grow the economy at the same time."[254] On July 24, 1997, the President again spoke eloquently at a climate change discussion at The White House:

> To me, we have to see this whole issue of climate change in terms of our deepest obligations to future generations. . . . It is obvious that we cannot fulfill our responsibilities to future generations unless we deal responsibly with the

[250] IPCC, Second Assessment: Climate Change 1995, A Report of the Intergovernmental Panel on Climate Change, p. 3, https://www.ipcc.ch/pdf/climate-changes-1995/ipcc-2nd-assessment/2nd-assessment-en.pdf.
[251] William J. Clinton, Remarks at the National Geographic Society, October 22, 1997, http://www.presidency.ucsb.edu/ws/?pid=53442. Ex. E-150 at 3. *See also* Katie McGinty, Dan Albritton, and Jerry Melillo, Press Briefing, Climate Change Briefing, July 24, 1997. Ex. E-151 at 7 (Dan Albritton: "this is not the view of one scientist, this is the view of thousands of scientists who were asked to give their current statement of scientific understanding. I believe that those statements made by the entire scientific community are of high value to decision-makers in government and industry and those who acquaint the public with such complex things.").
[252] William J. Clinton, Remarks on Earth Day, April 21, 1993. Ex. E-138.
[253] William J. Clinton, Remarks on the 25th Observance of Earth Day in Havre de Grace, Maryland, April 21, 1995. Ex. E-152.
[254] William J. Clinton, Remarks to the Business Roundtable, Washington, DC, June 12, 1997. Ex. E-153 at 10.

> challenge of climate change. . . . I believe the science demands we face this challenge now. I'm positive that we owe it to our children.[255]

On October 6, 1997, at The White House Conference on Climate Change, President Clinton again referenced the younger generation: "We do not want the young people who sat on these steps today, for whom 33 years will also pass in the flash of an eye, to have to be burdened or to burden their children with our failure to act."[256]

Vice President Gore also often spoke of the peril that government refusal to change our nation's energy system posed for children/future generations. The Vice President remarked at the July 24, 1997 climate change discussion at The White House that "all of this gives rise to a great concern that we are committing future generations to a planet that is altered in profound ways that can cause great harm to future generations."[257]

The Clinton Administration's focus on protecting children from environmental harms is further reflected in a 1996 EPA report announcing a national agenda to protect children's health from environmental threats.[258] EPA's agenda was reinforced by a 1997 Executive Order (EO 13045), which set out that "[e]ach Federal agency: (a) shall make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children; and (b) shall ensure that its policies, programs, activities, and standards address disproportionate risks to children that result from environmental health risks or safety risks."[259]

On April 5, 1995, Timothy E. Wirth, then Undersecretary of State, spoke at the UNFCCC Conference of the Parties. He noted the scientific consensus on climate change and the risk it posed to future generations. "Every major peer-reviewed study has suggested that the most likely scenario is for a 3 to 8 degree F warming if carbon dioxide doubles from preindustrial levels. By increasing the concentration of greenhouse gases in the atmosphere at a rate unknown in all of human history, we are rolling the dice – gambling with our children's and grandchildren's future."[260]

The CEQ also issued a warning referencing our children. Its 1996 report states: "Our rising emissions of greenhouse gases have begun to affect the world's climate, and unless we take

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[255] William J. Clinton and Al Gore, Opening Remarks by the President and the Vice President at Discussion on Climate Change, The White House, July 24, 1997. Ex. E-154 at 3-5.
[256] William J. Clinton, Opening Remarks at the White House Conference on Climate Change, October 6, 1997. Ex. E-155 at 5.
[257] William J. Clinton and Al Gore, Opening Remarks by the President and the Vice President at Discussion on Climate Change, The White House, July 24, 1997. Ex. E-154 at 2.
[258] U.S. Environmental Protection Agency, National Agenda to Protect Children's Health from Environmental Threats, 1996. Ex. E-156.
[259] Executive Order 13045, Protection of Children from Environmental Health Risks and Safety Risks, Fed. Reg, Vol. 62, No. 78, 1997. Ex. E-157 at 1.
[260] Timothy E. Wirth, Undersecretary of State, Remarks at the First Conference of the Parties to the Framework Convention on Climate Change, April 5, 1995. Ex. E-158 at 3.

action to reduce them, our children and grandchildren will pay the price."[261] The Proceedings of the September, 1995 Conference on Human Health and Climate Change, organized by the National Science and Technology Council and the Institute of Medicine/National Academy of Sciences, also contained several references to the particular vulnerability of children to climate change impacts, especially increasingly frequent and severe heatwaves.[262]

3. <u>The Clinton Administration Understood that Severe Climate Impacts Would Result from Unrestrained Greenhouse Gas Emissions.</u>

The Clinton Administration was also well aware of the likely impacts associated with climate change such as rising seas and coastal inundation, resource strains, spread of infectious diseases (particularly to children), biodiversity loss, increased conflict, and extreme heat and precipitation.

Undersecretary Timothy E. Wirth, speaking at the Conference of the Parties (COP) in April 1995, recognized, "The steady buildup of greenhouse gases in our atmosphere threatens to raise sea levels, change hydrological cycles and damage many of the world's ecosystems."[263] A year later on July 17, 1996, he again spoke at the Second Conference of the Parties held in Geneva, Switzerland: "Human health is at risk from projected increases in the spread of diseases like malaria, yellow fever and cholera; Food security is threatened in certain regions of the world; Water resources are expected to be increasingly stressed. . . . Coastal areas – where a large percentage of the global population lives – are at risk from sea level rise."[264]

Vice President Gore delivered remarks at the Conference on Human Health and Global Climate Change in September 1995, which was organized by the White House and EPA. His remarks show a keen understanding of climate science, particularly the projected effects of atmospheric carbon loading on humans and particular sectors of society, including children:

> How will global warming affect us? There are clearly profound implications at the regional level for food security, water supplies, natural ecosystems, loss of land due to sea level rise, and human health. A temperature increase of 2 to 8 degrees Fahrenheit is projected to double heat-related deaths in New York City, and triple the number of deaths in Chicago, L.A. and Montreal. And an increase of 8 degrees Fahrenheit may be correlated with an increase in the heat/humidity index of 12 to 15 degrees. The very young, the elderly, and the poor will be the ones most at risk. So will those with chronic cardiovascular and respiratory diseases...

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[261] Council on Environmental Quality, Along the American River: The 1996 Report of the Council on Environmental Quality, 1997. Ex. E-148 at xi.

[262] National Science and Technology Council and the Institute of Medicine/National Academy of Sciences, Conference on Human Health and Global Climate Change: Summary of Proceedings, Washington, D.C., 1996. Ex. E-143 at 9, 58.

[263] Timothy E. Wirth, Undersecretary of State, Remarks at COP, April 5, 1995. Ex. E-158 at 3.

[264] Timothy E. Wirth, Undersecretary for Global Affairs on behalf of the United States of America, Statement at the Second Conference of the Parties, Framework Convention on Climate Change, July 17, 1996. Ex. E-139 at 2.

> Changing temperatures and rainfall patterns are predicted to also increase the spread of infectious diseases. Insects that carry disease organisms may now move to areas that were once too cold for them to survive. These new breeding sites and higher temperatures may also speed reproduction. Diseases we had hoped were just a memory in this country are suddenly a renewed threat.[265]

Speaking at a climate change discussion at The White House on July 24, 1997, the President noted the potential consequences of climate change:

> If we fail to act, scientists expect that our seas will rise one to three feet, and thousands of square miles here in the United States, in Florida, Louisiana, and other coastal areas will be flooded. Infectious diseases will spread to new regions. Severe heat waves will claim lives. Agriculture will suffer. Severe droughts and floods will be more common. These are the things that are reasonably predictable.[266]

Federal agencies during the Clinton Administration were also in the process of developing increasingly sophisticated knowledge of the present and projected impacts to specific ecosystems. For example, in its April, 1993 report concerning the impacts of climate change on forests, the EPA found:

> Changes in soil conditions due to loss of forest cover could slow forest reestablishment. Consequently, there could be a shift in area from forest to non-forest vegetation. Fire frequencies are likely to increase in the region given increased temperatures, unchanged precipitation and higher potential evapotranspiration. . . . . [T]he distribution and composition of forests in Washington and Oregon could change substantially. . . . In Central Oregon, total forested area is projected to decrease by almost half under a 5°C warming.[267]

A 2000 U.S. Forest Service report, "The Impact of Climate Change on America's Forests," further solidified knowledge amongst federal agencies of the particular vulnerabilities of the nation's forests to climate change.[268] The Forest Service Report rather presciently projected "longer fire seasons and potentially more frequent and larger fires in all forest zones (even those

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[265] National Science and Technology Council and the Institute of Medicine/National Academy of Sciences, Conference on Human Health and Global Climate Change: Summary of Proceedings, Washington, D.C., 1996 (Al Gore, The Interplay of Climate Change, Ozone Depletion, and Human Health, excerpts from Vice President Al Gore's remarks at the Conference on Human Health and Global Climate Change, September 11, 1995). Ex. E-143 at 3-4.

[266] William J. Clinton and Al Gore, Opening Remarks by the President and the Vice President at Discussion on Climate Change, The White House, July 24, 1997. Ex. E-154 at 4.

[267] U.S. Environmental Protection Agency, Effects of CO_2 and Climate Change on Forest Trees, April 1993. Ex. E-144 at 17-18 (internal citation omitted).

[268] U.S. Department of Agriculture, Forest Service, The Impact of Climate Change on America's Forests: A Technical Document Supporting the 2000 USDA Forest Service RPA Assessment, 2000. Ex. E-159.

that do not currently support fire)," and confirmed that "'improved forest management' appears to offer the most cost-effective means to sequester additional C in forest ecosystems in the short term."[269]

Federal agencies were also increasingly aware of the risks of climate change-induced sea level rise to coastal ecosystems. A June 1997 report by the U.S. Geological Survey recognized that, according to IPCC sea-level rise projections "major portions of the coastal zone would be permanently flooded."[270] The USGS Report also found that sea level rise could increasing the severity of storm surge and increase the existing vulnerability of coastal wetlands.[271]

The Department of Interior, meanwhile, recognized the risks climate change posed to public lands, as evidenced by its May 1997 report, Climatic Change in the National Parks, Wildlife Refuges and Other Department of Interior Lands in the United States."[272] The report found that

> The climate that has helped shape the vegetation and wildlife and other characteristics of the DOI lands is expected to shift, while the boundaries of the natural protected areas (parks, refuges, wilderness areas and other DOI lands) remain fixed. . . . [T]he basic vulnerability of DOI lands under these climatic conditions may be characterized by species that fail to migrate, fail to adapt, migrate to a less-protected environment, or are otherwise placed at a competitive disadvantage.[273]

Finally, federal agencies were gaining increasing knowledge of the projected regional differentiation in climate change impacts.[274]

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[269] *Id.* at 34, 128 (internal quotations omitted).
[270] U.S. Geological Survey, Coastal Wetlands and Global Change: Overview, June 1997. Ex. E-160 at 4.
[271] *Id.* at 1.
[272] U.S. Department of the Interior, Climate Change in the National Parks, Wildlife Refuges and Other Department of Interior Lands in the United States, May 1997. Ex. E-161.
[273] *Id.* at 1.
[274] *See, e.g.*, Katie McGinty, Dan Albritton, and Jerry Melillo, Press Briefing, Climate Change Briefing, July 24, 1997. Ex. E-151 at 9 (Jerry Melillo of OSTP discussing melting permafrost in Alaska from climate change and that this could make it difficult to keep rural airports functioning and roads flat – two essential ways that people move around Alaska); The White House, Global Climate Change: An East Room Roundtable, July 24, 1997. Ex. E-162 at 4-5 (a White House roundtable meeting discussing loss of sugar maples in New England Forests, submergence of salt marshes in Louisiana, and loss of glacial areas in Glacier National Park.); Gene Sperling, Katie McGinty, and Daniel Tarullo, Memorandum for the President, Climate change scenarios, September 15, 1997. Ex. E-163 at 16 (a memorandum to President Clinton discussing "a rise in sea levels that will inundate more than 9000 square miles in the United States (with Florida and Louisiana most vulnerable)," from a temperature increase of 2-6.5°F above pre-industrial levels.).

B. Government Action

1. The Byrd-Hegel Resolution, the Fall of the Kyoto Protocol, and the Rise of Debilitating Partisanship

The Kyoto Protocol was the first major agreement aimed at implementing the UNFCCC and achieving its "ultimate objective" to "stabiliz[e] greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[275] It was signed by roughly 190 countries that are parties to the convention, and was adopted in Kyoto, Japan in December of 1997.[276] In pertinent part, the protocol provided that the developed country parties (what the protocol called "Annex I" parties), but not the developing countries, agreed to reduce their greenhouse gases 6-8 percent below their 1990 levels by the 2008-2012 period.[277] The U.S. target was 7 percent.[278]

As the protocol was being negotiated, coal state Senator Robert Byrd and his colleague Senator Chuck Hegel introduced Senate Resolution 98 in June of 1997, and it promptly passed 95-0 the following month.[279] The Resolution expressed the sense of the Senate that no protocol was acceptable unless it included the developing countries and would not harm the U.S. economy.

The senators understood perfectly that they had just thrown a spanner into the Kyoto works. Contemporaneous reporting identified that, "[w]ithout the participation of the United States, the leading source of waste industrial gases, the agreement would collapse."[280] The developing world was adamant that it was not ready to undertake binding obligations and that the rich countries, those responsible for most past and current emissions, must act first and foremost. The issue of their inclusion was one of the hottest ones at Kyoto.

In order to strengthen public understand of the climate issue, and thus improve its political prospects, and to salvage a stalemated negotiation in Kyoto, the Clinton Administration undertook two important initiatives. In October 1997, headlined by the White House Conference on Global Climate Change, the Administration launched a wide-ranging and extensive public

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[275] United Nations, Framework Convention on Climate Change, 1992. Ex. E-130 at Article 2; United Nations, Kyoto Protocol to the United Nations Framework Convention on Climate Change, 1997. Ex. E-164.
[276] John Cushman, U.S. Signs a Pact to Reduce Gases Tied to Warming, *The New York Times*, Nov. 13, 1998, https://www.nytimes.com/1998/11/13/world/us-signs-a-pact-to-reduce-gases-tied-to-warming.html. Ex. E-165.
[277] United Nations, Kyoto Protocol to the United Nations Framework Convention on Climate Change, 1997. Ex. E-164.
[278] *Id.*
[279] S.Res.98, A resolution expressing the sense of the Senate regarding the conditions for the United States becoming a signatory to any international agreement on greenhouse gas emissions under the United Nations Framework Convention on Climate Change, 1997.
[280] John Cushman, U.S. Signs a Pact to Reduce Gases Tied to Warming, *The New York Times*, Nov. 13, 1998, https://www.nytimes.com/1998/11/13/world/us-signs-a-pact-to-reduce-gases-tied-to-warming.html. Ex. E-165.

education and media campaign aimed at communicating the message that climate change was real and was a serious problem.[281] Then, in December Vice President made a special trip to Kyoto to help salvage the negotiations.

Both actions underscore the seriousness of the Clinton Administration's desire to move the issue forward, but in the end neither was successful in the U.S. context. The Kyoto Protocol emerged from final negotiations with the terms described above, thus guaranteeing its easy defeat in the Senate. As a result, the Clinton Administration never submitted it to the Senate for ratification and the U.S. never joined, thus doing serious damage to the overall international process.

Meanwhile, the public education effort took a strange turn. It appears from studies of the effects of that effort on public attitudes that it sharpened the partisan divide on climate, a divide that would only grow in the future and become more debilitating. For example, one sophisticated poling effort led by Stanford University found that the percentage of strong Democrats who believed that global warming would happen in the future held steady at about 75 percent, before and after the educational effort, but that the percentage of strong Republicans actually fell from 67 to 55 percent! When the issue was seen as being championed by Democrats, Republicans fled.[282] The climate issue has become steadily more partisan, and progress on climate is now stymied in part by an entrenched partisan gridlock. A huge partisan divide is one factor contributing to the inability of our political system to act meaningfully to confront the climate crisis.

2. <u>The Clinton Administration Continued the U.S.'s Commitment to a Non-Renewable, Fossil Fuel-Based Energy System.</u>

Despite the Clinton Administration's acknowledgement of the climate issue and impacts, fossil fuels continued to be central to the nation's energy system under President Clinton. President Clinton's Climate Change Action Plan released October 18, 1993, sought to decrease U.S. greenhouse gas emission to 1990 levels by the year 2000, but the plan was not integrated into energy policy or implemented with real teeth.[283] Overall, U.S. GHG emissions (see Figure 10) and fossil use (see Figure 11) continued to increase during the 1990s.[284]

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[281] *See* William J. Clinton, Remarks by the President at White House Conference on Climate Change, October 6, 1997. Ex. E-155.; U.S. General Accounting Office, Global Warming: Administration's Proposal in Support of the Kyoto Protocol, June 4, 1998. Ex. E-166.

[282] Jon A. Krosnick et al., American Opinion on Global Warming: The Impact of the Fall 1997 Debate, Resources 133, 1988. Ex. E-167 at 8.

[283] William J. Clinton and Al Gore, Jr., Climate Change Action Plan, October 1993. Ex. 168 at 7. *But see,* Q&A document on the Plan cautioned that, "[t]his plan by itself is unlikely to stabilize emissions at 1990 levels under reasonable assumptions regarding economic growth, the diffusion of existing technologies, and new technology development." Selected Questions and Answers on the President's Climate Change Action Plan, document included in the Memorandum to the President and the Vice President from Katie McGinty, October 8, 1993. Ex. E-169 at 8.

[284] Jonathan L. Ramseur, U.S. Greenhouse Gas Emissions: Recent Trends and Factors, Congressional Research Service, November 24, 2014. Ex. E-170.

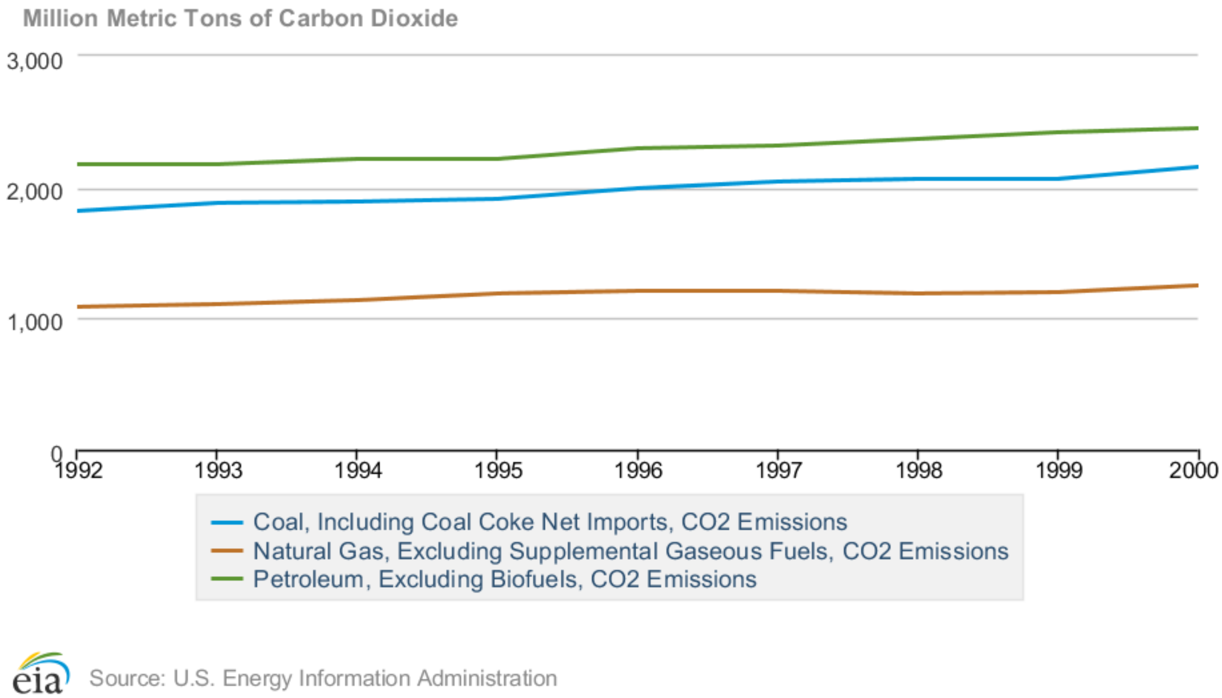

Figure 10: Carbon Dioxide Emissions from Energy Consumption by Source.[285]

[285] Data source: U.S. Energy Information Administration Monthly Energy Review, July 2018, https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf. Ex. E-171.; Chart source: U.S. Energy Information Administration Total Energy Data Browser, https://www.eia.gov/totalenergy/data/monthly, accessed July 31, 2018

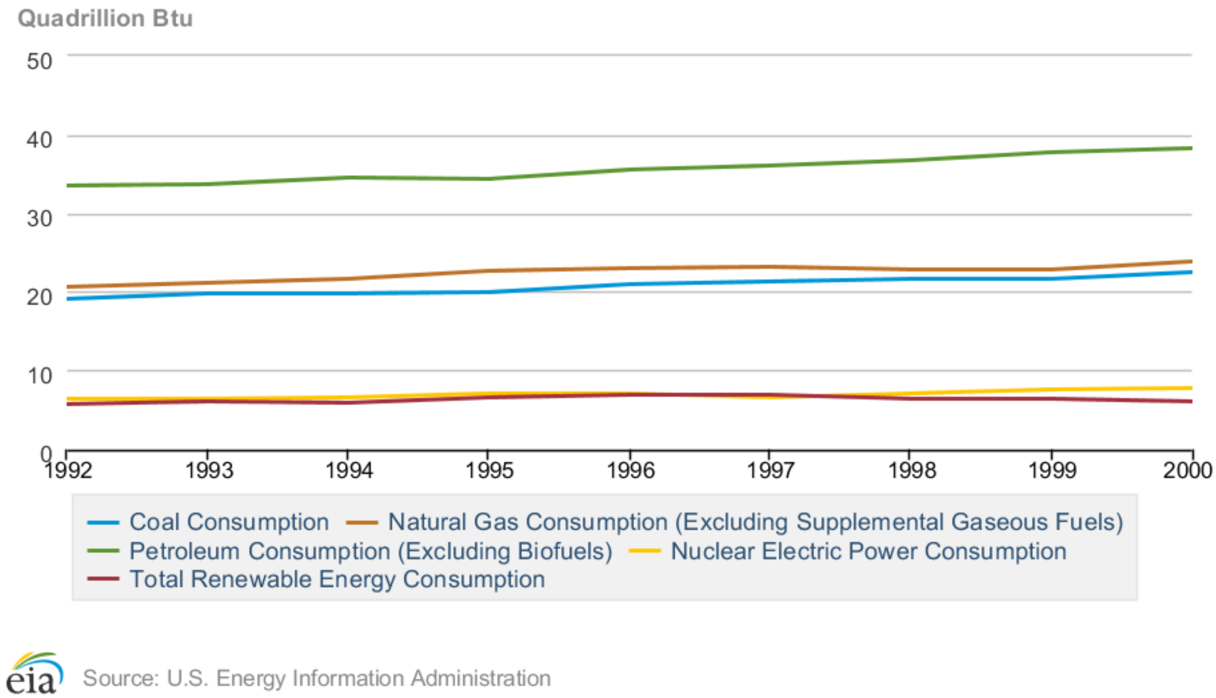

Figure 11: Primary Energy Consumption by Source.[286]

As Figure 11 shows, there was an increase in consumption of energy from petroleum, natural gas, and coal, while the consumption of energy from renewable sources remained steady. While some of the graphic presentations reflect only modest changes in U.S. energy use and emissions over time, it is important to remember the bathtub analogy: even if the flow into the tub (atmosphere) is constant, the tub will fill up. If you want to stop the build-up, you have got to turn off the spigot! U.S. GHG emissions have remained extremely high throughout the long period being examined, and have contributed greatly to "filling up the (atmospheric) tub." Estimates vary, but a common result in climate modeling today is that climate security requires that GHG emissions decline steadily to near zero by or before mid-century.

In addition to the Climate Action Plan's support for natural gas,[287] other federal agencies actively supported expanding fossil fuels. The Department of Energy, through its Office of Fossil Energy, continued to promote fracking and natural gas. An October 1999 report, "Environmental Benefits of Advanced Oil and Gas Exploration and Production Technology," touted the promise of natural gas drilling:

> Fortunately, in recognition of its environmental desirability, natural gas use has grown. Major advances in natural gas technology and supply have occurred over the past 25 years. New technology for finding, producing, transporting, storing,

[286] *Id.*
[287] *See* William J. Clinton and Al Gore, Jr., Climate Change Action Plan, October 1993. Ex. E-168 at 20. (The Plan directed EPA, DOE, and FERC to encourage the use of natural gas.)

> and using natural gas has been developed. Increasingly higher estimates of economically producible natural gas resources have improved the market's confidence in the reliability of long-term supplies.[288]

The Clinton Administration directly supported the oil and gas industry in a number of ways, including by providing preferential tax treatment to the domestic oil and gas industry to encourage oil and gas production, providing federal funding for development of new technologies to increase oil extraction productivity, and providing continued support through research and development funding related to fossil fuel exploration to new places such as the Arctic and Alaska.[289] For example, the Administration supported legislation to reduce federal royalty payments for offshore drilling.[290] While domestic oil production declined during the Clinton Administration, oil imports increased significantly.

EPA had also proposed a "CO_2 cap with emissions trading" as "perhaps the most economically efficient mechanism possible for achieving emission reduction goals, irrespective of the level of the target."[291] Despite the fact that the EPA had received legal advice from the Office of General Counsel that CO_2 was an air pollutant under the CAA, and EPA had the authority to regulate CO_2 under the CAA, it declined to do so.[292]The Clinton Administration also broke a campaign pledge in failing to increase the federal CAFE standard, with the Administration arguing that "the impact of CAFE on GHG emissions before the year 2000 would be minimal" and "isn't the silver bullet it's cracked up to be."[293]

The DOE, especially the DOE Office of Energy Efficiency and Renewable Energy, did do some important work during the Clinton Administration to increase research and funding for renewable energy programs and implementation. For example, in 1997 DOE launched the Million Solar Roofs initiative, with the goal of installing solar energy systems on one millions buildings in the U.S. by 2010.[294] (The one million goal was hit in 2016.[295]) DOE also launched the Wind Powering America initiative in 1999, with the goal of increasing the use of wind energy throughout the U.S. and providing 5 percent of the nation's energy with wind by 2020.[296]

[288] U.S. Department of Energy Office of Fossil Energy, Environmental Benefits of Advanced Oil and Gas Exploration and Production Technology, October 1999. Ex. E-172 at 8.
[289] Domestic Policy Council, Domestic Oil and Gas Incentives, 1994. Ex. E-173 at 16, 35.
[290] Deep Water Royalty Relief Act, P.L. 104-58, November 28, 1995.
[291] *See also* Rick Morgan, Fax to Mike Toman, Post-2000 Option: CO_2, Cap & Emissions Trading for Electricity, Natural Gas, and Transportation Fuels, October 21, 1994. Ex. E-174 at 5.
[292] Johnathan Z. Cannon, Memorandum to Carol M. Browner, EPA's Authority to Regulate Pollutants Emitted by Electric Power Generation Sources, April 10, 1998. Ex. E-175.
[293] Selected Questions and Answers on the President's Climate Change Action Plan, document included in the Memorandum to the President and the Vice President from Katie McGinty, October 8, 1993. Ex. E-169 at 10.
[294] Department of Energy, Million Solar Roofs, 2003. Ex. E-176.
[295] SEIA, Solar Industry Research Data, accessed August 3, 2018, https://www.seia.org/solar-industry-research-data. Ex. E-177.
[296] L.T. Flowers and P.J. Dougherty, Wind Powering America: Goals, Approach, Perspectives, and Prospects, March 2002. Ex. E-178 at 1.

The DOE also adopted new appliance and equipment efficiency standards and allocated money for research and development of renewable energy supplies and the development of efficient vehicles. However, these efforts did not bend the fossil fuel emissions curve downward.

The Clinton Administration fully acknowledged the climate problem, had abundant scientific evidence of the urgency and the dire consequences for children if action was not taken, and had policy options to bend the emissions trend downward. However, the national fossil fuel energy system and policies continued full throttle under the Clinton Administration.

VI. George W. Bush Administration (2001 – 2009)

The administration of George W. Bush enacted policies favoring fossil fuels and failed to meaningfully address the worsening problem of climate change. Despite abundant scientific evidence and warnings, including two more Assessment Reports from the Intergovernmental Panel on Climate Change (IPCC), the Bush Administration continued to encourage the nation's reliance on fossil fuels. Elements in the Administration, indeed in the Executive Office of the President, attempted to undermine public confidence in and understanding of climate science. According to a December 2007 report from the House's Committee on Oversight and Government Reform, "the Bush Administration has engaged in a systematic effort to manipulate climate change science and mislead policymakers and the public about the dangers of global warming."[297] Publicly, Bush's White House did not deny the problem of global warming. It acknowledged the risks, especially during the early days of the Administration. Yet the Administration emphasized uncertainties in order to justify delaying action; it adopted what were at best half-measures; it officially abandoned the Kyoto Protocol; and it committed the U.S. to increasing domestic fossil fuel production.

A. Government Knowledge

1. Climate Science and Climate Change

During the second Bush administration, research on carbon dioxide and other GHG emissions, as well as climate change generally, continued and climate models improved. The Bush Administration recognized climate change early on (though it also tried to emphasize uncertainties in the science). For example, in speaking at a G8 Environmental Ministerial Meeting in March 2001 in Trieste, Italy, new EPA Administrator Christine Todd Whitman remarked:

> Increasingly, there is little room for doubt that humans are affecting the Earth's climate, that the climate change we've seen during the past century is the result of human activity, and that we must continue our efforts to stop and reverse the growth in the emission of greenhouse gases. If we fail to take the steps necessary

[297] U.S. House of Representatives, Political Interference with Climate Change Science Under the Bush Administration, Committee on Oversight and Government Reform, December 2007. Ex. E-179 at i.

> to address the very real concern of global climate change, we put our people, our economies, and our way of life at risk.[298]

In May 2001, the IPCC Third Assessment Report was released and found new and even stronger evidence that global warming was caused by human activities.[299] The IPCC Report predicted that global temperatures would increase by 1.4 to 5.8 degrees Celsius by 2100.[300] In June 2001, the National Academy of Sciences published a report, in response to a request by the White House to identify uncertainties in climate science and to evaluate the findings and conclusions of the IPCC Report.[301] The NAS Report affirmed the findings of the IPCC, and rather than casting doubt on climate change, stated unequivocally: "Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise. Temperatures are, in fact, rising."[302] The report predicted warming 3 degrees Celsius by 2100.[303]

A 2002 Department of State report, "U.S. Climate Action Report – 2002," which was submitted to the UNFCCC Secretariat, reinforced the IPCC's findings. That report stated: "Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities causing global mean surface air temperature and subsurface ocean temperature to rise. . . . Carbon dioxide from fossil fuel combustion was the dominant contributor. Emissions from this source category grew by 13 percent between 1990 and 1999."[304] The Department of State report also provided detailed evidence on the impacts of climate change, finding that: 1) sea level rise would lead to the loss of coastal wetland and put coastal communities at risk; 2) increases in heat waves were likely; 3) water shortages were likely to be exacerbated; 4) temperatures during the 21st century could rise 3-9°F; 5) the global sea level rose 4-8 inches during the 20th century at a rate significantly faster than the rate over the past several thousand years; and 6) climate models were predicting up to three feet of sea level rise during the 21st century.[305] The Department of State report also found that the impacts of climate change would be worse in the 21st century than the 20th century, stating: "all climate model results suggest that warming during the 21st century across the country is very likely to be greater, that sea level and the heat index are going to rise more, and that precipitation is more likely to come in the heavier categories experienced in each region."[306]

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[298] Talking Points for Governor Christine Todd Whitman, U.S. Environmental Protection Agency at the G8 Environmental Ministerial Meeting Working Session on Climate Change, Trieste, Italy, March 3, 2001. Ex. E-180 at 1.
[299] John Houghton et al., Climate Change 2001: The Scientific Basis, Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report, May 2001, at 10.
[300] *Id.* at 13.
[301] National Academy of Sciences, Climate Change Science: An Analysis of Some Key Questions, June 2001. Ex. E-181 at Exhibit A.
[302] *Id.* at 1.
[303] *Id.*
[304] U.S. Department of State, U.S. Climate Action Report 2002: Third National Communication of the United States of America Under the United Nations Framework Convention on Climate Change, Washington, D.C., May 2002. Ex. E-182 at 4-5.
[305] *Id*. at 82, 84, 103.
[306] *Id.* at 84.

Finally, the Department of State report projected that GHG emissions would rise by 43 percent between 2000 and 2020.[307]

Evidence of the human influence on climate and the potential impacts continued to accumulate during the George Bush era. NOAA, for example, released various climate studies related to extreme weather events,[308] tropical storms and hurricanes,[309] coral bleaching,[310] and the Arctic.[311] With respect to coral reefs, NOAA warned that reefs were currently experiencing temperatures exceeding that the reefs have experienced in the last 400,000 years and that temperature increases of 1-2°C would enough to wreak havoc and cause mass bleaching.[312]

In a hearing before the House Committee on Government Reform on July 20, 2006, the Director of the National Center for Atmospheric Research, Thomas Karl, summarized the scientific knowledge of global climate change at that time:

> In conclusion, the state of the science continues to indicate that modern climate change is affected by human influences, primarily human induced changes in atmospheric composition . . . . Recent evidence suggests there will be changes in extremes of temperature and precipitation, decreases in seasonal and perennial snow and ice extent, sea level rise, and increases in hurricane intensity and related heavy and extreme precipitation.[313]

Also in 2006, NOAA published the first "State of the Arctic Report," finding that freshwater flow to the Arctic Ocean has been rising for the past several decades and will continue to rise due to climate change.[314] The report also noted that "2002–2005 has been characterized by an *unprecedented* series of extreme ice extent minima."[315] A 2006 Congressional Budget Office Report noted the intergenerational harm issue, stating that "the combustion of fossil fuels may

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[307] *Id*. at 6.
[308] National Oceanic and Atmospheric Administration, National Climatic Data Center, A Climatology of Recent Extreme Weather and Climate Events, October 2002. Ex. E-183.
[309] National Oceanic and Atmospheric Administration A, State of the Climate: Hurricanes and Tropical Storms for Annual 2005, January 2006. Ex. E-184.
[310] National Oceanic and Atmospheric Administration, A Reef Manager's Guide to Coral Bleaching, 2006. Ex. E-185.
[311] National Oceanic and Atmospheric Administration, First State of the Arctic Report, October 2006. Ex. E-186.
[312] National Oceanic and Atmospheric Administration, A Reef Manager's Guide to Coral Bleaching, 2006. Ex. E-185 at 109-110.
[313] Climate Change: Understanding the Degree of the Problem, Hearing Before the House of Representatives Committee on Government Reform, July 20, 2006. Ex. E-187 at 88.
[314] National Oceanic and Atmospheric Administration, First State of the Arctic Report, October 2006. Ex. E-186 at 24.
[315] *Id.* at 28 (emphasis added).

create external costs that are borne by society as a whole—particularly by future generations . . . ."[316] That CBO Report also stated there is a:

> possibility that greenhouse gases could build up to a critical level, or threshold, in the atmosphere and thus could trigger a rapid increase in damages. . . . In order to avoid passing such a threshold, it may be necessary to develop fundamentally new technologies that could provide a large share of the world's energy needs without releasing carbon or that could sequester similarly large shares of carbon emissions.[317]

The IPCC finalized its Fourth Assessment Report in 2007. The report contained a strong acknowledgment that humans are responsible for most of the observed planetary warming: "Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic GHG concentrations."[318] In a February 2, 2007 press release on the report, Dr. Sharon Hays, the leader of the U.S. delegation at the meeting and Associate Director/Deputy Director for Science at the White House Office of Science and Technology Policy, described the IPCC Report's significance:

> This Summary for Policymakers . . . will serve as a valuable source of information for policymakers. It reflects the sizeable and robust body of knowledge regarding the physical science of climate change, including the finding that the Earth is warming and that human activities have very likely caused most of the warming of the last 50 years.[319]

Later that year, President Bush referenced the IPCC Report in remarks during a meeting on energy security and climate change. "A report issued earlier this year by the U.N. Intergovernmental Panel on Climate Change concluded both that global temperatures are rising and that this is caused largely by human activities," the President said. "When we burn fossil fuels, we release greenhouse gases into the atmosphere, and the concentration of greenhouse gases has increased substantially."[320] This statement unequivocally demonstrates the President's understanding of the basic issue.

In 2007, the U.S. Climate Change Science Program published a report, "Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations," that included various scenarios

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[316] Congressional Budget Office, Evaluating the Role of Prices and R&D in Reducing Carbon Dioxide Emissions, Sept. 2006. Ex. E-188 at 5.; *see also* Congressional Budget Office, The Economics of Climate Change: A Primer, April 2003. Ex. E-189 at 2 ("Inaction benefits people who are alive today while potentially harming future generations. Reducing emissions now may benefit future generations while imposing costs on the current population . . . .").
[317] *Id.* at 17.
[318] IPCC, Climate Change 2007: Synthesis Report, A Summary for Policymakers, 2007 at 5.
[319] Statement by the Office of Science and Technology Policy: Intergovernmental Panel on Climate Change Finalizes Report, February 2, 2007. Ex. E-190.
[320] George W. Bush, Remarks During a Meeting on Energy Security and Climate Change, September 28, 2007. Ex. E-191.

for CO_2 concentrations through the end of the 21st century, including multiple scenarios in which CO_2 concentrations were stabilized (i.e., no longer rising). While the lowest stabilization scenarios would have stabilized CO_2 concentrations at 450 ppm by 2100 (still too high), the report nonetheless illustrates that the federal government was evaluating and modeling various CO_2 concentration trajectories through the end of the 21st century.[321] The report noted that the stabilization scenarios "require[] a transformation of the global energy system" and that fossil fuel use and energy consumption must be reduced.[322]

The U.S. Climate Change Science Program, under EPA leadership, was issuing its own climate change warning in 2008, releasing a report describing threats such as more powerful hurricanes and heat waves, decreased snowpack and shrinking water supplies in the West, and spread of disease.[323] Among other important finding, the report noted there have been abrupt changes in the global climate in the past over periods of a few years to decades and that rapid changes were already being observed.[324] For example, the report noted that there have been "dramatic declines in Arctic sea ice," which models were underestimating, and the Arctic could be seasonally ice-free earlier than IPCC projections.[325] A *Washington Post* story on the report noted, "[t]he EPA report yesterday was less notable for its warnings . . . than for its source. The Bush Administration has resisted the conclusion that increasing temperatures will harm human health, but in yesterday's report, that finding was unmistakable."[326]

Prominent government climate scientists like Dr. James Hansen, meanwhile, continued to issue important warnings. An article published in *Reuters* in 2007 quoted Dr. Hansen, then-director of NASA's Goddard Institute for Space Studies, stating: "We're a lot closer to tipping points than we thought we were. If we are to have any chance in avoiding the points of no return, we're going to have to make some changes."[327]

The following year, twenty years after his landmark testimony to Congress, Dr. Hansen and nine colleagues (Dr. Hansen and two other authors were working for the federal government at the time for the Goddard Institute for Space Studies) published a very important scientific paper indicating that stabilizing the climate system requires limiting atmospheric CO_2 concentrations to a maximum of 350 parts per million – a concentration that had already been exceeded. The article found that:

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[321] CCSP, Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations (Part A), A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, Department of Energy, Washington, D.C., 2007. Ex. E-192 at 94-95.
[322] *Id.* at 99.
[323] CCSP, Our Changing Planet: The U.S. Climate Change Science Program for Fiscal Year 2009, A Report by the Climate Change Science Program and the Subcommittee on Global Change Research, July 2008. Ex. E-193.
[324] *Id.* at 25-26.
[325] *Id.* at 57-58.
[326] Warming is Major Threat to Humans, EPA Warns, *Washington Post*, July 18, 2008. Ex. E-194.
[327] Amanda Beck, Carbon cuts a must to halt warming – US Scientists, *Reuters*, December 13, 2007. Ex. E-195.

> If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, paleoclimate evidence and ongoing climate change suggest that **CO_2 will need to be reduced from its current 385 ppm to at most 350 ppm**.[328]

President Bush acknowledged the need to reduce GHG emissions, stating in 2001: "Our approach [to reduce greenhouse gas emissions] must be consistent with the long-term goal of stabilizing greenhouse gas concentrations in the atmosphere."[329] However, the Bush Administration did not take a position on what CO_2 concentration would prevent dangerous interference with the climate. As James L. Connaughton, Chairman of the CEQ under President Bush put it:

> The President has reaffirmed America's commitment to the goal of stabilizing atmospheric greenhouse gas concentrations at a level that will prevent dangerous interference with the climate. At the same time, the President noted that given current scientific uncertainties, no one knows what that level is.[330]

When Connaughton was asked again in 2007 for the White House's position on "dangerous climate change," Connaughton replied, "[w]e don't have a view on that."[331]

2. Renewables and Efficiency

As with previous administrations, the federal government during the Bush Administration was aware of renewable energy sources that could reduce reliance on fossil fuels and alleviate the threats posed by climate change.

The 2002 Department of State report, "U.S. Climate Action Report – 2002" contained a whole chapter on policies and measures that would reduce GHG emissions.[332] The Department of State Report considered specific ways to reduce GHG emissions from various sectors of the economy, including electricity, transportation, industry, buildings, agriculture and forestry, and the federal government. More specifically, the report considered ways to incentivize energy efficiency in the residential and commercial sector; ways to reduce waste and GHG emissions from industry; ways the federal government could support wind, solar, hydropower, and other renewable energy

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[328] James Hansen et al., Target Atmospheric CO_2: Where Should Humanity Aim? 2 Open Atmospheric Science Journal 217, 2008 (emphasis added).
[329] George W. Bush, President Bush Discuses Global Climate Change, The Rose Garden, June 11, 2001. Ex. E-196 at 4.
[330] James L. Connaughton, Chairman, White House Council on Environmental Quality, Statement for the Hearing Before the Committee On Commerce, Science, and Transportation, U.S. Senate, July 11, 2002. Ex. E-197 at 4-5.
[331] Jim Connaughton, Sharon Hays, and Harlan Watson, Press Briefing Via Conference Call by Senior Administration Officials on IPCC Report, November 16, 2007. Ex. E-198.
[332] U.S. Department of State, U.S. Climate Action Report 2002: Third National Communication of the United States of America Under the United Nations Framework Convention on Climate Change, Washington, D.C., May 2002. Ex. E-182 at Chapter 4.

sources; and ways to reduce GHG emissions from the transportation sector, including through the use of hydrogen as a fuel source.[333]

A 2004 GAO Report found that the Midwest has enough wind power potential "to meet a significant portion of the nation's electricity needs."[334] The GAO Report also noted that, "most of the nation's wind potential remains untapped. Wind power's growth will depend largely on the continued availability of federal and state financial incentives, including tax credits, and expected increases in prices for fossil fuels."[335] In a 2005 presentation, Dr. Harlan Watson, the Senior Climate Negotiator and Special Representative for the Department of State, set forth various federal programs that could be used to reduce GHG emissions, including fuel economy standards, energy efficiency standards, renewable energy tax incentives, hybrid/fuel cell vehicle tax incentives, clean air rules, and biological sequestration.[336] In 2006, a National Renewable Energy Laboratory report found that "[t]he potential for wind to supply a significant quantity of energy in the United States is enormous," and that 2,000-4,000 million metric tons of carbon could be avoided by 2030 through the use of wind energy.[337]

A Congressional Budget Office Report noted how different government policies can encourage the use of fossil fuels, such as federal funds for highway construction or tax provisions to promote oil and gas production, while other policies can discourage the use of fossil fuels, such as a federal gas tax, subsidies for mass transit.[338] It also observed that setting a price or cap on carbon would be a way to correct the market failure due to the negative externalities of carbon pollution and climate change.[339]As noted in a 2007 GAO report:

> [I]t is unlikely that DOE's current level of R&D funding or the nation's current energy policies will be sufficient to deploy advanced energy technologies in the next 25 years. Without sustained high energy prices or concerted, high-profile federal government leadership, U.S. consumers are unlikely to change their energy-use patterns, and the United States will continue to rely upon its current energy portfolio.[340]

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[333] *Id.* at 52-58, 64-69.
[334] U.S. Government Accountability Office, Renewable Energy: Wind Power's Contribution to Electric Power Generation and Impact of Farms and Rural Communities, 2004. Ex. E-199 at 5.
[335] *Id.* at cover page.
[336] Dr. Harlan Watson, U.S. Climate Change Policy, Presentation given in Berlin, Germany, Aug. 12, 2005. Ex. E-200.
[337] U.S. Dept. of Energy, Tackling Climate Change in the United States: The Potential Contribution from Wind Power, National Renewable Energy Laboratory, July 7-13 2006. Ex. E-201 at 1, 5.
[338] Congressional Budget Office, Evaluating the Role of Prices and R&D in Reducing Carbon Dioxide Emissions, September 2006. Ex. E-188 at 10.
[339] *Id.* at 1.
[340] U.S. Government Accountability Office, Advanced Energy Technologies: Key Challenges to Their Development and Deployment, Statement of Jim Wells Before the Subcommittee on Energy and Water Development, Committee on Appropriations, House of Representatives, February 28, 2007. Ex. E-202 at 10.

The 2007 GAO Report also noted that the percent of U.S. energy coming from renewable sources, six percent, had not increased since 1973.[341]

While the Bush Administration was aware of renewable energy sources, the Administration focused its research and development on fossil fuels and not renewable energy research. As one GAO Report from 2008 stated:

> DOE has focused its R&D on increasing domestic production primarily by improving exploration technologies, extending the life of current oil reservoirs, developing drilling technology to tap into deep oil deposits, and addressing environmental protection. DOE officials stated that if the oil R&D program continues, it would focus on such areas as enhanced oil recovery technologies and expanding production from independent producers.[342]

As noted by the GAO report, DOE's budget for renewable energy had been cut by 85%, despite the need to advance renewable energies.[343] The Administration was also aware that one of the hurdles to more widespread adoption of renewable energy sources was the low cost of fossil fuels.[344]

B. Government Action

While the robust body of scientific knowledge showed that human-caused climate change was a clear and present danger, the Bush Administration took actions that were at odds with the science. Energy lobbyists with access to the White House pushed administration officials to play up the uncertainties and play down the risks. The result was a misrepresentation of the strength of climate science by the Administration and a clear attempt to undermine the findings.

As for actual climate policies, President Bush offered only modest initiatives as he relinquished U.S. climate leadership in the international arena, and his EPA refused to regulate carbon pollution. All the while the Administration encouraged domestic fossil fuel production and oversaw an energy policy favorable to the interests of the fossil industries.

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[341] *Id.* at 4.
[342] U.S. Government Accountability Office, Advanced Energy Technologies: Budget Trends and Challenges for DOE's Energy R&D Program, Statement of Mark E. Gaffigan Before the Subcommittee on Energy and Environment, Committee on Science and Technology, House of Representatives, March 5, 2008. Ex. E-203 at 10.
[343] U.S. Government Accountability Office, Department of Energy: Key Challenges Remain for Developing and Deploying Advanced Energy Technologies to Meet Future Needs, Report to Congressional Requesters, December 2006. Ex. E-204.
[344] *Id.* at 3 (describing how the low cost of fossil fuels does not include negative externalities, such as environmental harms).

1. Misleading the Public on Scientific Findings

Evidence of political interference with scientific information as well as inappropriate influence from the oil industry appeared early in the Bush Administration. A March 2002 document faxed to CEQ's Philip Cooney from ExxonMobil's Randy Randol revealed Exxon's perspective on the state of climate science and suggested focusing more on the uncertainties. Exxon claimed that scientific knowledge of climate change was limited and suggested research be geared towards areas that could enhance doubts. It also criticized the IPCC for its "all-too-apparent bias . . . to downplay the significance of scientific uncertainty and gaps."[345]

Cooney, a former lobbyist for the American Petroleum Institute who would later go on to work for ExxonMobil, was in direct communications with the fossil fuel industry and its associated think tanks while at CEQ. He received emails[346] and memos from Myron Ebell at the Competitive Enterprise Institute, for example. One such memo dated June 3, 2002 suggested, "our only leverage to push you in the right direction is to drive a wedge between the President and those in the Administration who think that they are serving the president's best interests by pushing this rubbish,"[347] with rubbish referring to the "U.S. Climate Action Report – 2002" prepared for the UNFCCC. Cooney was later found to have played a role in manipulating scientific reports. According to a House of Representatives Committee on Oversight and Government Reform report, "CEQ Chief of Staff Phil Cooney and other CEQ officials made at least 294 edits to the Administration's Strategic Plan of the Climate Change Science Program to exaggerate or emphasize scientific uncertainties or to deemphasize or diminish the importance of the human role in global warming."[348] The House report stated:

> The Committee's 16-month investigation reveals a systematic White House effort to censor climate scientists by controlling their access to the press and editing testimony to Congress. The White House was particularly active in stifling discussions of the link between increased hurricane intensity and global warming. The White House also sought to minimize the significance and certainty of climate change by extensively editing government climate change reports. Other actions taken by the White House involved editing EPA legal opinions and op-eds on climate change.[349]

The House Committee came to "one inescapable conclusion: the Bush Administration has engaged in a systematic effort to manipulate climate change science and mislead policymakers

[345] Randy Randol, Memorandum to Phil Cooney, March 22, 2002. Ex. E-205 at 5.
[346] Myron Ebell, Competitive Enterprise Institute, Email to Philip Cooney, June 3, 2002. Ex. E-206.
[347] *Id.* at 1.
[348] U.S. House of Representatives, Political Interference with Climate Change Science Under the Bush Administration, Committee on Oversight and Government Reform, December 2007. Ex. E-179 at ii.
[349] *Id.* at 33.

and the public about the dangers of global warming."[350] When Cooney's line-by-line edits became public, the ensuing scandal was enough to force his resignation.[351]

An internal investigation also revealed climate science censoring by NASA's Public Affairs Office during the Bush Administration. According to a June 2008 NASA Office of Inspector General investigative summary:

> [O]fficials in the NASA Headquarters Office of Public Affairs did, in fact, manage the release of information concerning climate change in a manner that reduced, marginalized, and mischaracterized the scientific information within the particular media over which that office had control. Further, on at least one occasion, the Headquarters Office of Public Affairs denied media access to a NASA scientist, Dr. Hansen, due, in part, to that office's concern that Dr. Hansen would not limit his statements to science but would, instead, entertain a policy discussion on the issue of climate change.[352]

2. <u>Weak Climate Policy</u>

By the turn of the new century, it was difficult (but as we shall see, not impossible!) for any Administration to simply walk away from the climate issue. The Bush Administration addressed the issue, but not meaningfully and often harmfully.

Political interferences aside, President Bush at least superficially accepted climate science and announced measures in response. "[M]y Administration is committed to a leadership role on the issue of climate change. We recognize our responsibility, and we will meet it at home, in our hemisphere, and in the world," the President said in 2001.[353] One approach the Administration took was, rather than to take steps to actually reduce GHG emissions and fossil fuels use, to instead emphasize the need for more research. Consistent with this approach, in 2002, the President announced the creation of the interagency Climate Change Science Program (CCSP) to coordinate and direct U.S. research efforts in the area of climate change.[354] The research was to be conducted as part of the U.S. Global Change Research Program (GCRP) and Climate Change Research Initiative (CCRI). Despite creating the CCSP, it was never given enough funding to fully carry out its research agenda and programs. As a NRC Report explained, "the present CCSP budget does not appear to be capable of supporting all of the activities in the strategic

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[350] *Id.* at i.
[351] Andrew C. Revkin, "Editor of Climate Reports Resigns," *The New York Times*, June 11, 2005, https://www.nytimes.com/2005/06/10/politics/editor-of-climate-reports-resigns.html. Ex. E-207.
[352] National Aeronautics and Space Administration OIG, Investigative Summary Regarding Allegations that NASA Suppressed Climate Change Science and Denied Media Access to Dr. James E. Hansen, a NASA Scientist, June 2008. Ex. E-208 at 47.
[353] President Bush Discusses Global Climate Change, June 11, 2001. Ex. E-196 at 3.
[354] *See* National Research Council, Implementing Climate Change and Global Change Research: A Review of the Final U.S. Climate Change Science Program Strategic Plan, 2004. Ex. E-209 at 1.

plan. . . . There is no evidence in the plan or elsewhere of a commitment to provide the necessary funds for these newer or expanded program elements."[355]

The President also made a pledge to reduce greenhouse gas emissions relative to economic activity – otherwise known as reducing GHG intensity. Specifically the President called for a GHG intensity reduction of 18 percent over 10 years. Speaking in Silver Spring, Maryland on February 14, 2002, he said:

> My administration is committed to cutting our Nation's greenhouse gas intensity . . . by 18 percent over the next 10 years. This will set America on a path to slow the growth of our greenhouse gas emissions and, as science justifies, to stop and then reverse the growth of emissions.[356]

It should be noted that reducing GHG intensity – the amount of GHG emitted per dollar of GDP – which President Bush claimed "sciences justifies," doesn't actually reduce total emissions unless intensity is declining faster than the economy is growing. President Bush's proposal called for an intensity decline of 2 percent a year, so that even if achieved (it wasn't), his proposal was unlikely to stabilize much less reduce actual U.S. GHG emissions.

President Bush also approved R&D for climate change science and technology. According to an open letter written by Bush science advisor John Marburger and CEQ Chair James Connaughton in February 2007, President Bush "committed nearly $3 billion annually – more than any other country in the world – to climate change technology research and deployment programs" from 2003 to 2006.[357] This was spent on energy efficiency technology programs, consumer information campaigns, and incentives, but also on research into sequestration of carbon dioxide, which was planned to be sold abroad by U.S. coal companies, and adaptation measures.[358]

President Bush's EPA started to work on a multi-pollutant cap-and-trade initiative called Clear Skies. At one point early in the legislative process carbon dioxide was considered for inclusion.[359] Ultimately, and even though the eventual bill excluded carbon dioxide as a pollutant, the Clear Skies legislation never passed Congress. Furthermore, the White House declared it would veto climate legislation such as the Lieberman-Warner Climate Security Act[360]

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[355] *Id.*
[356] George W. Bush, Remarks by the President on Climate Change and Clean Air, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, February 14, 2002. Ex. E-210.
[357] George W. Bush, Open Letter on the President's Position on Climate Change, February 7, 2007. Ex. E-211.
[358] *Id.*
[359] Governor Christine Todd Whitman, Administrator of the U.S. Environmental Protection Agency, Remarks at The Business Council, 2001. Ex. E-212 at 3-4.
[360] Statement of Administration Policy: S. 3036 - Lieberman-Warner Climate Security Act, June 2, 2008. Ex. E-213.

and moved to block an EPA proposal for regulating carbon emissions from mobile sources.[361] The Administration also opposed a national renewable energy portfolio standard, that would have increased renewable energy, and it opposed increasing the CAFE standards (by regulation or statute), which remained at 27.5 mpg throughout the Bush presidency.[362]

The Bush Administration also reversed a Clinton Administration determination that GHGs could be regulated under the Clean Air Act, taking the position that GHGs were not air pollutants.[363] However, after the Supreme Court issued its decision in *Massachusetts v. EPA*, the President directed the EPA, DOT, and other federal agencies to "take the first steps toward regulations that would cut gasoline consumption and greenhouse gases."[364] In a letter to the President, EPA Administrator Stephen L. Johnson wrote:

> [T]he Supreme Court's Massachusetts v EPA decision still requires a response. That case combined with the latest science of climate change requires the Agency to propose a positive endangerment finding, as was agreed to at the Cabinet-level meeting in November. . . . [T]he state of the latest climate change science does not permit a negative finding, nor does it permit a credible finding that we need to wait for more research.[365]

Despite commitments by President Bush and pressure from the EPA, the White House Office of Management and Budget moved to block an EPA report outlining how the EPA could regulate CO_2 from mobile and stationary sources.[366] By the time President Bush left office, the EPA had not yet proposed a rule to regulate GHG emissions.[367]

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[361] Juliet Eilperin, White House Tried to Silence EPA Proposal on Car Emissions, *Washington Post*, June 26, 2008. Ex. E-214.
[362] George W. Bush, Statement of Administration Policy: H.R. 6 – Energy Policy Act of 2005, Sen. Domenici, June 14, 2005. Ex. E-215.
[363] Robert Fabricant, EPA General Counsel, Memorandum to Marianne Horniko, Acting EPA Administrator, EPA's authority to regulate pollutants emitted by electric power generation sources. Ex. E-216 at section IV.
[364] George W. Bush, Remarks on Energy in Athens, Alabama, June 21, 2007. Ex. E-217.
[365] Stephen L. Johnson, EPA Administrator, Letter to President George W. Bush, Jan. 31, 2008. Ex. E-218 at 2.
[366] Ian Talley and Siobhan Hughes, White House Blocks EPA Emissions Draft, The Wall Street Journal, July 30, 2018, https://www.wsj.com/articles/SB121478564162114625. Ex. E-219.
[367] U.S. Environmental Protection Agency, Proposed Rules Regulating Greenhouse Gases Under the Clean Air Act, 44354 Federal Register, Vol. 73, No. 147, July 30, 2008. Ex. E-220.; *see also,* Warming is Major Threat to Humans, EPA Warns, *Washington Post*, July 18, 2008. Ex. E-194 ("Last Friday, the EPA announced that it would solicit comments on the idea of regulating greenhouse gases under the federal Clean Air Act. But at the same time it released a lengthy preamble, with messages from EPA Administrator Stephen L. Johnson and four other Cabinet members, saying that this idea was ill-advised. Burnett said that this, too, was ordered by administration officials: 'We were told . . . that the [document] should not establish a path forward or a framework for regulation, but should emphasize the complexity of the challenge.'").

On the international stage, President Bush officially backed out of the Kyoto Protocol, already a dead letter in the U.S., claiming the agreement would hurt our economic growth and jobs. "The Kyoto Protocol would have required the United States to drastically reduce greenhouse gas emissions. The impact of this agreement, however, would have been to limit our economic growth and to shift American jobs to other countries," the President remarked in April 2008.[368] However, even though the U.S. withdrew from the Kyoto Protocol, the Bush Administration still made efforts to undermine international climate negotiations. For example, the U.S. firmly opposed proposed binding international GHG emission reduction targets that called for reductions in GHG reductions of 25-40 percent below 1990 levels by 2020. In an effort to undermine the international negotiations on the binding targets, the U.S. advanced parallel international talks for voluntary goals.[369]

C. The Bush Administration Embraces Fossil Fuels

The Bush Administration understood and embraced the prominence of the federal government in setting national energy policy. Unfortunately, the Administration's national policies embraced fossil fuels, not renewable energy and efficiency. Soon after taking office, President Bush signed Executive Order 13211, which stated: "The Federal Government can significantly affect the supply, distribution, and use of energy."[370] The EO required all federal agencies to prepare a statement explaining how their regulatory authority could have "any adverse effects on energy supply, distribution, or use . . . ."[371] A memorandum to the heads of executive departments regarding the EO made clear that the purpose of the EO was to eliminate regulatory barriers to fossil fuel production.[372] Another Executive Order, signed on the same day, called for federal agencies to expedite their review of energy-related projects.[373]

Also during the first few months of his presidency, Bush created the National Energy Policy Development Group, headed by Vice President Dick Cheney, and gave it the mission to "develop a national energy policy designed to help the private sector, and as necessary and appropriate Federal, State, and local governments . . . ."[374] In May 2001, the National Energy Policy Development Group released a report with over 100 recommendations to the President. The

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[368] Remarks on Energy and Climate Change, George W. Bush, April 16, 2008. Ex. E-221.
[369] Thomas Fuller and Peter Gelling, Deadlock Stymies Global Climate Talks, *The New York Times*, December 12, 2007, https://www.nytimes.com/2007/12/12/world/12climate.html. Ex. E-222.
[370] Executive Order 13211, Actions Concerning Regulations that Significantly Affect Energy Supply, Distribution, or Use, Federal Register Vol. 66, No. 99, 28355, May 18, 2001. Ex. E-223 at 28355.
[371] *Id.*
[372] Mitchell E. Daniels, Memorandum for Heads of Executive Departments and Agencies, and Independent Regulatory Agencies, Guidance for Implementing E.O. 13211, July 13, 2001. Ex. E-224 at 2.
[373] Executive Order 13212, Actions to Expedite Energy-Related Projects, Federal Register Vol. 66, No. 99, 28357, May 18, 2001. Ex. E-225.
[374] George W. Bush, Memorandum to the Vice President, National Energy Policy Development Group, January 29, 2001. Ex. E-226 at 2.

National Energy Policy Report did mention renewable energy but mostly emphasized enhancing fossil fuel production. It stated:

> A primary goal of the National Energy Policy is to add supply from diverse sources. This means domestic oil, gas, and coal. It also means hydropower and nuclear power. And it means making greater use of non-hydro renewable sources now available. . . . Currently, the U.S. has enough coal to last for another 250 years.[375]

The National Energy Policy Report recommended that federal agencies incentivize offshore oil and gas development, reduce oil and gas royalties, boost natural gas production, and expand natural gas pipelines, among other actions to reduce regulatory hurdles to expanding fossil fuels extraction and transportation. It concluded that U.S. oil consumption would increase by 33 percent and demand for energy would increase by 45% in the next 20 years.

The recommendations in the National Energy Policy Report were largely influenced by industry groups and petroleum lobbyists. The *Washington Post* reported that in the year of its existence the task force had met with over 300 groups and individuals.[376] The policy developed for and executed by the Bush Administration included encouraging oil and gas production, investments in oil and gas infrastructure, and increased exploration and production of oil, natural gas, and coal.[377] The vast majority of the groups the task force consulted with represented oil and gas interests or fossil fuel companies and trade groups, including the National Mining Association, the Interstate Natural Gas Association of America, and the American Petroleum Institute.

President Bush highlighted oil and gas during remarks announcing his energy plan in Minnesota on May 17, 2001, stating: "New technology makes drilling for oil far more productive. . . . My administration's energy plan anticipates that most new electric plants will be fueled by the cleanest of all fossil fuels, natural gas. . . . I will call on Congress to pass legislation to bring more gas to market . . . ."[378]

The President also touted coal, the dirtiest and most emissions-intensive fossil fuel (though he claimed it could be burned cleanly). "Increasing our energy security begins with a firm commitment to America's most abundant energy sources—source, and that is coal. . . . Clean coal technology advances—will advance, and when it does, our society will be better off."[379]

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[375] National Energy Policy, Report of the National Energy Policy Development Group, May 2001. Ex. E-227 at xiii.
[376] Michael Abramowitz and Steven Mufson, Papers Detail Industry's Role in Cheney's Energy Report, *Washington Post*, July 18, 2007, http://www.washingtonpost.com/wp-dyn/content/article/2007/07/17/AR2007071701987.html?nav=rss_politi%20cs. Ex. E-228.
[377] National Energy Policy, Report of the National Energy Policy Development Group, May 2001. Ex. E-227 at ix-x.
[378] George W. Bush, Remarks Announcing the Energy Plan in St. Paul, Minnesota, May 17, 2001. Ex. E-229.
[379] Office of the Press Secretary, President Discusses Energy Policy in Columbus, Ohio, March 9, 2005. Ex. E-230.

The Bush Administration's favoritism towards fossil fuels was evident in the Energy Policy Act of 2005. This legislation contained an exemption for hydraulic fracturing from the Safe Drinking Water Act, a gift to the oil and gas industry from Vice President Dick Cheney, a former Halliburton CEO, that was dubbed the "Halliburton Loophole."[380]

The Bush Administration used the advent of the Energy Policy Act of 2005 to advocate for opening up Arctic National Wildlife Refuge (ANWR) to oil and gas development. Although the final legislation did not include drilling in ANWR, it is notable that the ANWR was not the only protected area under federal control that the Administration wished to open to fossil fuel exploitation. President Bush supported "increasing the production of traditional energy resources on the Outer Continental Shelf (OCS), Federal onshore lands, and Indian lands, consistent with the National Energy Policy."[381] A September 2005 memorandum to the President further demonstrates the administration's pro-fossil fuel agenda: "Your advisors are developing options to: 1. increase refining capacity; 2. address natural gas shortages, in both the short and long term; and 3. increase oil and natural gas production."[382]

This push to increase oil and gas production came during a crucial time when America could have been leading the effort to address climate change. Instead, the Bush Administration, heavily influenced by the oil and gas industry, largely abandoned that responsibility. The concept of using less energy was openly scoffed at by Vice President Cheney, who famously said in a 2001 speech: "Conservation may be a sign of personal virtue, but it is not a sufficient basis for a sound, comprehensive energy policy. . . . The aim here is efficiency, not austerity."[383] While the administration did pay lip service to renewables and energy efficiency, policies and funding measures showed the real priorities: securing more oil supplies, developing natural gas resources, and producing as much coal as possible. Its priorities were reflected in its federal leasing, permitting, subsidies, and infrastructure in support of the fossil fuel energy system. As a result, greenhouse gas emissions increased throughout the Bush administration until the Great Recession of 2008.

Notwithstanding the emerging impacts of climate change, the ever-growing literature on climate science, and the availability of renewable energy sources to provide energy for the nation, the Bush Administration strategy was to cast doubt on the science and focus on the need for more research while prioritizing short-term economic interest, especially those of the fossil fuel companies. The Administration opposed any binding measures to reduce GHG emissions and instead called for weak, voluntary measures, both nationally and internationally. Unfortunately

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[380] The Halliburton Loophole, *The New York Times*, November 2, 2009, https://www.nytimes.com/2009/11/03/opinion/03tue3.html. Ex. E-231.
[381] George W. Bush, Statement of Administration Policy: H.R. 6 - Energy Policy Act of 2005, June 14, 2005. Ex. E-215.
[382] Keith Hennessey and Bryan Hannegan, Memorandum to the President, Energy Policy – Interim Report, September 30, 2005. Ex. E-232 at 2.
[383] Martin Kettle, Cheney tells US to carry on guzzling, *The Guardian*, May 10, 2001, https://www.theguardian.com/world/2001/may/10/dickcheney.martinkettle. Ex. E-233.

for the climate system and the Youth Plaintiffs in this case, the Administration was successful in expanding fossil fuel development and production.

VII. Obama Administration (2009 – 2017)

President Barack Obama appeared to personally take the threat of climate change seriously and did more than any other president to address it. By this point the unequivocally robust climate science and already evident impacts were effectively impossible to ignore. The federal government, from EPA and research institutions to the Department of Defense, fully and openly acknowledged the scientific warnings. EPA notably issued, after years of litigation during the Bush Administration and an eventual Supreme Court decision mandating that it do so,[384] an Endangerment Finding for greenhouse gases in 2009 based on the overwhelming scientific information on climate change and its impacts. Reports continued to add to the body of knowledge underpinning the danger of anthropogenic climate change.

The President, like many of his predecessors, spoke of the problem – particularly the risk it posed to future generations – and did take some steps towards significant action particularly during his second term in office. He announced a Climate Action Plan, and his EPA issued regulations addressing emissions from motor vehicles and power plants. President Obama also participated in international climate summits culminating in the Paris Agreement in late 2015.

But by simultaneously continuing an "all-of-the-above" national energy policy and approving more fracked gas and unconventional fossil fuel pipelines than any president before him, fossil fuels remained an entrenched engine of our economy and the dominant fuel of America's energy system. Under the Obama Administration, petroleum products and natural gas liquid exports increased, as did domestic oil and gas production. This locked in further greenhouse gas warming at a time when the climate science alarm sirens were blaring. Despite President Obama's concerns and piecemeal efforts to take action on climate, the problem only worsened during his Administration.

A. Government Knowledge

1. <u>Knowledge of Climate Science, Impacts, and Children</u>

The state of scientific understanding of human-caused climate change was well advanced by the time Barack Obama took office as the 44th president, and this knowledge continued to advance during his eight years in office.

Early on in his first term, in June 2009, the U.S. Global Change Research Program released its Second National Assessment detailing climate change impacts in the United States. The report explained the expected impacts across a variety of areas including public health and social costs. As the report noted, "[c]limate change is likely to exacerbate these challenges as changes in temperature, precipitation, sea levels, and extreme weather events increasingly affect homes,

[384] *Massachusetts v. EPA*, 549 U.S. 497, 2007.

communities, water supplies, land resources, transportation, urban infrastructure, and regional characteristics that people have come to value and depend on."[385]

Statements made in U.S. Senate committees during the summer of 2009, meanwhile, confirmed that climate change represented a risk to national security[386] and to the national park system.[387]

Also in 2009, the USGS published a report warning about how rising ocean temperatures, ocean acidification, and sea level rise was threatening coral reefs. The USGS Report stated that, "[b]usiness-as-usual scenarios that project increasing carbon dioxide concentrations in the atmosphere and oceans from burning fossil fuels and deforestation portend unprecedented changes in the distribution, abundance, and survival of coral communities and life in the global oceans."[388]

By the end of 2009, the EPA issued its most sweeping declaration of the threat of climate change, officially publishing an Endangerment Finding under Sec. 202(a) of the Clean Air Act.[389] EPA stated in its finding that "[w]arming of the climate system is unequivocal" and "the evidence provides compelling support for finding that greenhouse gas air pollution endangers the public welfare of both current and future generations. The risk and the severity of adverse impacts on public welfare are expected to increase over time."[390] In an April 28, 2010 congressional subcommittee hearing, EPA Administrator Lisa Jackson pointed out the scientific consensus supporting this finding:

> I found in December 2009 that motor vehicle greenhouse gas emissions do endanger Americans' health and welfare. I am not alone in reaching that conclusion. Scientists of the 13 Federal agencies that make up the U.S. Global Change Research Program have reported that unchecked greenhouse gas emissions pose significant risk to the well-being of the American public. The National Academy of Sciences has stated that the climate is changing . . . and that those changes will transform the environmental conditions on Earth unless countermeasures are taken.[391]

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[385] U.S. Global Change Research Program, Second National Assessment: Global Climate Change Impacts in the United States, June 2009. Ex. E-234 at 100.
[386] Climate Change and National Security, Hearing before the Committee on Environment and Public Works, United States Senate, July 30, 2009. Ex. E-235.
[387] Climate Change Impacts on National Parks in Colorado, Hearing before the Subcommittee on National Parks of the Committee on Energy and Natural Resources, United States Senate, August 24, 2009. Ex. E-236.
[388] U.S. Geological Survey, Science-Based Strategies for Sustaining Coral, September 2009. Ex. E-237 at 1.
[389] U.S. Environmental Protection Agency, Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, 2009. Ex. E-238.
[390] *Id.* at 66498-99, 66517.
[391] U.S. House of Representatives, Clean Energy Policies That Reduce our Dependence on Oil, Hearing before the Subcommittee on Energy and Environment of the Committee on Energy and Commerce, April 28, 2010. Ex. E-239 at 30-31.

Following EPA's groundbreaking Endangerment Finding, multiple reports were issued under the Obama Administration that corroborated the already strong scientific knowledge on the danger of global warming.[392]

In 2011, a National Research Council report looked at the impacts of climate change based on varying levels of CO_2 concentration and temperature rise. The NRC Report found that under a "business as usual" scenario a CO_2 concentration of 1000 ppm could be reached by 2100 and stabilizing the atmospheric CO_2 concentration at any target level "would require reductions in total emissions of at least 80 percent (relative to any peak emission level)."[393] A graphic in the report illustrates the cumulative carbon emissions and temperature change for various CO_2 concentration trajectories (see Figure 12). Importantly, "[t]he report concludes that certain levels of warming associated with carbon dioxide emissions could lock Earth and many future generations of humans into very large impacts."[394]

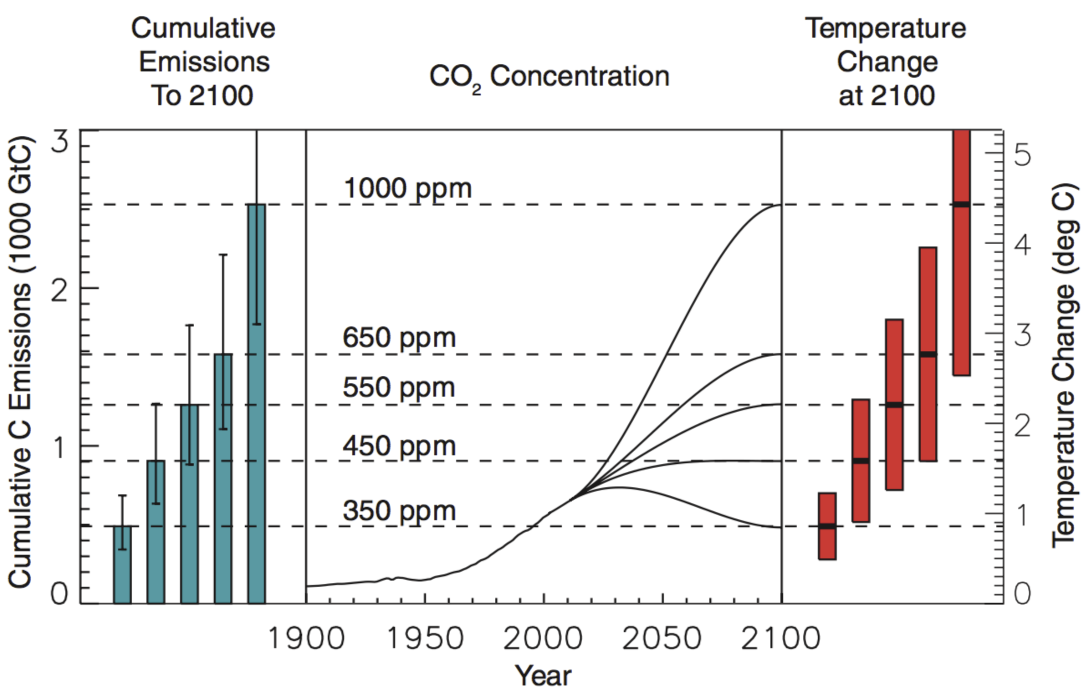

Figure 12: CO_2 Concentration Scenarios Reaching Between 350 and 1,000 ppm by 2100.[395]

[392] *See, e.g.,* National Research Council, Advancing the Science of Climate Change. America's Climate Choices: Panel on Advancing the Science of Climate Change, 2010. Ex. E-240 at 227-28. This report addressed the issue of abrupt changes in the climate, or "surprises," when tipping points are crossed. Such abrupt changes could include rapid ice sheet disintegration (with a corresponding rise in sea levels), irreversible drying and desertification of the subtropics, the release of methane from permafrost or methane hydrates in the oceans, or rapid increases in temperatures.

[393] National Research Council, Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia, 2011. Ex. E-241 at 21, 52.

[394] *Id.* at 9.

[395] *Id.* at 104.

Additionally, a 2011 CRS report discussed using a "science-based approach" to evaluate a "safe" or "tolerable" amount of climate change.[396] This science-based approach focuses on the relationship between temperature change, projected climate change impacts, and GHG concentrations. While the CRS report did not take a position on what CO_2 concentration is "safe," it is still noteworthy that the CRS was considering various CO_2 concentrations (including 350 ppm) and the corresponding temperature increase.

EPA issued its "Climate Change Indicators in the United States: Second Edition" report in 2012.[397] Among other findings, the 2012 EPA report noted that the minimum extent of Arctic sea ice has been decreasing over time, and that September 2012 was the smallest level ever recorded.[398] Two years later the third edition report of "Climate Change Indicators" came out, finding climate change contributes to an increase in heat-related deaths as well an increase in Lyme disease, allergies, and asthma-related problems. The 2014 Report also found that climate change threatens human health, and in particular the health of children, by exacerbating the risk of wildfires, hurricanes, the loss of coastal land, the loss of glacial water storage, and the loss of ice in the Arctic.[399] EPA also issued a report in 2013 specifically about children, in which it found that children are especially vulnerable to the impacts of climate change such as higher temperatures and heat waves, increased air pollution, and spreading infectious diseases.[400]

The U.S. Global Change Research Program continued to be a leading authority on climate science, issuing two additional reports in 2014 and 2016. The 2014 Third National Climate Assessment report notably stated: "Climate change, once considered an issue for a distant future, has moved firmly into the present."[401] According to findings of the Third National Climate Assessment, "[t]he global warming of the past 50 years is primarily due to human activities, predominantly the burning of fossil fuels. . . . U.S. average temperature has increased by 1.3°F to 1.9°F since record keeping began in 1895; most of this increase has occurred since about 1970."[402] The 2016 Assessment detailed the health impacts of climate change and noted disproportional impacts on classes of people like children, those with preexisting medical conditions, communities of color, indigenous peoples, and coastal populations.[403] The executive

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[396] Congressional Research Service, Climate Change: Conceptual Approaches and Policy Tools, August 29, 2011. Ex. E-242 at 5-9.
[397] U.S. Environmental Protection Agency, Climate Change Indicators in the United States, Second Ed., 2012. Ex. E-243.
[398] *Id.* at 8.
[399] U.S. Environmental Protection Agency, Climate Change Indicators in the United States, Third Ed., 2014. Ex. E-244.
[400] U.S. Environmental Protection Agency, America's Children and the Environment, Third Ed., 2013. Ex. E-245 at 107.
[401] U.S. Global Change Research Program, Climate Change Impacts in the United States: Third National Climate Assessment, 2014. Ex. E-246 at 1.
[402] *Id.* at 15.
[403] U.S. Global Change Research Program, The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment, Executive Summary 2016. Ex. E-247 at 4, 13.

summary of that report bluntly stated: "Climate change threatens human health and well-being in the United States."[404]

Another key climate report that came out during Obama's second term was the IPCC's Fifth Assessment Report (AR5). The language in that report was the strongest yet in describing the observed warming and associated impacts. The report stated: "Human influence on the climate system is clear, and recent anthropogenic emissions of green-house gases are the highest in history. . . . Warming of the climate system is unequivocal. . . . Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems."[405]

President Obama clearly understood the severity of these scientific warnings and in particular the impacts on children. During his Second Inaugural Address in January 2013 he made an important reference to children and future generations in the context of climate change. "We will respond to the threat of climate change, knowing that the failure to do so would betray our children and future generations," the president remarked.[406] He again spoke of the threat during his 2013 State of the Union Address:

> Now, it's true that no single event makes a trend. But the fact is the 12 hottest years on record have all come in the last 15. Heat waves, droughts, wildfires, floods—all are now more frequent and more intense. We can choose to believe that Superstorm Sandy, and the most severe drought in decades, and the worst wildfires some states have ever seen were all just a freak coincidence. Or we can choose to believe in the overwhelming judgment of science—and act before it's too late.[407]

In a candid interview with *The New York Times* published September 2016, President Obama revealed his reaction to his briefings on the latest climate information. "'My top science adviser, John Holdren, periodically will issue some chart or report or graph in the morning meetings,' he said, 'and they're terrifying.'"[408]

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[404] *Id.* at 1.
[405] Intergovernmental Panel on Climate Change, Climate Change 2014 Synthesis Report: Summary for Policymakers, 2014, https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf. Ex. E-248 at 2, 8.
[406] Barack Obama, Inaugural Address by President Barack Obama, January 21, 2013. Ex. E-249.
[407] Barack Obama, Remarks by the President in the State of the Union Address, February 12, 2013. Ex. E-250.
[408] Julie Hirshfeld et al. Obama on Climate Change: The Trends Are Terrifying, *The New York Times*, September 8, 2016, https://www.nytimes.com/2016/09/08/us/politics/obama-climate-change.html. Ex. E-251.

2. Knowledge Regarding Renewable Energy Sources.

In 2009, only 4 percent of U.S. electric power industry was made up of non-hydro renewable energy sources.[409] The Obama Administration, however, was aware of the federal government's role in shaping national energy policy, and knew of viable renewable energy sources available to reduce dependence on fossil fuels.

In 2010, the DOE projected that 20 percent of the nation's electrical supply could come from wind energy by 2030.[410] In 2011, the DOE, after noting that 80% of total U.S. primary energy and over 95% of U.S. transportation fuel comes from fossil resources, said:

> The Department has a unique role in defining end-use standards for appliances and other electronic devices and informs the vehicle fuel economy standards set by the Department of Transportation. . . . The United States has the opportunity to lead the world in a new industrial revolution to manufacture the clean energy technologies we need and create the jobs of the future. To ensure America's competitiveness in this century and achieve our energy goals, we must develop and deploy clean energy technologies in our nation.[411]

Then, in 2012, the DOE, through its National Renewable Energy Laboratory, found that by 2050, "[e]lectricity supply and demand can be balanced in every hour of the year in each region with nearly 80% electricity from renewable resources, including nearly 50% from variable renewable generation . . . ."[412]

Speaking in 2013, President Obama said:

> The path towards sustainable energy sources will be long and sometimes difficult. But America cannot resist this transition, we must lead it. We cannot cede to other nations the technology that will power new jobs and new industries, we must claim its promise. That's how we will maintain our economic vitality and our national treasure . . . .[413]

In 2017 the DOE, in discussing the nation's energy system, stated that "the Federal Government will play a major role in managing the challenges and taking advantage of the opportunities that the 21st-century grid presents."[414]

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[409] Congressional Research Service, Options for Federal Renewable Electricity Standard, November 12, 2010. Ex. E-252 at 2.
[410] *Id.* at 4.
[411] U.S. Department of Energy, Strategic Plan, May 2011. Ex. E-253 at 10, 12-13.
[412] National Renewable Energy Laboratory, Renewable Electricity Futures Study, Volume 1: Exploration of High-Penetration Renewable Electricity Futures, June 2012. Ex. E-254 at xviii.
[413] Barack Obama, Inaugural Address by President Barack Obama, January 21, 2013. Ex. E-249.
[414] U.S. Department of Energy, Transforming the Nation's Electricity System, Ch. I, January 2017. Ex. E-255 at 1-2.

Finally, the Obama Administration knew that any delay in reducing emission would significantly increase the eventual cost of the necessary reductions. A report from the Executive Office of the President found that for each decade of delay, mitigation costs increased by approximately 40 percent. According to the White House Report, "each year of delay means more CO_2 emissions, so it becomes increasingly difficult, or even infeasible, to hit a climate target that is likely to yield only moderate temperature increases."[415]

B. Government Action

Compared to the previous administration, the Obama Administration went further in terms of actions addressing the climate problem. However, President Obama did not reverse decades of government support for fossil fuel energy, and he continued to support fossil fuels in many ways, embracing domestic oil and gas production and touting an "all of the above" energy strategy that implied indefinite reliance on fossil fuels.

1. Climate Change Policy Under Obama

Obama's climate policy consisted of trying to implement policies to cut carbon pollution, limit other greenhouse gas pollutants, encourage a clean energy economy, improve federal climate adaptation efforts, and return the United States to a position of leadership in the global climate negotiations.[416] I will highlight the Administration's most notable efforts here.

First, following the Supreme Court's ruling in *Massachusetts v. EPA* in 2007 that EPA had the authority and duty to regulate greenhouse gas emissions under the Clean Air Act, Obama's EPA promulgated new vehicle emission and mileage standards starting in 2010 for light-duty vehicles for model years 2012 through 2016 raising vehicle standards to an average of 30.2 miles per gallon (mpg) up from 27.5 mpg before the rule.[417] In October 2012, standards for model years 2017-2025 were added, which would require manufacturers to produce light-duty vehicles for model years 2017-2025 to achieve industry-average fuel efficiency equivalents of 54.5 mpg.[418] A rule for EPA and the National Highway Traffic Safety Administration also later established standards for medium and heavy-duty trucks.[419]

The cornerstone of Obama's climate policy was his Climate Action Plan, announced on June 25, 2013. Speaking on a hot summer day at Georgetown University and pausing to wipe sweat from

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[415] Executive Office of the President, The Cost of Delaying Action to Stem Climate Change, July 2014. Ex. E-256 at 2.
[416] The Obama Administration's account of its climate record can be found at: https://obamawhitehouse.archives.gov/the-record/climate.
[417] U.S. Environmental Protection Agency, Dept. of Transportation, Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule 75 Fed. Reg. 25325, 25369, May 7, 2010.
[418] U.S. Environmental Protection Agency, Dept. of Transportation, 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule 77 Fed. Reg. 62624, 62627,Oct. 12, 2012.
[419] *See* https://obamawhitehouse.archives.gov/the-record/climate.

his forehead,[420] President Obama revealed his plan to bypass Congress and direct EPA to set limits on carbon pollution:

> [T]his is a challenge that does not pause for partisan gridlock. It demands our attention now. And this is my plan to meet it – a plan to cut carbon pollution, a plan to protect our country from the impacts of climate change, and a plan to lead the world in a coordinated assault on a changing climate. . . . [T]oday, for the sake of our children, and for the health and safety of all Americans, I'm directing the Environmental Protection Agency to put an end to the limitless dumping of carbon pollution from our power plants and complete new pollution standards for both new and existing power plants.[421]

The EPA followed through and issued the first-ever power plant carbon pollution standards, starting with new power plants in September 2013 and existing power plants in August 2015. The resulting regulations were called the Clean Power Plan (CPP).[422] The CPP was the centerpiece of America's climate policy under Obama. When the U.S. officially pledged to reduce carbon emissions by 26 percent to 28 percent below 2005 levels by 2025—its "intended nationally determined contribution" offered ahead of the Paris climate talks in 2015[423]—the CPP was advertised as central to that goal. However, Federal Defendants stated in their Answer to Youth Plaintiff's First Amended Complaint that "the Clean Power Plan is not intended to 'preserve a habitable climate system.'"[424] (Moreover, it was never implemented and the Trump Administration is replacing it with a new rule that will not require significant changes to the energy industry or reductions in GHG emissions.[425]) In the Obama Administration's report to the UNFCCC on its progress to meet its stated goals, Defendants showed that even if the CPP were fully implemented, U.S. emissions would essentially decrease, and then continue a slight downward trend or possibly increase, but not decrease at the rate urgently needed to respond to the crisis (Figure 13). Defendant DOE's EIA also confirmed a brief decline in emissions followed by a flatline with CPP implementation, as illustrated by Defendant's graphics below in Figure 14.

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420 *See* Barack Obama, Climate Action Plan announcement, June 25, 2013, https://www.youtube.com/watch?v=TC17DJl6-Ck.

421 Barack Obama, Remarks by the President on Climate Change, Georgetown University, Washington DC, June 25, 2013. Ex. E-257.

422 Barack Obama, The President's Clean Power Plan. Ex. E-258.

423 The White House, Fact Sheet: U.S. Reports its 2025 Emissions Target to the UNFCCC, March 31, 2015. Ex. E-259.

424 Federal Defendants' Answer to First Amended Complaint, January 13, 2017, ECF. No. 98 at ¶ 127.

425 Lisa Friedman and Brad Plumer, E.P.A. Drafts Rule On Coal Plants To Replace Clean Power Plan, *The New York Times*, July 5, 2018, https://www.nytimes.com/2018/07/05/climate/clean-power-plan-replacement.html. Ex. E-260.

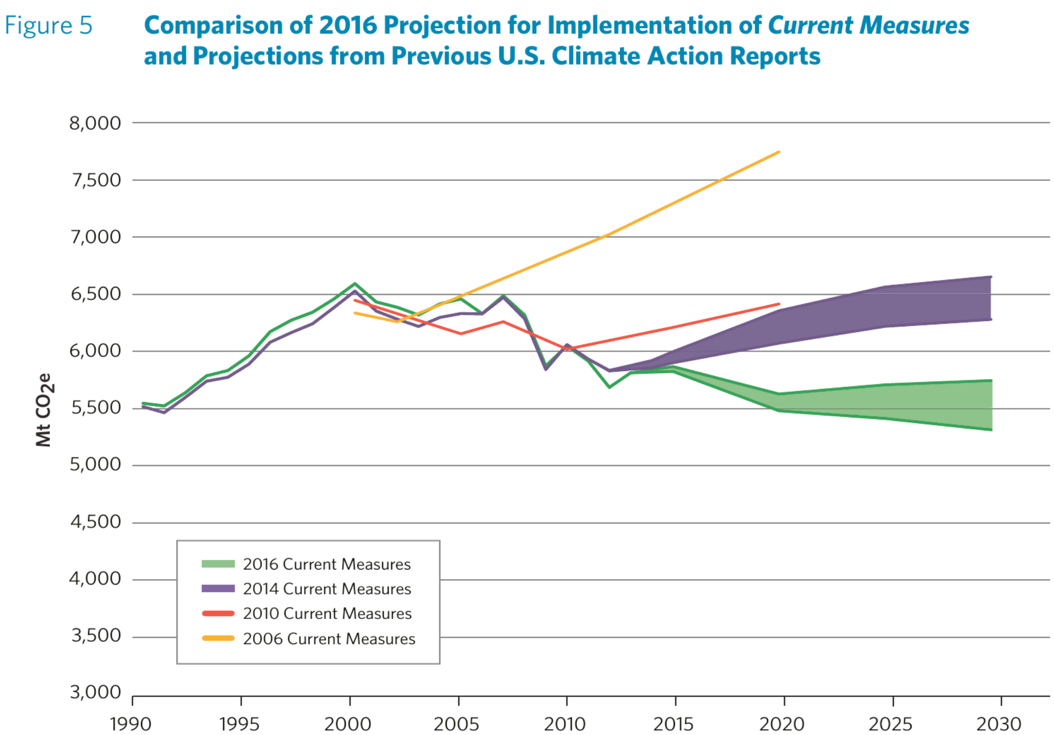

Figure 13: United States 2016 Second Biennial Report Under the UNFCCC.[426]

[426] U.S. Department of State, Second Biennial Report of the United States Under the United Nations Framework Convention on Climate Change, 2016. Ex. E-261 at 35.

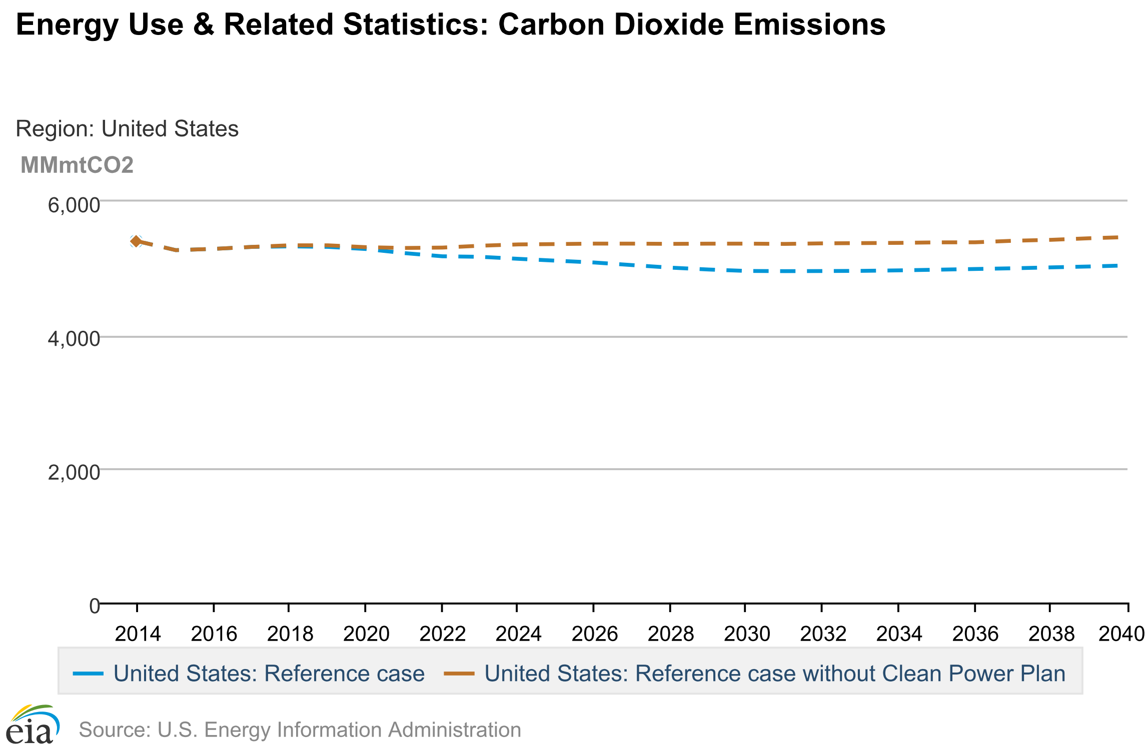

Figure 14: Energy Use & Related Statistics: Carbon Dioxide Emissions projected with and without Clean Power Plan implementation through 2040.[427]

Defendant DOE, under Obama, also finalized energy efficiency rules, including those governing large scale, commercial air conditioners, heat pumps, and furnaces, which could have avoided significant carbon emissions just through efficiencies had Defendant President Trump not directed the halt to implementation of those rules.

The Obama Administration also promulgated new standards to lower methane emissions from oil and gas development and landfills and recommitted to reducing HFCs and other greenhouse gases.

The initial adoption of the Paris Agreement in December 2015 was hailed as a landmark moment in international climate policy. The U.S. under the Obama Administration signed onto the Paris Agreement, which declared a global goal of "[h]olding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre- industrial levels."[428] This built upon the 2009

[427] U.S. Energy Information Administration, Energy Use & Related Statistics: Carbon Dioxide Emissions, https://www.eia.gov (graph created through EIA's interactive table browser using EIA data from the publication "Annual Energy Outlook 2016" and the table "Energy Consumption by Sector and Source" comparing the "Reference Case" with the "Reference Case without Clean Power Plan").
[428] United Nations, Paris Agreement, Article 2, Sect. 1(a), United Nations, 2015, https://unfccc.int/sites/default/files/english_paris_agreement.pdf. Ex. E-262.

Copenhagen Accord that recognized the need to limit global temperature rise below 2°C.[429] Despite the majority of negotiating parties supporting the adoption of a 1.5°C target in the treaty's text, U.S. negotiators advocated—ultimately unsuccessfully—for a 2°C target in the treaty's preamble only.[430] The U.S. did however, succeed in having the language in key sections of the Paris Agreement regarding climate change mitigation and finance altered so that they only constituted aspirational or voluntary provisions, rather than binding obligations, under international law.[431]

Around the time of the Paris Agreement, the Administration also released its Mid-Century Strategy for Deep Decarbonization, focused on cost-effective decarbonization pathways. That plan, aimed at emission reduction rates lower than those needed to protect the climate system, was a start of a national plan but was never implemented and has since been shelved like all prior plans and roadmaps considered by prior administrations.

President Obama also led the way to greater federal investments in clean energy and approved the first-ever large-scale renewable energy project on federal public lands, as well as announced a 21st Century Clean Transportation Plan to scale up national electric vehicle infrastructure.

President Obama also signed several executive orders pertaining to climate change and climate adaptation in particular. An executive order issued October 5, 2009 directed the new Interagency Climate Change Adaptation Task Force to develop "approaches through which the policies and practices of the agencies can be made compatible with and reinforce" a national climate change adaptation strategy.[432] This task force was replaced with an interagency Council on Climate Preparedness and Resilience, established through executive order on preparing the United States for the impacts of climate change on November 1, 2013.[433] These actions represent an attempt at a coordinated federal response to prepare for the inevitable effects of a changing climate.

However, when viewed in light of Defendants' energy policies under the Obama Administration, the climate policy efforts fell far short of a reasonable response to the dangerous climate situation facing young people.

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429 United Nations Framework Convention on Climate Change, Report of the Conference of the Parties on its Fifteenth Session, https://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf. Ex. E-263.
430 Radoslav Dimitrov, The Paris Agreement: Behind Closed Doors, 16(3) Global Environmental Politics 1, 4, 2016 ("One important political development in Paris was the surge of countries who wanted to limit the global temperature rise to 1.5 degrees Celsius above pre-industrial levels. For the first time, now the majority (106 states, to be precise) demanded preventing a temperature rise of 1.5°C. Northern countries preferred 2 degrees instead. The U.S. was mildly opposed even to that, proposing that 2 degrees appear only in the preamble and not in the substantive sections of the treaty.").
431 *Id.* at 3.
432 Executive Order 13514 – Federal Leadership in Environmental, Energy, and Economic Performance, October 5, 2009. Ex. E-264 at 7.
433 Executive Order – Preparing the United States for the Impacts of Climate Change, November 1, 2013. Ex. E-265.

2. Obama Administration Energy Policy

Recognizing that climate change and energy policy were closely intertwined, the Department of Energy cautioned in its May 2011 Strategic Plan that a "business as usual" energy strategy "will imperil future generations with dangerous and unacceptable economic, social, and environmental risks."[434] DOE further noted: "As part of prudent risk management, our responsibility to future generations is to eliminate most of our carbon emissions and transition to a sustainable energy future. . . . To ensure America's competitiveness in this century and achieve our energy goals, we must develop and deploy clean energy technologies in our nation."[435]

Throughout the Obama years, however, fossil fuel supplied the vast majority of our energy. Both natural gas and petroleum consumption increased during the Obama Administration while coal consumption decreased (see Figures 15 and 16). The national energy policies of the Administration did not align with the urgent need to act on climate or the recommendations of Defendant agencies, including the DOE.

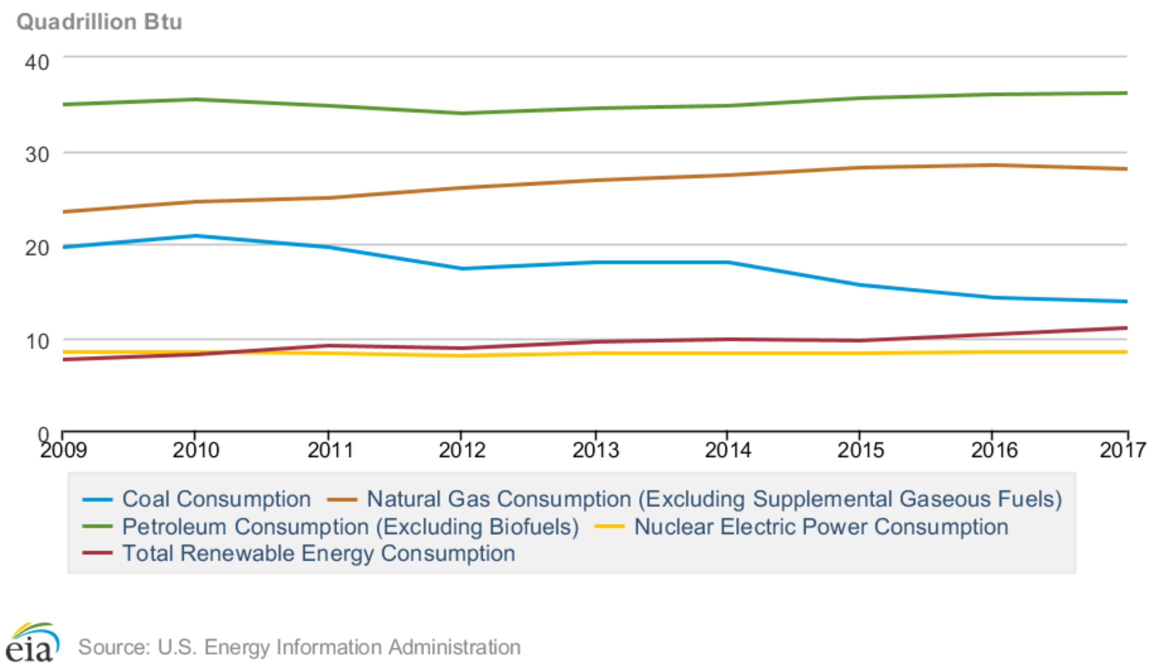

Figure 15: Primary Energy Consumption by Source from 2009 to 2017.[436]

[434] U.S. Department of Energy, Strategic Plan, May 2011. Ex. E-253 at 2.
[435] *Id.* at 2, 13.
[436] Data source: U.S. Energy Information Administration Monthly Energy Review, July 2018, https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf. Ex. E-171; Chart source: U.S. Energy Information Administration Total Energy Data Browser, https://www.eia.gov/totalenergy/data/monthly, accessed August 3, 2018.

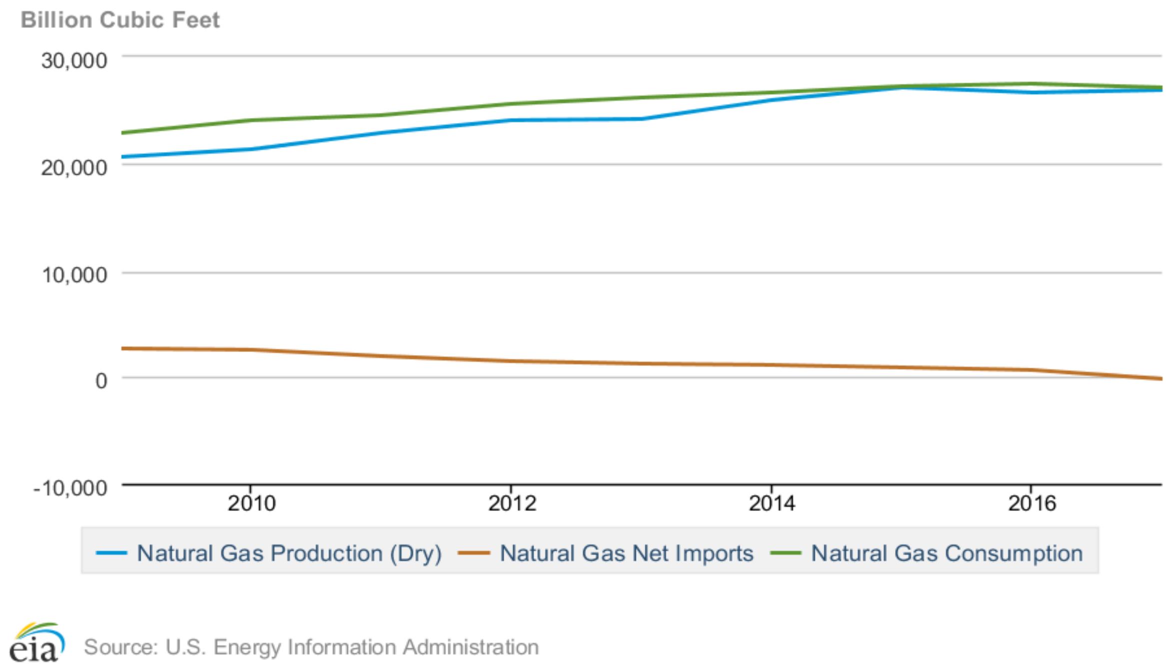

Figure 16: Natural Gas Production, Imports, and Consumption from 2009 to 2017.[437]

A July 2011 CBO report, "The Effects of Renewable or Clean Electricity Standards," pointed out the dominant role that coal and natural gas played in the electricity portfolio. "Currently, only about 10 percent of U.S. electricity is produced from renewable sources of energy," the report noted. "The bulk of electricity is produced using coal (45 percent), natural gas (24 percent), and nuclear power (19 percent)."[438] A report from the Executive Office of the President noted that 40 percent of coal production in the United States came from federal lands and that the regulations and administrative process governing leasing of federal coal have been largely unchanged since the late 1970s and early 1980s.[439] A 2017 DOE report stated:

> A sustained, 40-year Federal policy commitment has enabled a robust, global oil market; a diversity of petroleum suppliers; the world's largest strategic oil reserve; international mechanisms for concerted action in the event of disruptions; increased domestic oil production; a shift away from oil-fired power generation; more-efficient vehicles; and a host of other benefits.[440]

The Obama Administration especially embraced oil and natural gas. According to a 2014 Congressional Research Service report, "[i]n August 2014, approximately 4.1 million barrels per

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[437] *Id.*
[438] Congressional Budget Office, The Effects of Renewable or Clean Electricity Standards, July 2011. Ex. E-266 at VII.
[439] The White House, The Economics of Coal Leasing on Federal Lands: Ensuring a Fair Return to Taxpayers, June 2016. Ex. E-267 at 6.
[440] U.S. Department of Energy, Transforming the Nation's Electricity System: the Second Installation of the Quadrennial Energy Review, Ch. I, January 2017. Ex. E-255 at 1-31.

day (bbl/d) of petroleum products, NGLs, and other liquids were exported from the United States—up from an average of nearly 1.4 million bbl/d in 2007."[441] According to that CRS Report, between 1970 and 2008, U.S. crude oil production was steadily declining but since 2009, crude oil production was rapidly increasing and expected to continue to rise.[442]

President Obama himself spoke about exploiting the country's supply of oil and natural gas. In his 2012 State of the Union Address he said:

> Over the last three years, we've opened millions of new acres for oil and gas exploration, and tonight, I'm directing my administration to open more than 75 percent of our potential offshore oil and gas resources. Right now—right now—American oil production is the highest that it's been in eight years…We have a supply of natural gas that can last America nearly 100 years. And my administration will take every possible action to safely develop this energy.[443]

A few months later, speaking at TransCanada Pipe Yard near Cushing, Oklahoma, President Obama bragged about domestic petroleum production under his administration, stating:

> Over the last three years, I've directed my administration to open up millions of acres for gas and oil exploration across 23 different states. We're opening up more than 75 percent of our potential oil resources offshore. We've quadrupled the number of operating rigs to a record high. We've added enough new oil and gas pipeline to encircle the Earth, and then some. So we are drilling all over the place – right now. That's not the challenge. That's not the problem. In fact, the problem . . . is that we're actually producing so much oil and gas . . . that we don't have enough pipeline capacity to transport all of it where it needs to go.[444]

In his 2013 State of the Union, the president described his energy policy as "all of the above," indicating that the U.S. would not be reducing its reliance on fossil fuels any time soon. "Now, in the meantime, the natural gas boom has led to cleaner power and greater energy independence. We need to encourage that. And that's why my administration will keep cutting red tape and speeding up new oil and gas permits," Obama remarked. "That's got to be part of an all-of-the-above plan."[445] President Obama's "all of the above" plan included significant levels of fossil fuel extraction continuing on federal public lands as illustrated in Figure 17.

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[441] Congressional Research Service, U.S. Crude Oil Export Policy: Background and Considerations, December 31, 2014. Ex. E-268 at 2.
[442] *Id.* at 4.
[443] Barack Obama, Remarks by the President in State of the Union Address, January 24, 2012. Ex. E-269.
[444] Barack Obama, Remarks by the President on American-Made Energy, March 22, 2012. Ex. E-270.
[445] Barack Obama, Remarks by the President in the State of the Union Address, February 12, 2013. Ex. E-250.

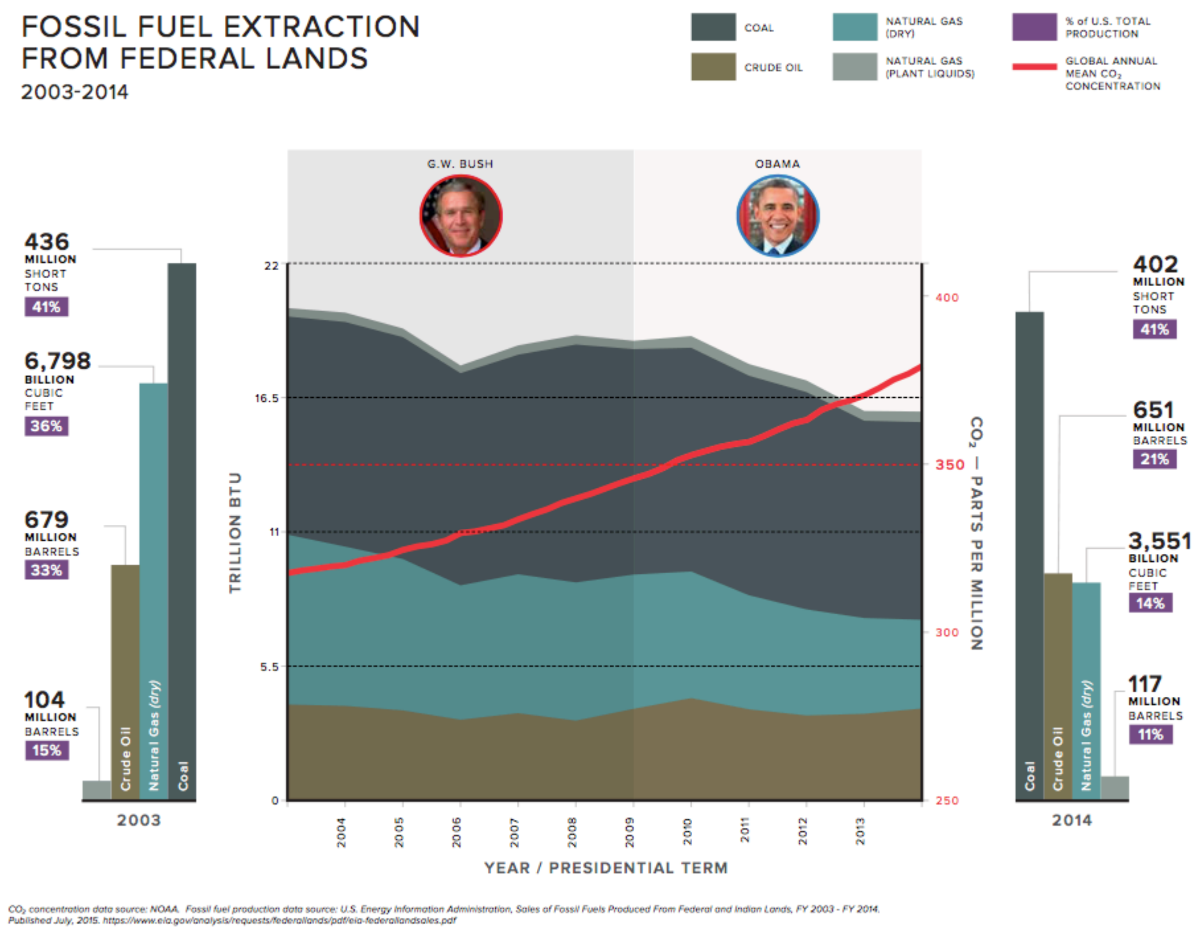

Figure 17: U.S. Fossil Fuel Extraction from Federal Public Lands during the G.W. Bush and Obama Administrations.[446]

Under President Obama's leadership, the U.S. began to take steps, primarily through EPA, towards regulating CO_2 and reengaging in the global arena through international negotiations on climate treaties. However, nearly all of this progress was undermined by efforts elsewhere in the Obama Administration to expand U.S. fossil fuel exploitation and production, and would be reversed altogether by the next president, Donald Trump.

VIII. Trump Administration: (2017-present)

No administration in modern times has acted with such disregard for and disdain of climate science nor proceeded to promote policies that so imperil the well-being of today's children and

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[446] Fossil Fuel Extraction Data Source: U.S. Department of Energy, Sales of Fossil Fuels Produced from Federal and Indian Lands, FY 2003 - FY 2014, July 2015, https://www.eia.gov/analysis/requests/federallands/pdf/eia-federallandsales.pdf; Source of global CO2 concentration: National Oceanic and Atmospheric Administration Earth System Research Laboratory, https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html, accessed July 2018.

future generations.[447] Even if many of Trump's efforts to roll back past gains and prevent others fail in the end for one reason or another, precious time and momentum will have been squandered – and indeed squandered at a critical moment in the history of the issue when developments seem to be coming together to offer honest hope. In particular, in its year and a half in office, the Trump administration has either done or proposed to do the following:

- Repeal the CPP.[448]
- Freeze fuel-efficiency standards for passenger cars and trucks at 37 mpg, rolling back a 2012 rule that would have doubled the fuel economy of passenger cars and trucks to 51 mpg by 2025.[449]
- Lift a ban on offshore drilling in many regions, and allow new offshore oil and gas drilling in nearly all United States coastal waters and take steps to open the Arctic to oil and gas drilling.[450]
- Auction off vast amount of onshore and offshore public lands for fossil fuel development.[451]
- Halt the closure coal plants and bail out failing coal-fired power plants by guaranteeing revenue from the federal government.[452]

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[447] At this late stage, there is no longer a need to recite the scientific knowledge of these Defendants of the climate crisis. It is enough to say that notwithstanding the public denials of climate science and the suppression of science within the federal government under President Trump, in November 2017, the U.S. Global Change Research Program (USGRCP) released the "Climate Science Special Report," or Volume I of the Fourth National Climate Assessment, and revealed once again the undeniable danger of the current (and past) Administration's push for fossil fuel development; *see* U.S. Global Change Research Program, Climate Science Special Report, Fourth National Climate Assessment (NCA4), Vol. I, 2017. Ex. E-271.
[448] EPA Takes Another Step to Advance President Trump's America First Strategy, Proposes Repeal of "Clean Power Plan", Oct. 10, 2017, https://www.epa.gov/newsreleases/epa-takes-another-step-advance-president-trumps-america-first-strategy-proposes-repeal.
[449] U.S. Environmental Protection Agency, The Safer and Affordable Fuel Efficient Vehicles Proposed Rule for Model Years 2021- 2026, https://www.epa.gov/regulations-emissions-vehicles-and-engines/safer-and-affordable-fuel-efficient-vehicles-proposed#rule-summary. Ex. E-272.
[450] U.S. Department of Energy, Secretary Zinke Announces Plan For Unleashing America's Offshore Oil and Gas Potential: Draft Proposed Program considers nearly the entire U.S. Outer Continental Shelf for potential oil and gas lease sales, January 4, 2018. Ex. E-273.
[451] *See, e.g.,* Executive Order 13795, Implementing an America-First Offshore Energy Strategy, April 28, 2017. Ex. E-274. (revoking Executive Order 13754, December 9, 2016); *see also* Sec. Order 3350, America First Offshore Energy Strategy, April 28, 2017. Ex. E-275; U.S. Dept. of Interior, Secretary Zinke Announces Largest Oil and Gas Lease Sale in U.S. History, October 24, 2017, https://www.doi.gov/pressreleases/secretary-zinke-announces-largest-oil-gas-lease-sale-us-history. Ex. E-276.
[452] *See* Brad Plumer, Trump Orders a Lifeline for Struggling Coal and Nuclear Plants, *The New York Times*, June 1, 2018, https://www.nytimes.com/2018/06/01/climate/trump-coal-nuclear-power.html. Ex. E-277.; Jennifer A. Dlouhy, Trump Prepares Lifeline for Money-Losing Coal Plants, Bloomberg, May 31, 2018, https://www.bloomberg.com/news/articles/2018-06-01/trump-

- Take steps to repeal the methane leak rule.[453]
- Put tariffs on solar panel imports.[454]
- Dissolve the Advisory Committee for the Sustained National Climate Assessment.[455]
- Withdraw the U.S. from the Paris Climate Agreement.[456]
- Remove data and other information related to climate change from agency websites and forbidden agency employees from talking about climate change.
- Reverse course from past administration and decide that climate change is not a national security threat.[457]
- Withdraw CEQ guidance for federal departments and agencies regarding their consideration of GHG emissions and the impacts of climate change during NEPA reviews.[458]
- Issue executive orders to revive the Dakota Access and Keystone XL pipelines.[459]
- Introduce his America First Energy Plan, which focuses on expanding fossil fuel production and rolling back investments in wind and solar.[460]
- And numerous other actions to promote fossil fuel development, undermine climate science research, and defund research and development for renewable energy sources.

I have followed the climate issue for 40 years now, and I have never been as frightened for my grandchildren as I am now, both because of the late hour to try to stop the onslaught of dangers and because of the dangerous disregard of this Administration of science and the rights of young people and all future generations.

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said-to-grant-lifeline-to-money-losing-coal-power-plants-jhv94ghl. Ex. E-278.; "Grid Memo," May 29, 2018, https://www.documentcloud.org/documents/4491203-Grid-Memo.html. Ex. E-279.

[453] BLM, BLM Offers Revision to Methane Waste Prevention Rule, February 12, 2018, https://www.blm.gov/press-release/blm-offers-revision-methane-waste-prevention-rule. Ex. E-280.

[454] Ana Swanson and Brad Plumer, Trump Slaps Steep Tariffs on Foreign Washing Machines and Solar Products, *The New York Times*, January 22, 2018, https://www.nytimes.com/2018/01/22/business/trump-tariffs-washing-machines-solar-panels.html. Ex. E-281.

[455] Jeff Tollefson, U.S. Government Disbands Climate-Science Advisory Committee, Scientific American, April 21, 2017, https://www.scientificamerican.com/article/u-s-government-disbands-climate-science-advisory-committee/. Ex. E-282.

[456] Kevin Liptak and Jim Acosta, Trump on Paris accord 'We're getting out', June 2, 2017, https://www.cnn.com/2017/06/01/politics/trump-paris-climate-decision/index.html. Ex. E-283.

[457] White House, National Security Strategy of the United States of America, December 2017. Ex. E-284 at 17.

[458] Council on Environmental Quality, Withdrawal of Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews, 82 FR 16576, April 5, 2017. Ex. E-285.

[459] Executive Order 13766 - Expediting Environmental Reviews and Approvals for High Priority Infrastructure Projects. Ex. 286; The White House, Presidential Memorandum Regarding Construction of the Keystone XL Pipeline, Jan. 24, 2017. Ex. E-287.

[460] The White House, Energy & Environment, https://www.whitehouse.gov/issues/energy-environment/. Ex. E-288.

CONCLUSION

Focusing on this history, no matter how extensive its scope, we have to see this period of almost half a century as an instant in time, for that is indeed what it is in Earth's time and in the lives of today's children and all those who must live with its consequences. And in this snapshot of decades, we find a federal government planning for, guiding, supporting, and encouraging massive fossil fuel use despite tragic consequences easily foreseen and avoided.

As a result of actions by the Federal Defendants, across Presidential Administrations, U.S. fossil fuel consumption and production have increased significantly since the 1950s (see Figures 18 and 19). While the U.S. relied heavily on fossil fuel imports for decades, recently, there has been an increase in fossil exports from the U.S., though the U.S. fossil fuel imports still greatly exceed fossil fuel exports (see Figure 20). Actions by the Federal Defendants that have perpetuated reliance on fossil fuels have resulted in the release of a massive, and dangerous, amount of CO_2 emissions since 1960 (see Figure 21). Cumulatively, the U.S. has emitted more CO_2 emissions than any other nation, and annually, the U.S. remains the second largest emitter in the world.

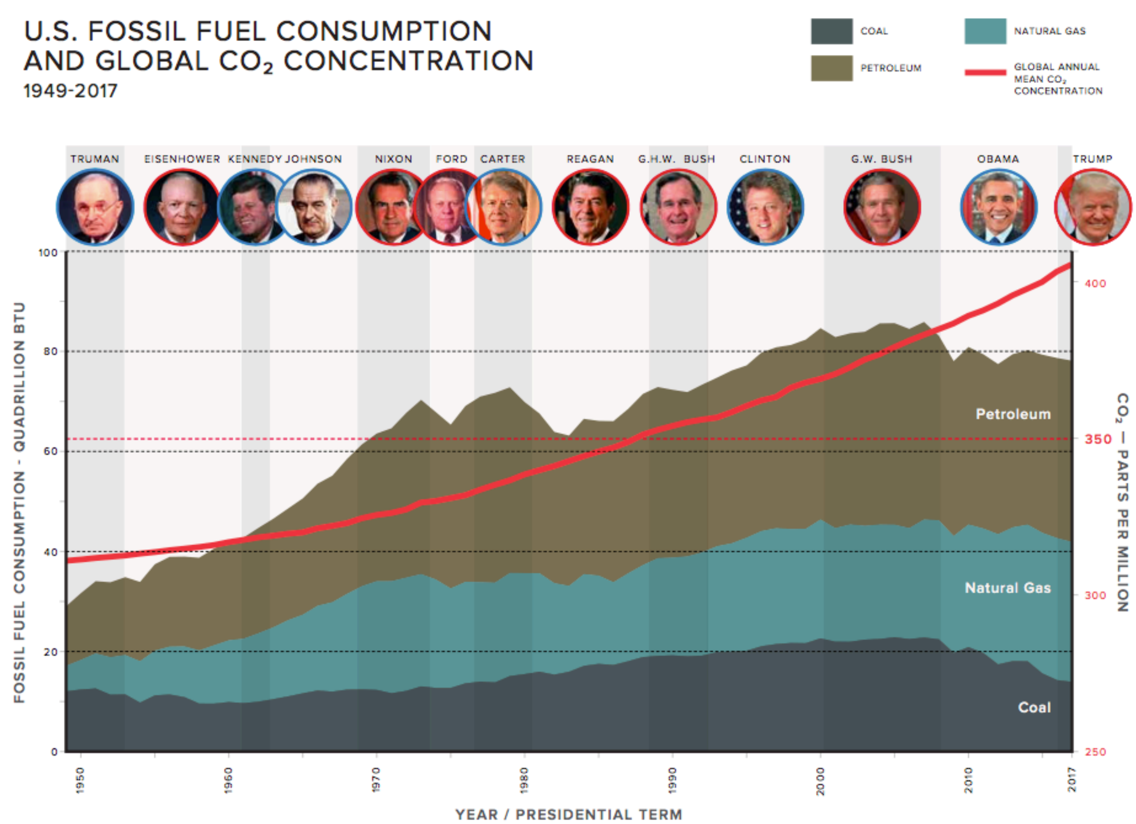

Figure 18: U.S. Fossil Fuel Consumption and Global CO_2 Concentration from 1949 to 2017.[461]

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[461] Fossil Fuel Consumption Data Source: U.S. Department of Energy, U.S. Energy Information Administration Monthly Energy Review, June 2018, https://www.eia.gov/totalenergy/data/monthly/archive/00351806.pdf; Source of global CO_2 concentration: 1949-1958: National Aeronautics and Space Administration, Global mean CO_2

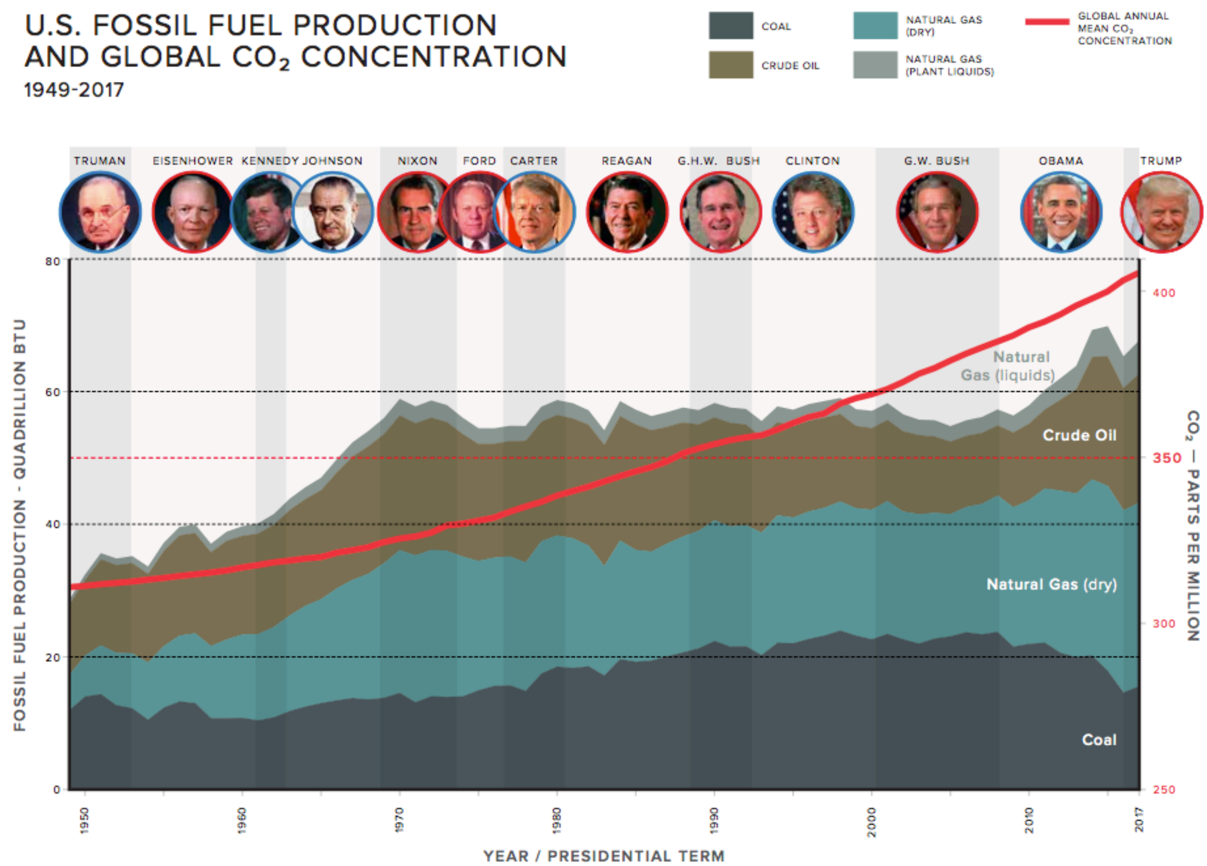

Figure 19: U.S. Fossil Fuel Production and Global CO_2 Concentration.[462]

mixing ratios, https://data.giss.nasa.gov/modelforce/ghgases/Fig1A.ext.txt, accessed July 2018. 1959-2017; National Oceanic and Atmospheric Administration Earth System Research Laboratory, https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html, accessed July 2018.

[462] Fossil Fuel Production Data Source: U.S. Department of Energy, U.S. Energy Information Administration Monthly Energy Review, June 2018, https://www.eia.gov/totalenergy/data/monthly/archive/00351806.pdf; Source of global CO_2 concentration: 1949-1958: National Aeronautics and Space Administration, Global mean CO_2 mixing ratios, https://data.giss.nasa.gov/modelforce/ghgases/Fig1A.ext.txt accessed July 2018.; 1959-2017: National Oceanic and Atmospheric Administration Earth System Research Laboratory, https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html accessed July 2018.

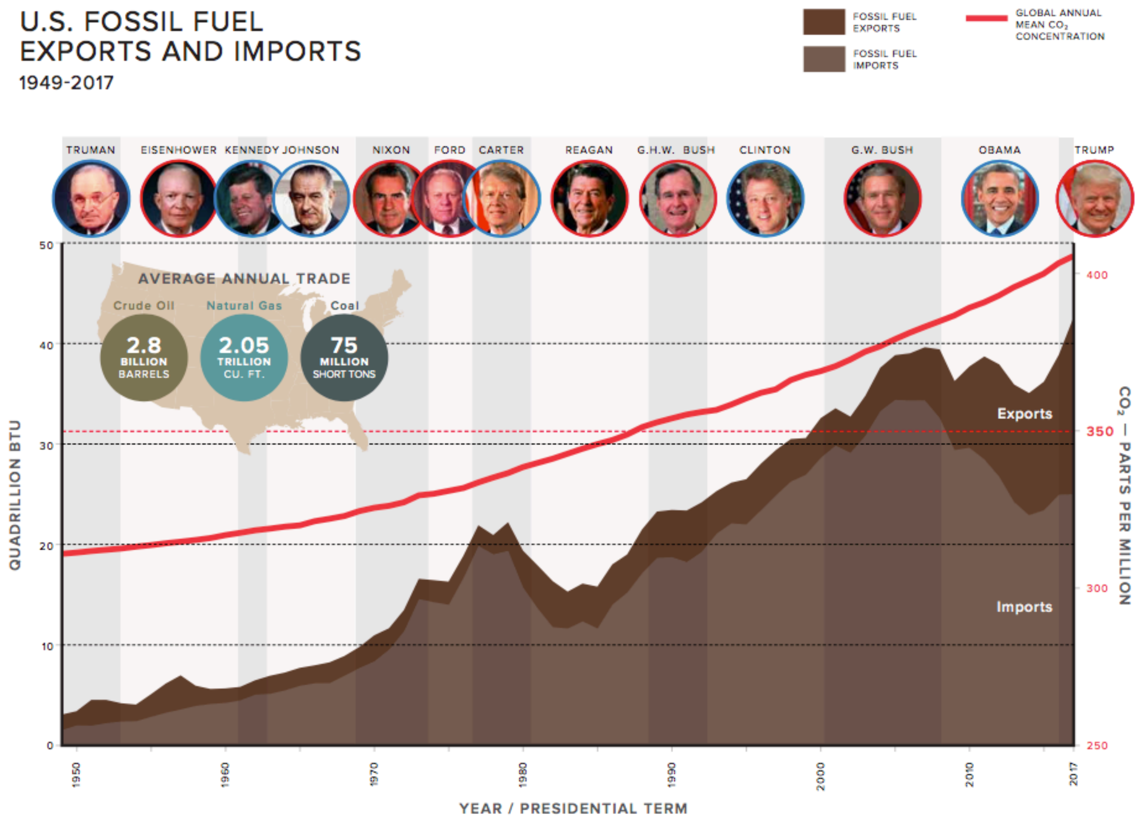

Figure 20: U.S. Fossil Fuel Exports and Imports from 1949 to 2017.[463]

[463] Fossil Fuel Export and Import Data Source: U.S. Department of Energy, U.S. Energy Information Administration Monthly Energy Review, June 2018, https://www.eia.gov/totalenergy/data/monthly/archive/00351806.pdf; Source of global CO_2 concentration: 1949-1958: National Aeronautics and Space Administration, Global mean CO2 mixing ratios, https://data.giss.nasa.gov/modelforce/ghgases/Fig1A.ext.txt, accessed July 2018. 1959-2017: National Oceanic and Atmospheric Administration Earth System Research Laboratory, https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html, accessed July 2018.

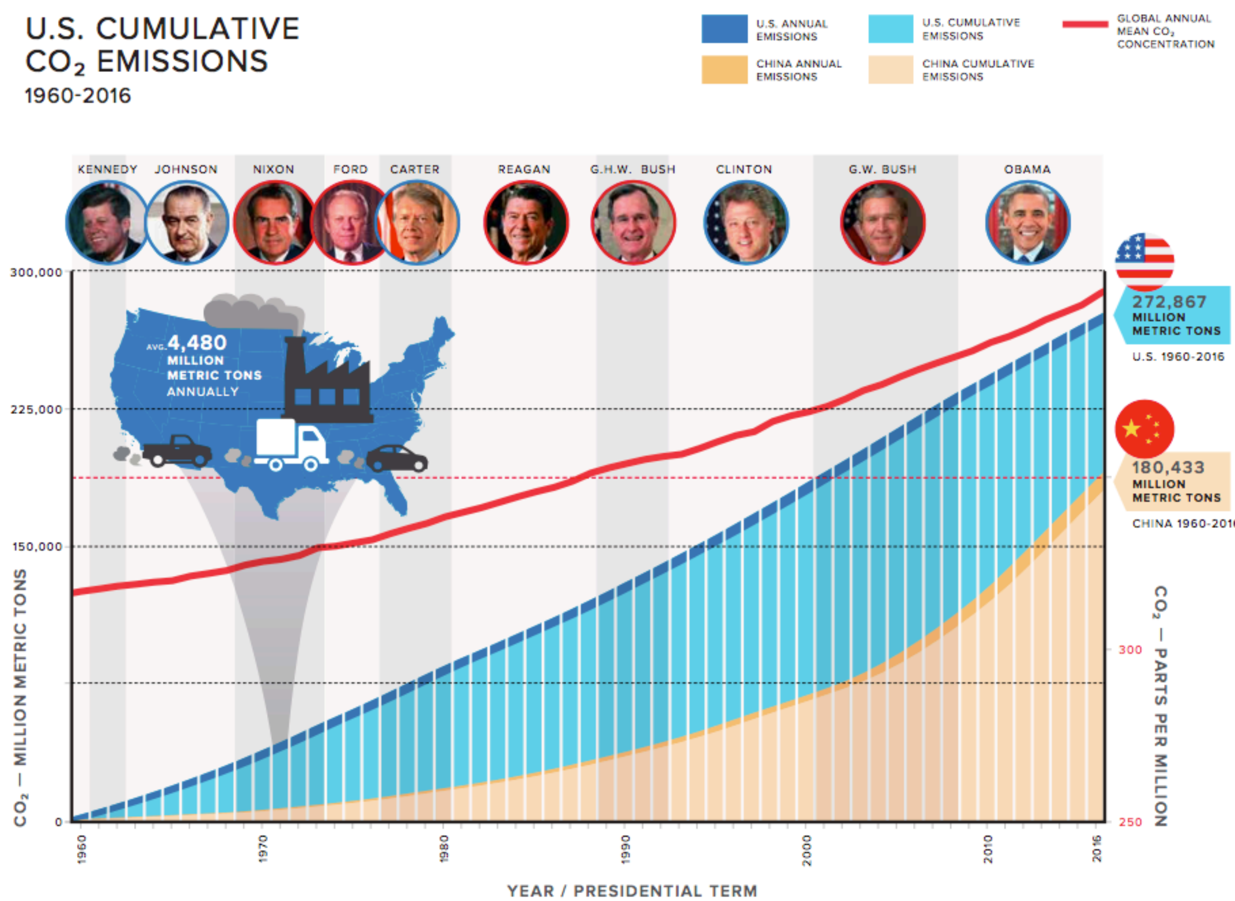

Figure 21: U.S. Cumulative CO_2 emissions from 1960 to 2016.[464]

After analyzing the last four decades of actions and inactions, a clear pattern of historical government conduct emerges relating to the nation's energy system and climate change. For decades:

a. Federal Defendants have understood both that the dangers of climate change are real, present, and intensifying and that they are caused predominantly by burning fossil fuels.
b. Federal Defendants have understood how climate change will harm the nation and especially youth Plaintiffs and future generations.
c. Federal Defendants have understood there are alternative national energy system pathways that would provide greater protection and safety for the nation and our people.

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[464] Source of U.S. and China Emissions Data: TA Boden, G Marland, G and RJ Andres, Global, Regional, and National Fossil-Fuel CO_2 Emissions, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, 2017, https://ess-dive.lbl.gov/2017/12/19/cdiac/; Source of global CO_2 concentration: National Oceanic and Atmospheric Administration Earth System Research Laboratory, https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html, accessed July 2018.

Notwithstanding these understandings, Federal Defendants have acted routinely and consistently, and continue to do so, to promote fossil fuels and thus to cause irreversible climate danger, a pattern that can only reflect a deliberate indifference to the severe impacts that will follow – impacts to be endured predominantly by youth Plaintiffs and future generations.

Signed this 28th day of September, 2018 in Strafford, Vermont.

EXHIBIT A: CURRICULUM VITAE

JAMES GUSTAVE SPETH

Senior Fellow, Democracy Collaborative
Co-Chair, Next System Project
Senior Fellow, Vermont Law School
Associate Fellow, Tellus Institute

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PAST PROFESSIONAL EXPERIENCE

PROFESSOR OF LAW, VERMONT LAW SCHOOL, SOUTH ROYALTON, VT 2010 TO 2015.

Carl W. Knobloch, Jr. DEAN and Sara Shallenberger Brown PROFESSOR in the Practice of Environmental Policy, Yale School of Forestry and Environmental Studies. New Haven, CT.
F&ES is a graduate and professional school of the environment. July 1999 to July 2009.

ADMINISTRATOR, United Nations Development Programme, New York, N.Y.
Chief executive officer of the principal arm of the United Nations for funding and coordination of international assistance for development. 1993–1999. Also served as first chair of the United Nations Development Group (UNDG), the coordinating body for all United Nations development activities.

SENIOR ADVISOR, President-Elect Bill Clinton's Transition Team. Washington, D.C.
Headed group on natural resources, energy and the environment. 1992.

PRESIDENT and FOUNDER, World Resources Institute. Washington, D.C.
President of WRI, a center for policy development and international assistance on environmental and sustainable development issues. 1982 to 1992.

PROFESSOR, Georgetown University Law Center. Washington, D.C.
Taught environmental and constitutional law. 1980–1981.

MEMBER and CHAIR, President's Council on Environmental Quality, Executive Office of the President. Washington, D.C. Principal White House advisor to President Carter on environmental affairs with over all responsibility for development and coordination of the Administration's environmental program. Member 1977–1978; Chair 1979–1980.

SENIOR ATTORNEY and COFOUNDER, Natural Resources Defense Council. New York, NY, and Washington, D.C.
Responsibilities included leadership of NRDC programs in energy and water. 1970–1977.

LAW CLERK TO SUPREME COURT JUSTICE, Hugo L. Black. Washington, D.C. 1969–1970.

EDUCATION

J.D. Yale Law School. New Haven, CT. 1969. Member of the *Yale Law Journal* and awarded Peres Prize for the best contribution to the *Journal* in 1969 (with others).
M.Litt, Economics, Rhodes Scholar. Balliol College, Oxford University, Oxford, England. 1966.
B.A. *summa cum laude.* Yale College. New Haven, CT. 1964.
Honors with Exceptional Distinction in Political Science

HONORS and AWARDS

Honorary Doctor of Laws, University of Massachusetts Boston, Boston, MA, 2013.
Honorary Doctor of Sustainability Science, Unity College, Unity, ME, 2013.
Honorary Doctor of Humane Letters, Green Mountain College, Poultney, VT. 2012.
Honorary Doctor of Humane Letters, University of South Carolina, Columbia, SC. 2008.
Honorary Doctor of Science, Middlebury College, Middlebury, VT. 2007.
Honorary Doctor of Laws, Vermont Law School, South Royalton, VT. 2005.
Honorary Master of Philosophy. College of the Atlantic. Bar Harbor, ME. 2001.
Honorary Doctor of Laws. Clark University. Worcester, MA. 1995.

Resource Defense Award. National Wildlife Federation. 1975.
Global 500 Honor Role. UN Environment Programme. 1988.
National Leadership Award. Keystone Center. 1991.
Barbara Swain Award. National Resources Council of America. 1992.
Keystone Center Creative Environmental Leadership Award, 1994.
Special Recognition Award. Society for International Development. 1997.
Special Leadership Award. Alliance for United Nations Sustainable Development Programs. 1998.
Ordre National du Lion of Senegal. 1998.
Grand Cordon du Wissam Alaouite of Morocco. 1999.
Lifetime Achievement Award. Environmental Law Institute. 1999.
Blue Planet Prize, 2002.
Global Environmental Award. International Association for Impact Assessment. 2005.
Connecticut Book Award, Best Nonfiction Book, 2005 (for *Red Sky at Morning*).
Yale Anglers' Journal Hall of Fame, 2006.
DeVane Lecturer, Yale University, 2007.
Straus Innovator Award, 2008.
Hutchinson Medal, The Horticultural Society of Chicago, 2008.
Lifetime Achievement Award, League of Conservation Voters, 2008.
A "Best Book" of the Year, Washington Post Book World, 2008 (for *The Bridge at the Edge of the World*).
Yale Law School Association Award of Merit, 2010.
Thomas Berry Great Work Award. Environmental Consortium of Colleges and Universities, 2013.
Thomas Berry Award, Forum on Religion and Ecology, 2014.

MEMBERSHIPS AND BOARDS

Co-Chair, Democracy Collaborative's Next System Project
Director, Climate Reality Project
Honorary Trustee, Natural Resources Defense Council
Honorary Director, World Resources Institute
Advisory board member: Vermont Natural Resources Council, Southern Environmental Law Center, 350.org, Labor Network for Sustainability, United Republic/RepresentUS.

PERSONAL

Born Orangeburg, S.C. in 1942. Son of Gus and Amelia Albergotti Speth. Attended Orangeburg High School. Husband of Cameron Council since 1965. Father of Catherine McCullough, Jim Speth and Charles Speth. Grandfather of Cameron McCullough, Rodgers McCullough, Lilla Speth, Charlotte Speth, Grace Speth, and James Speth.

PUBLICATIONS

BOOKS

Getting to the Next System: Guideposts on the Way to a New Political Economy, The Democracy Collaborative, 2015.

Angels by the River: A Memoir (Chelsea Green Publishing: White River Junction, VT, 2014).

America the Possible: Manifesto for a New Economy (New Haven, CT: Yale University Press, 2012; paperback, 2013). Translated: German.

Climate Change Law: Mitigation and Adaptation (St. Paul: Thomson Reuters, 2009) (with others).

The Coming Transformation: Values To Sustain Human and Natural Communities (Yale School of Forestry and Environmental Studies, 2009) (Ed. with Stephen Kellert).

The Bridge at the Edge of the World: Capitalism, the Environment, and Crossing from Crisis to Sustainability (New Haven, CT: Yale University Press, 2008; paperback, 2009). Translated: Japanese, Chinese, Arabic, Korean.

Global Environmental Governance (Washington, D.C.: Island Press, 2006) (with Peter Haas).

Red Sky at Morning: America and the Crisis of the Global Environment (New Haven, CT: Yale University Press, 2004). Translated: German, Japanese, Korean, Chinese, Turkish. Paperback with new "Afterword" (2005).

Worlds Apart: Globalization and the Environment (Washington, D.C.: Island Press, 2003) (Ed).

OTHER

"A Radical Alliance of Black and Green," *The Environmental Forum*, May-June 2018, 46 (with J. Phillip Thompson III).

Essays Editor, "New Systems: Possibilities and Proposals," Next System Project, 2016-18, https://thenextsystem.org/learn/collections/new-systems-possibilities-and-proposals.

"Stress Test: Democracy Confronts Climate Change," Next System Project, 2018, https://thenextsystem.org/learn/stories/stress-test-democracy-confronts-climate-change.

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EXHIBIT D: DOCUMENTARY EVIDENCE

Exhibit	Document	Bates Range
E-1	Rob Monroe, The History of the Keeling Curve, April 3, 2013.	P00000073222-P00000073225
E-2	Office of Science and Technology, Responses of the Federal Departments and Agencies to the President's Science Advisory Committee Report, "Restoring the Quality of Our Environment", May 1967.	P00000054158-P00000054192
E-3	National Science Foundation, Weather and Climate Modification, Report of the Special Commission on Weather Modification, Washington, D.C., Dec. 20, 1965.	P00000054000-P00000054157
E-4	National Academy of Sciences, Weather and Climate Modification—Problems and Prospects, Vol. I: Summary and Recommendations, Final report of the Panel on Weather and Climate Modification to the Committee on Atmospheric Sciences, Washington, 1966.	P00000073175-P00000073218
E-5	U.S. Department of Commerce, Panel on Electrically Powered Vehicles, Commerce Technical Advisory Board, The Automobile and Air Pollution: A Program for Progress. Report to the Commerce Technical Advisory Board, Oct. 1967.	P00000054193-P00000054238
E-6	Energy Policy and Conservation Act of 1975, (Pub. L. 94–163, 89 Stat. 871, Sec. 502(a)(1), enacted Dec. 22, 1975).	P00000065705-P00000065803
E-7	Daniel Moynihan, Memorandum to John Ehrlichman, Sept. 17, 1969.	P00000029996-P00000029997
E-8	Richard Nixon, letter to Lee DuBridge, Director of Office of Science and Technology, Nov. 20, 1969.	P00000054239-P00000054239
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Exhibit 5

SUPPLEMENTAL EXPERT REPORT
OF
DR. HAROLD R. WANLESS

Professor of Geological Sciences
University of Miami

Kelsey Cascadia Rose Juliana; Xiuhtezcatl Tonatiuh M.,
through his Guardian Tamara Roske-Martinez; et al.,
Plaintiffs,

v.

The United States of America; Donald Trump,
in his official capacity as President of the United States; et al.,
Defendants.

IN THE UNITED STATES DISTRICT COURT
DISTRICT OF OREGON

(Case No.: 6:15-cv-01517-TC)

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TABLE OF ACRONYMS AND ABBREVIATIONS

C:	Celsius
CCATF:	Miami-Dade County Climate Change Advisory Task Force
CO_2:	carbon dioxide
EPA:	United States Environmental Protection Agency
F:	Fahrenheit
ft:	feet
GMSL:	global mean sea level
IPCC:	Intergovernmental Panel on Climate Change
LiDAR:	Light Detection and Ranging
m:	meters
NAO:	North Atlantic Oscillation
NOAA:	National Oceanic and Atmospheric Administration
ppm:	parts per million
SFWMD:	South Florida Water Management District
SLR:	sea level rise
USGCRP:	United States Global Change Research Program

INTRODUCTION

I, Harold Rogers Wanless, have been retained by Plaintiffs in the above-captioned matter to provide expert testimony regarding how human-caused CO_2 emissions are causing sea level rise, which results in some of the injuries and constitutional violations alleged in the Complaint in this case. I discuss the paleoclimate record and fluctuations in sea level rise, and how human-caused climate change, ocean warming, and polar ice melt are accelerating sea level rise. I also describe the very real harms the Plaintiffs face associated with sea level rise, particularly as young people. I have also been asked to opine on the urgency of stopping additional greenhouse gas emissions in order to arrest the even more significant consequences of sea level rise. To render my opinions in this report, I have relied upon my extensive qualifications and 46 years of experience in the fields of geology, marine geology, and the paleo-sea level record. I have also reviewed a number of documents identified at the end of this report.

The opinions expressed in this report are my own and are based on the data and facts available to me at the time of writing. All opinions expressed herein are to a reasonable degree of scientific certainty and historical accuracy, unless otherwise specifically stated. Should additional relevant or pertinent information become available, I reserve the right to supplement the discussion and findings in this expert report in this action.

This report contains my opinions, conclusions and the reasons therefore. My professional and educational experience is summarized in my curriculum vitae attached to this declaration as **Exhibit A**. My curriculum vitae also contains a list of publications I authored within the last ten years and more. My report contains citations to all documents that I have used or considered in forming my opinions, listed in **Exhibit B**. In the past four years I have provided testimony as an expert in two cases, listed in **Exhibit C**.

In preparing my expert report and testifying at trial, I am deferring my expert witness fees charged to the Plaintiffs given the financial circumstances of these young Plaintiffs. If a party seeks discovery under Federal Rule 26(b), I will charge my reasonable fee of $250 per hour for the time spent in addressing that party's discovery.

EXECUTIVE SUMMARY

Geologic evidence reveals that, following the last ice age 18,000 years ago, sea level rose over 128 meters (420 feet), to near its present level, but it did not do so slowly and steadily. Rather it rose in a series of rapid 1m to 10m "pulses" over a short timeframe of just a century or so, each in response to a pulse of rapid disintegration of some ice sheet sector. This is also how ice melt and sea level rise will occur in the future, and means that anthropogenic warming and loss of glacial ice is having and will have grave implications for the future of coastal cities and people around the world.

The geologic evidence for repeated rapid pulses of sea level rise during the past 18,000 years can only be explained by repeated pulses of disintegration of ice sheet sectors. This occurred throughout the rapid and slower phases of increasing global temperatures in response to naturally increasing CO_2 levels from 180 to 280 ppm over that 18,000 years.

Since the beginning of the industrial revolution, the burning of fossil fuels has very rapidly increased atmospheric CO_2 levels another 125 ppm. We now have global air temperatures at almost 1°C warmer than at the beginning of the Industrial Revolution and an ocean that has absorbed over 93 percent of the atmospheric heat produced by buildup of these anthropogenic greenhouse gases. This warmed ocean and atmosphere is now accelerating melt of the Ice Sheets of Greenland and Antarctica.

Ice melt acceleration and associated sea level rise is occurring faster than any of the climate models predict, including those used by the Intergovernmental Panel on Climate Change (IPCC) for sea level rise projections, because the models have not included, and still do not include, many of the numerous accelerating feedbacks in ice melt anticipated by the paleo record and that are now being observed in real time. These accelerating feedbacks that are accelerating ice melt and sea level rise are the real time display of the onset of a new pulse of rapid sea level rise. This pulse of rise has been triggered by the atmospheric and ocean warming resulting from the extremely rapid buildup of CO_2 in the atmosphere from our burning of fossil fuels.

Meaningful U.S. Government Global Mean Sea Level projections are for a further 5 to 8.2 feet of rise this century. When regional sea level rise projections are added in, southeast Florida should be anticipating from 7.0 to as much as 14.1 feet of further sea level rise by 2100. This could be 2 more feet of rise by 2039-2041, enough to limit habitability of our barrier islands and other low coasts.

Sea level rise impacts are exacerbated by increasingly intense storms that bring storm surges and heavy rains, worsening the flooding that stems from sea level rise alone. Although the precise timing and landfall of an individual storm event cannot be specifically attributed to human-induced global warming, scientists can now calculate that powerful storms are more likely and made worse from the additional heat and water vapor in the atmosphere and heat in the oceans due to the increasing concentration of atmospheric CO_2. In addition, storm surges are acting at higher sea levels. Simply put, warmer ocean temperatures provide more energy to fuel storms. Increasingly destructive storms and rainfall events are not off in the future, they are here now.

For Plaintiffs like Levi, who lives on a low-lying barrier reef island off of the southeastern seaboard, or Miko, whose birth family and relatives live in the Marshall Islands, sea level rise and storm surges will make their home and homeland, respectively, uninhabitable within decades, and eventually inundate them permanently with sea water.

QUALIFICATIONS

I am a Professor in the Department of Geological Sciences where I was also Chair for the previous 19 years and was Cooper Fellow of the College of Arts and Sciences at the University of Miami from 2010 to 2013. My office is located in Coral Gables, Florida. I am a Registered Professional Geologist in the State of Florida #985.

My father, Dr. Harold Rollin Wanless, was a sedimentary geologist who extensively studied the rocks of Paleozoic Pennsylvania Period and was one of the first to publish on the cyclical nature of sedimentation during Pennsylvanian Period resulting from sea level rises and falls in response to repetitive glaciations. As a child, I grew up immersed in the history of the "rocks" of the

Pennsylvanian Period and the ancient stories they told of dramatic and repetitive fluctuations of sea level on scales from hundreds to millions of years. Those early beginnings led me to my own deep study of geology and the paleo-sea level record, and ultimately human-induced climate change and resulting modern-day sea level rise.

I received an A.B. degree in Geology from Princeton University in 1964; a M.S. degree in Marine Geology and Geophysics from the University of Miami in 1967; and a Ph.D. degree in Earth and Planetary Sciences from the John Hopkins University in 1973. My Master's Thesis was on the Holocene sediments that have accumulated in the Biscayne Bay region over the past 7,000 years and the character and role of sea level rise and storm and biological processes in defining the nature of these sediments. During my time as a Master's student, I worked for my Advisor, Dr. A. Conrad Neumann, on developing a sea level curve for south Florida, the Bahamas and Bermuda using core boring samples from freshwater peat deposits that formed close to sea level elevation. My Ph.D. dissertation was on the Paleozoic Cambrian strata in the Grand Canyon, Arizona, where small-scale sedimentary cyclic sequences were deposited in response to natural cycles of sea level fluctuation operating a half billion years ago.

Since 1971, I have had 46 years of experience as a geologist and marine geologist on the faculty at the University of Miami. My research specialty is coastal and shallow marine sedimentology, modern and ancient, with a focus on documenting and understanding the role of sea level dynamics and storm processes in creating and modifying coastal and shallow marine environments. Much of my research, and that of my students, has focused on determining the fine-scale sea level history over the past 7,000 years and the associated response of coastal and shallow marine environments. This research has focused on the South Florida-Bahamas-Caicos region. Our research has been funded from a variety of sources, including the National Science Foundation, the Department of the Interior (National Park Service), the Department of Commerce (Sea Grant and National Oceanic and Atmospheric Administration), Miami-Dade County Department of Environmental Resource Management, petroleum companies (including Exxon, for whom I received research funding through much of the 1980s), and development companies. I have been publishing on past sea level trends in the juried literature since 1976 and have been projecting future trends since 1982 (Wanless, 1976; Wanless, 1982; Wanless and Parkinson, 1989; Dominguez and Wanless, 1991; Wanless, Parkinson, and Tedesco, 1994; Science Committee, 2008; Technical Ad Hoc Work Group, 2011 and 2015).

Since 1981, I have been using our knowledge of past environments to look to the future. My students and I have been documenting the changes in south Florida coastal environments in response to both accelerated sea level rise occurring since 1930 and major (category 4 and 5) hurricanes. Through this research, we have studied the coastal and low wetland environments bordering Biscayne Bay, Florida Bay, southwest Florida from Cape Sable to Everglades City, and the 10,000 islands. We focus our research on coral and oyster reefs, coastal lagoons and estuaries, coastal sandy beaches and barrier islands, saline mangrove wetlands, low-lying freshwater wetlands near the coast, as well as the adjacent fresh-water Everglades and low-lying upland. To put it simply, the scientific study of islands, mangroves, sand, mud, reefs, and rocks gives us a clear window into historic sea level rise and, combined with other scientific tools, allows us to better project sea level rise into the future.

As polar ice sheet melt has significantly accelerated on both Greenland and Antarctica since about the 1990s, I have been active in working with other scientists, communities, Miami-Dade County, the State of Florida and Federal agencies in using new research data from myself and others to project future sea level rise both globally and regionally and to determine the impact it will have on low-lying coastal environments, coastal communities, agriculture, and industry. This includes an evaluation of the changing anthropogenic effects on coastal and shallow marine environments with rising sea level (Science Committee, 2008; Technical Ad Hoc Work Group, 2011 and 2015).

I was an active member of, and invited speaker at, the Miami-Dade County Climate Change Advisory Task Force (CCATF), comprised of 25 members, appointed by the Commissioners, Mayor, and County Manager. Throughout its existence, I served as the Chair of CCATF's Science Committee and drafted their reports. From 2006–2011, the CCATF served as an advisory board to the Board of County Commissioners and was charged with identifying potential future climate change impacts to Miami-Dade County, while providing recommendations regarding realistic and necessary mitigation and adaptation measures to respond to climate change.

Miami-Dade County has officially recognized and relied upon my expertise and peer-reviewed research on climate change and sea level rise as evidenced through County review and adoption of CCATF recommendations, which was based in part upon my peer-reviewed research, as well my position as the Chair of CCATF's Science Committee.

In 2010, the Southeast Florida Regional Planning Council initiated efforts to create a four county "Regional Compact," an agreed-upon statement of climate change and anticipated sea level rise. I was part of the committees that used the peer-reviewed scientific literature and our expertise to write reports on anticipated sea level rise for the Compact. These reports are incorporated into the overall "Regional Compact" Documents (Technical Ad Hoc Work Group, 2011 and 2015).

The South Florida Water Management District ("SFWMD") has previously relied upon and cited to my peer-reviewed research in assessing sea level rise implications for South Florida. (SFWMD, "*Preliminary Estimate of Impacts of Sea Level Rise on The Regional Water Resources of Southeastern Florida*;" SFWMD, "*Estimated Impacts of Sea Level Rise on Florida's East Coast.*")

U.S. Army Corps of Engineers personnel acknowledged and cited to my research regarding sea level rise in a presentation entitled "Climate Change Concerns for Everglades Restoration Planning," which was presented at the Planning Community of Practice Conference 2008.

I have twice been an invited speaker to the State of Florida legislature to present evidence for anticipated sea level rise and implications to South Florida coastal environments and the Everglades (2007). I have been an invited speaker to the Council on Environmental Quality at the White House, addressing sea level rise and the urgent need to shift the Mississippi River outlet back onto the continental shelf to help save the Mississippi River Delta (2009).

I am familiar with the findings of the U.S. Global Change Research Program ("USGCRP") and the 2014 Report entitled "Global Climate Change Impacts in the United States: A State of Knowledge Report from the U.S. Global Change Research Program" as well as the 2017

USGCRP National Climate Assessment. I am also familiar with the broad body of scientific literature on climate change and sea level rise.

EXPERT OPINION

I. The Paleoclimate Record and Fluctuations in Sea Level Rise

Earth has different orbital cycles that affect global temperatures. One of the three Milankovitch Cycles is a ~100,000 year cycle of Earth's eccentricity, or the shape of its orbit around the sun, which fluctuates between a more circular to a more oval orbit. This cycle, which affects polar cooling and warming is primarily responsible for driving Earth in and out of glacial periods over the past million years. A second cycle, obliquity, is how the Earth's axis is tilted toward the sun, which varies between 21.5 and 24.5 degrees every ~40,000 years. The third, precession, are ~19,000 and ~21,000 year cycles, which changes the wobble of the Earth as it moves around the sun and determines whether the poles are tilted towards the sun or are sideways to the sun when closest in the orbit. **Figure 1** below depicts these cycles.

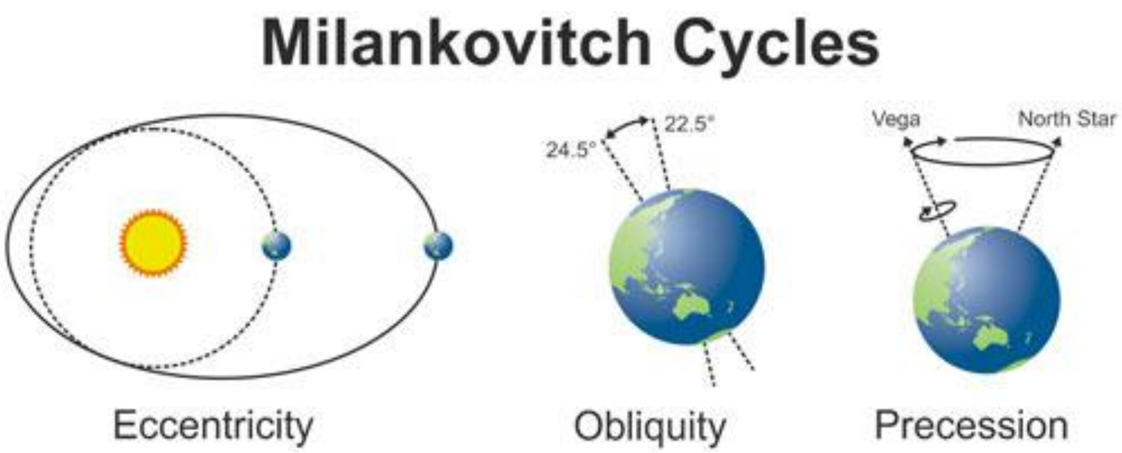


Figure 1. The Earth's orbital cycles that affect global temperatures.

These natural cycles of how Earth presents herself to the Sun result in slight differences in illumination and warming/cooling which trigger slight changes in productivity and surficial rock and soil weathering, which in turn result in changes in CO_2 and warming. By studying historic CO_2 levels through ice cores and deep ocean sampling, the scientific community has established with high confidence the close correlation between atmospheric CO_2 levels and temperature change across geologic time.

During the most recent period of the Holocene (past 12,000 years) when human civilization developed, Earth's optimum presentation to the sun occurred about 6,500 years ago, which was the warmest period of the Holocene before human-caused climate change began occurring. During that time, atmospheric CO_2 levels were ~280 ppm. As the Earth's orbit moved away from the optimum presentation, a natural, slow and slight cooling would have naturally occurred, and has been clearly documented for the 1,000 years prior to the beginning of the industrial revolution

(Mann, 1994). This natural cooling has since become overshadowed by increasing human-caused greenhouse gas emissions, predominantly CO_2. Since about 1950, human inputs of CO_2 have become the primary and dominating control of climate (Mann et al., 1995).

In contrast to the Holocene, 120,000 years ago during the warmest interglacial period, known as the Eemian, atmospheric CO_2 levels were at 280–300 ppm, temperatures were only slightly warmer than today and sea level rise was 26 feet higher than it is today (because of greater ice melt from both Greenland and Antarctica than today). As shown in **Figure 2** below, the fluctuations of CO_2 from between 280–180 ppm for hundreds of thousands of years (green line) moves in parallel with the warming and cooling of Earth's atmospheric temperature (red line) and with the cyclic rise and fall of sea level (blue line) of about 100 meters (330 feet).

These 'geologically rapid' changes in climate typically occur over thousands of years. However, since the industrial revolution, human burning of fossil fuels has caused CO_2 to shoot up from 280 ppm to over 410 ppm, which is a 40% increase over preindustrial levels, and more than double the 100 ppm increase from the natural glacial to interglacial level which resulted in 100 meters (330 feet) of sea level rise. This human-driven increase has happened in a very short period of time as compared to earlier natural shifts. Based on our understanding about how increases in CO_2 drive atmospheric and oceanic warming, which in turn cause ocean expansion and polar ice melt, leading to global sea level rise, the results will be dire for humanity at current CO_2 levels, and even worse if we continue to inject even more CO_2 into the system. The last time CO_2 levels were above 400 ppm, global sea level was some 21–27 meters (70–90 feet) higher. This was over one million years ago.

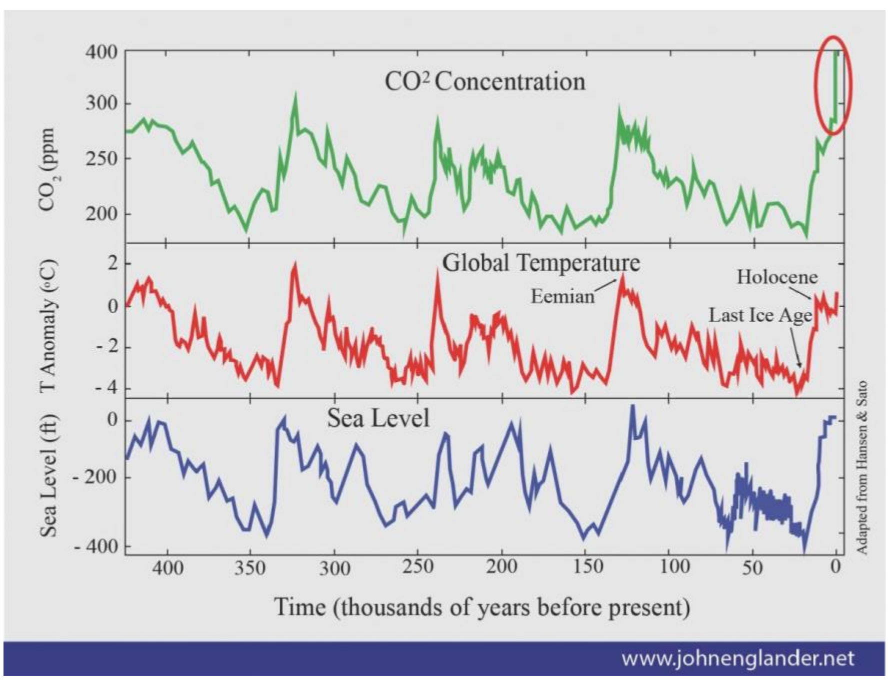


Figure 2. Graphs of 400,000 years of carbon dioxide, temperature change, and sea level. Adapted by Hansen for Englander (2013).

Figure 3 below shows the coastline of the southeastern United States, where Plaintiffs Jayden and Levi live, the last time CO_2 levels were above 400 ppm, well over a million years ago. At that time, sea levels were about 20 meters (70 feet) higher than they are today. As you can see, sea levels that high would result in the submersion of much of the states of Florida and Louisiana, along with a vast expanse along the Gulf Coast and Eastern Seaboard. Even a sea level rise of 6 meters, which happened during the last interglacial episode approximately 125,000 years ago, would result in the total loss of the cities of Miami, FL, New Orleans, LA, and other coastal cities throughout the United States.

The increase in carbon dioxide from 280 to 410 ppm from the burning of fossil fuels has occurred more than 100 times faster than the natural increase in carbon dioxide from 180 to 280 ppm following the last ice age. The reason we have not yet seen the significantly higher sea levels that were present the last time CO_2 levels were above 400ppm is that there is simply a short time lag between the greenhouse gas buildup in the atmosphere and the heat buildup in the atmosphere, and then the heat buildup in the shallow ocean and then the heat buildup in the deeper ocean. Each one of these processes takes more time. By the 1950s, there was enough CO_2 in the atmosphere to basically control atmospheric climate. By the 1990s, the human-induced buildup of heat transferred to the oceans was enough to begin melting both the Greenland and Antarctic Ice Sheets. As the Ice Sheets are warming through atmospheric and ocean water melt-water penetration, fracturing and softening, they are accelerating their melt. We are also dramatically speeding up the rate of heat production by global warming. As you can see by where we are on the projected sea level rise rate for the future (on **Figure 6** below), we are just beginning the acceleration of sea level rise from ice melt and this will become a dominating factor later in the century. And this is why scientists are so deeply concerned. We are at a tipping point that may well spin out of control this century. That is what happened repeatedly in the past as we warmed following the last ice age 18,000 years ago.

Figure 3. Map of the south Atlantic and Gulf coasts showing the inundation that would occur with 20 meters (70 feet) of sea level rise.

A. Sea Level Rise Pulses

Through scientific study of the geologic record, we have shown that sea levels did not rise in a gradual linear manner in response to gradually increasing natural warming and carbon dioxide levels as we came out of the last glacial period. Global sea level rose from about -128 meters (-420 feet) 18,000 years ago to the present level as a series of rapid pulses of rise followed by pauses as warming initiated one pulse of ice sheet collapse after another. This is evidenced by drowned coastal deposits left across the continental shelves of the world. Through research and radiometric dating by myself and others of deposits from former coastal wetlands (especially red mangrove and salt marsh peats), reefal systems (coral and oyster), sandy barrier islands, intertidal encrusting and boring organisms (such as barnacles), we have understood for the past 30 years that there is a pattern of 1–10 meter (3.3–33.0 foot) sea level pulses of rapid coastal inundation followed by pauses, repeated rapid flooding and more pauses.

These pulses of sea level rise occur over relatively short periods of time (within a century or so) and are a reflection of a phase of rapid disintegration of some former ice sheet sector**.** Each pulse that has been documented to date was associated with a rather small increase in CO_2 as compared to the large and extremely rapid human-induced increase that has occurred since the beginning of the industrial revolution. When the sea rises slowly, barrier islands and coastal marshes can keep up and grow or gradually migrate landward and thus stay above sea level, and mature reefs would be able to grow upwards in response to increased subtidal space becoming available. But, if the rise is too rapid, it will simply overstep and drown the barrier island, the reef, or the coastal wetland and begin forming a new one shifted landward. All across the continental shelves of the world are old sandy barrier islands, reefs and coastal wetlands that were drowned out and left behind. If subsequent waves and currents permitted, these relict coastal deposits remain as testament. We can definitively establish that during certain periods the rises in sea level occurred very rapidly. This geologic evidence for rapid ice sheet disintegration, once destabilized, is the verification that the numerous reinforcing, accelerating feedbacks scientists are observing for recent ice sheet melt on Greenland and Antarctica is cause for deep concern. We most certainly are witnessing the onset of one of these rapid pulses of ice sheet disintegration and resulting sea level rise.

In the summer of 2013, I was able to witness the fact that accelerating ice melt is happening significantly faster than previously thought when flying about 50 miles onto the Greenland Ice Sheet following the deep channel of the Jacobshaven Icefjord in western Greenland. We reached an elevation on the Ice Sheet of over 2,000 meters (6,500 feet). It was like flying up a large, meandering, fractured, dry stream bed in the ice surface. The channel-like depression on the ice surface was some 150 m (500 feet) below the level of the ice sheet and was dramatically fractured from the accelerated ice melt from below and resulting fracture and flow. This was created by melt at the base of the ice sheet from deeply penetrating 'warmed' ocean water. As a result of the fracturing and detachment from the bottom, the forward velocity of the ice has accelerated from a couple of miles per year to over twenty. Overall, this was a spectacular, but most disturbing experience given what this means for accelerating future sea level rise.

Figure 4 below depicts the post-glacial pulses of rapid sea level rise and pauses that are well documented in the literature. These include those over the past 5,500 years that my students and I have measured in Florida and Brazil (Dominguez and Wanless, 1991; Gelsanliter, 1996;

Gelsanliter and Wanless, 1995). Others have documented earlier pulses of rapid rise, including Locker *et al*., 1996; Jarrett *et al*., 2005; Milliken *et al*., 2008; and Pretorius *et al.*, 2017.

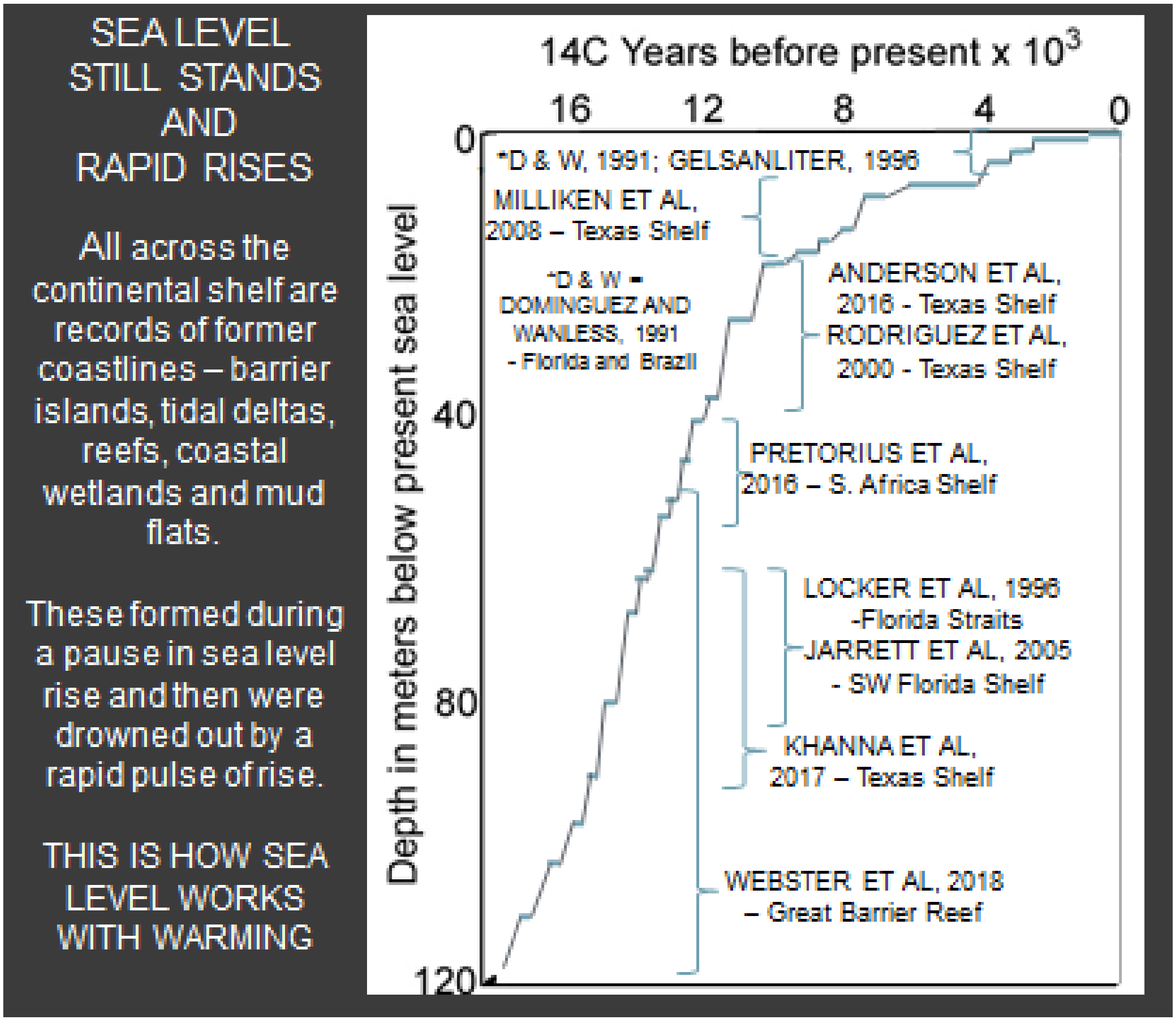


Figure 4. Reconstructed post glacial sea level history incorporating pulses of sea level rise following brief still-stands in which coastal barrier islands, tidal deltas, bay-head deltas, reefs, wetlands and tidal flats formed and were then drowned out. Age is in thousands of years before present. Each pulse of rise must represent a pulse of rapid ice sheet disintegration.

The reason for the pulses of sea level rise is the non-linear melting of ice superimposed on the thermal expansion of water and other lesser influences. James Hansen (2007) best describes this phenomenon as rapid ice sheet disintegration. Since 1990, we are now witnessing the onset of a new pulse of ice melt in both Greenland and Antarctica, which I discuss in greater detail below.

II. The Reality of Human-Caused Climate Change, Ocean Warming, and Accelerating Sea Level Rise.

Notwithstanding the natural long-term Milankovitch Cycles affecting Earth's temperatures and incoming solar radiation, the most significant effect on Earth's temperatures since the 1950s is from the increasing CO_2 levels in the atmosphere that result from humans burning fossil fuels. There is an extremely strong consensus with a high level of confidence among actively publishing climate scientists and strong scientific evidence that the climate is warming due to human activities, primarily the burning of fossil fuels such as coal, oil, and gas. Carbon dioxide emissions are the strongest human-induced climate forces, but other human-induced greenhouse gas emissions also contribute to climate change, including methane and nitrous oxide. At the beginning of the industrial revolution global CO_2 levels were ~280 ppm. They are currently above 410 ppm and increasing at greater than 3 ppm per year.

As depicted in **Figure 2** above, for the past 400,000 years, CO_2 fluctuated between 180 ppm and 280 ppm, and in concert sea level went down and up 100 meters or more. These natural changes in CO_2, temperature, and sea level occurred over thousands of years. For the first time in the paleo-record, CO_2 levels have risen by more than 125 ppm and within only 150 years. This is more than double the 180–280 ppm post-glacial CO_2 increase which drove the entire series of pulses that totaled 120 meters of sea level rise in response to warming and ice melt. There is no historical precedent for this rapidity of change that we can find in the paleo-record. The unprecedented rate and degree of human-caused CO_2 increase and warming should serve as a warning. The Earth will now respond in unprecedented, dire, and most certainly rapid ways.

Referring to the late 18th century as the beginning of the HyperAnthropocene, when the improved steam engine initiated the industrial revolution (Hills, 1993) and the exponential growth in fossil fuel combustion, Hansen et al. explain that three-quarters of human-caused warming since 1850 (~1°C) has occurred since 1975 (Hansen et al., 2016). When I was born in 1942, there were less than two billion people on the planet, and many countries were not at all industrialized. Now we have over 7.5 billion people, and also many large countries are rapidly industrializing.

The global-mean temperature has increased by more than 1.8°F (1°C) over the past century, and is projected to warm by a total of 3.6–4.8°F/2–4.8°C over the next century depending upon future emissions of greenhouse gases (IPCC, 2014).

A. Thermal Expansion of the Ocean

Very importantly, nearly all the excess atmospheric heat produced by the greenhouse gasses from burning fossil fuels has transferred to the oceans. Approximately 93.4% of the excess energy (heat) human pollution has forced on the planet has been absorbed by the oceans, with much of it penetrating to 1,000 meters or more in depth. This heat transfer is rapidly accelerating as people burn more and more fossil fuels. Over half of this excess heat from human-induced global warming has transferred to the ocean since 1997. **Figure 5** shows the distribution of global-warming energy accumulation (heat) relative to 1971 and from 1971–2010.

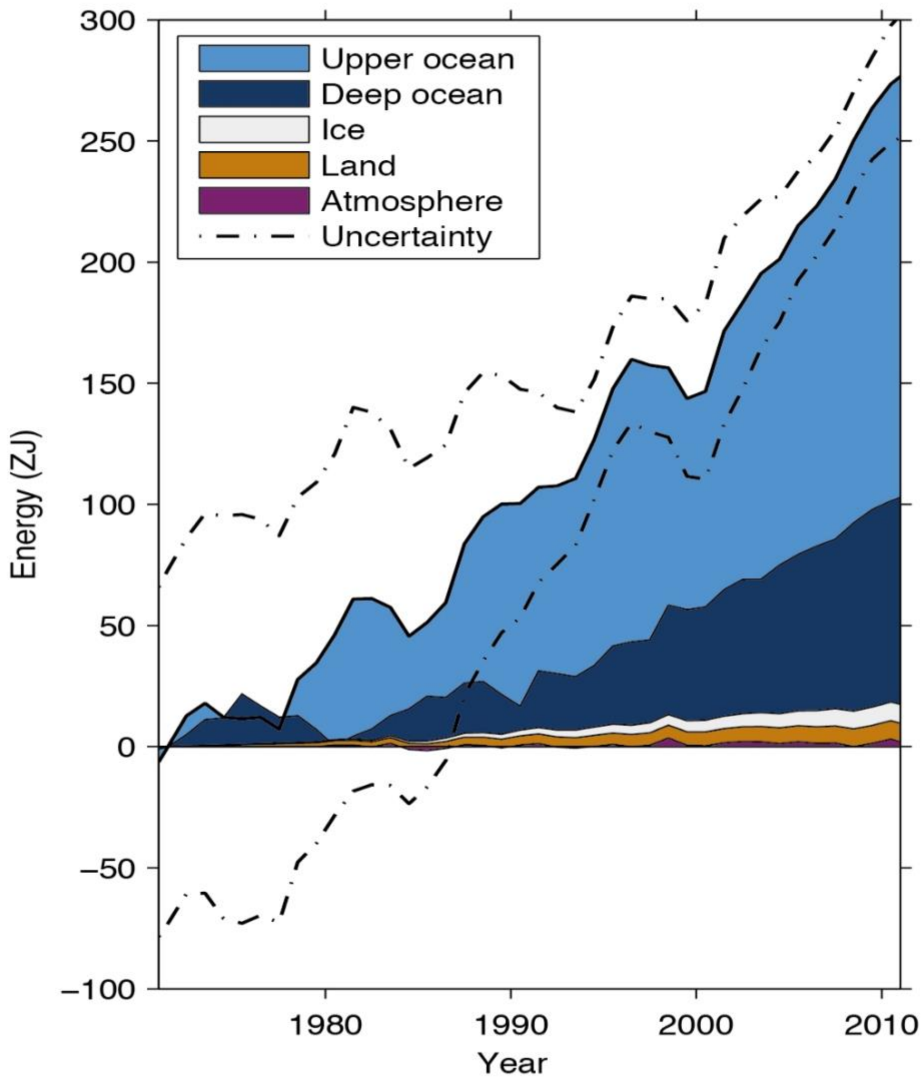


Figure 5. Plot shows the distribution of global-warming energy accumulation (heat) relative to 1971 and from 1971 to 2011 (IPCC, 2014). Half of the human-produced global warming heat has entered the ocean since 1997.

In high school physics, children are taught that water has great capacity to take in, hold, and use heat. Atmospheric warming will continue for some 30 years after we stop putting more greenhouse gasses into the atmosphere. But that warmed atmosphere will continue warming the ocean for centuries, and the accumulating heat in the oceans will persist for millennia.

The temperature of the ocean is significant for sea level rise because the density of seawater largely depends upon temperature. Because warmer water is less dense than colder water, the volume of the ocean increases even if it stays at a constant mass. Thus, thermal expansion of the ocean is one of the major contributors to sea level change. Scientists have predicted that "[i]f the upper 1,000 meters of some portion of the ocean were to warm by 1 degree Celsius, then the sea level would increase by about 50 centimeters [1.67 feet]."[1] Ocean temperature measurements have shown that the warming of the upper ocean has contributed about 30 percent of the total sea level rise between 1971 and 2010. Ice melt from mountain glaciers, Greenland, and Antarctica accounts for most of the remaining rise.

The CO_2 addition to the atmosphere has a several thousand-year residence time and is not consumed as it warms the atmosphere and ocean. Due to that large thermal inertia, the climate will continue to warm over the next half-century, even if a reduction in fossil fuel emissions and stabilization of CO_2 concentrations occurred today, and the warmed ocean will continue to melt polar ice for centuries. Put simply, the climate has warmed and future warming is unavoidable. However, how much more climate-forcing we put into the system through CO_2 and other greenhouse gas emissions this year and in the years to follow, and how much carbon we sequester from the atmosphere through improved land management practices and active sequestration, will dictate how much additional warming will occur and whether the impacts of climate change are survivable for much of humanity and many other species living on the planet.

Global warming from the atmospheric influx of CO_2 and other greenhouse gasses leads to a number of changes in climate beyond simply an increase in ocean and land-surface temperatures. These include, but are not limited to: increased frequency and intensity of heavy rainfall events and floods, increased sea level, more intense hurricanes, higher atmospheric and oceanic temperatures, ocean acidification, loss of coastal wetlands, and destabilization of permafrost in the arctic and of methane hydrates frozen in the sediments in the Arctic Ocean bottom.

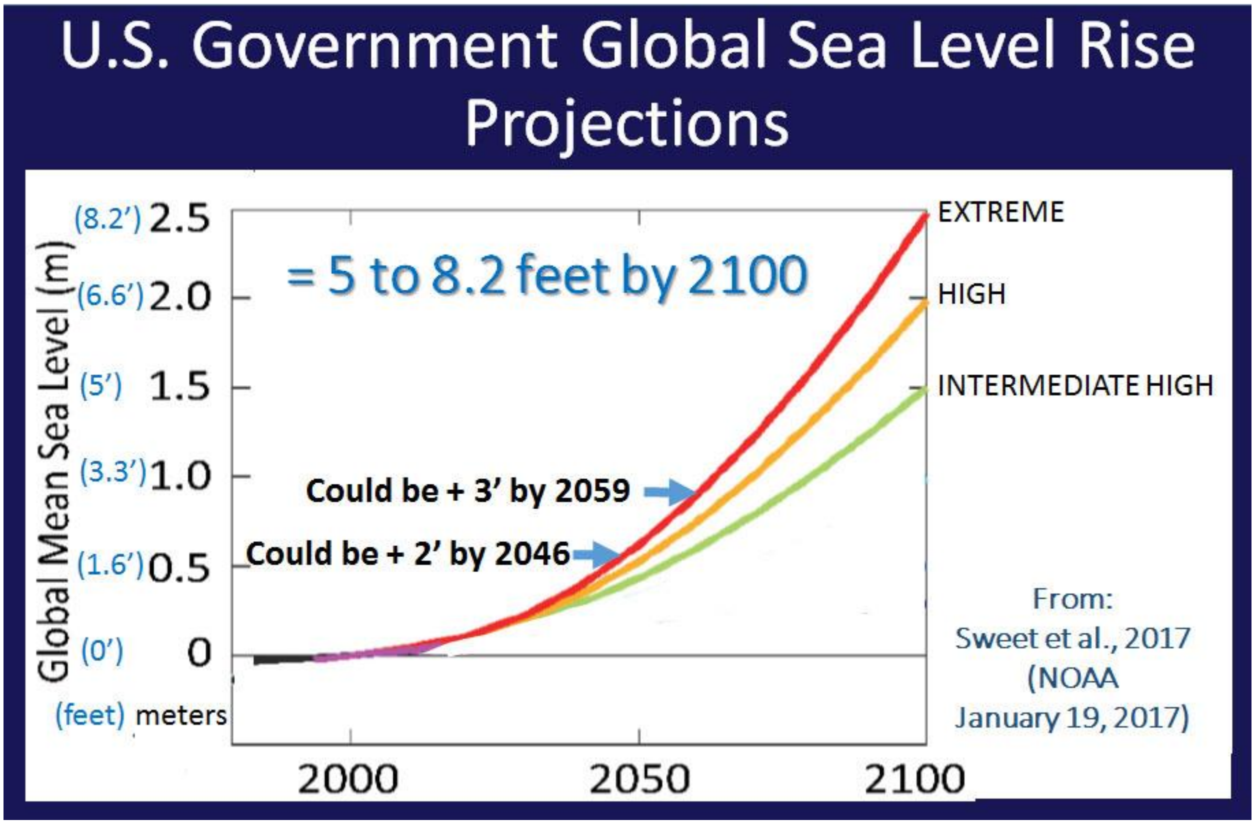
B. Sea Level Rise Projections

Global mean sea level (GMSL) has risen about 20–23 cm (8–9 inches) since the industrial revolution and 8 of those centimeters (3 inches) have occurred between 1993 and 2009 (Church and White, 2011; Hay et al., 2015; Nerem et al., 2010). Even these relatively small increases have had substantial effect on low-lying areas, like we have seen in south Florida and Louisiana. The question now is not whether the seas will continue to rise, but by how much and by when.

In 2017, the National Oceanic and Atmospheric Administration (NOAA) published the most recent United States Government sea level rise projections, once again confirming that sea level rise is a certain impact of climate change (*Global Sea Level Rise Scenarios for the United States; National Climate Assessment* (NOAA, January, 2017)). NOAA's projections, which included acceleration of ice melt from Greenland and Antarctica, included a range between 1.5–2.5 m (5–8.2 ft.) global mean sea level rise (GMSL) for 2100 (**Figure 6**). NOAA's 2017 projections are higher than the projections NOAA made just five years ago in its 2012 assessment. NOAA's 2017 projections are also higher than the conservative IPCC projections for the 4th and 5th reports. The reason for this is that the IPCC is required to use only jury refereed published articles (usually published 3–4 years after the research). The IPCC cuts off use of literature 2–3 years before report publication because of the need for gaining scientific consensus and public review. The sea level working group has been dominated by modelers who do not see beyond their numerical models

[1] Hine, C., et al., Sea Level Rise in Florida, Science, Impacts, and Options, Univ. of Fla. Press (2016) at 41.

(which cannot yet incorporate many of the accelerating ice-melt feedbacks being observed), and there is governmental political pressure on some scientists to go low on sea level projections, and the consensus agreed upon will be by definition very conservative. For all the above reasons, the IPCC has put out unreasonably low sea level rise projections in their 4th and 5th reports (2007 and 2013). NOAA's and most other projections conclude that sea level rise will continue to rise and to accelerate even more after 2100. If, for example, sea level has risen 1.5 m (5 feet) by 2100, it will be rising at a rate of 30 centimeters (one foot) per decade—and accelerating.



GMSL Scenario (meters)	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100	2120	2150	2200
Low	0.03	0.06	0.09	0.13	0.16	0.19	0.22	0.25	0.28	0.30	0.34	0.37	0.39
Intermediate-Low	0.04	0.08	0.13	0.18	0.24	0.29	0.35	0.4	0.45	0.50	0.60	0.73	0.95
Intermediate	0.04	0.10	0.16	0.25	0.34	0.45	0.57	0.71	0.85	1.0	1.3	1.8	2.8
Intermediate-High	0.05	0.10	0.19	0.30	0.44	0.60	0.79	1.0	1.2	1.5	2.0	3.1	5.1
High	0.05	0.11	0.21	0.36	0.54	0.77	1.0	1.3	1.7	2.0	2.8	4.3	7.5
Extreme	0.04	0.11	0.24	0.41	0.63	0.90	1.2	1.6	2.0	2.5	3.6	5.5	9.7

Figure 6. Top: 2017 NOAA projections for Global Mean Sea Level rise which include accelerating ice melt from ice sheet disintegration and a warming, expanding ocean (Modified from Sweet et al, 2017). Bottom: Global Mean Sea Level rise scenario heights for 19-year averages centered on decade through 2200. From Sweet *et al.*, 2017. Low,

Intermediate Low and Intermediate are unrealistically low projections because they do not incorporate significant acceleration in polar ice melt.

Using NOAA's higher projections, which as discussed below are conservative, the time at which each foot of sea level rise will be reached can be anticipated by using their 'Intermediate High,' 'High,' and 'Extreme' scenarios. The Intermediate High scenario projects sea level rise incorporating a warming ocean and 'limited ice sheet loss' and some ice melt acceleration. The 'Intermediate Low' scenario only incorporates sea level rise from ocean warming, minor ice melt but no ice melt acceleration. The 'Lowest' scenario is a linear projection based on historical sea level rates derived from tide gauge measurements beginning in 1900. Neither the Lowest nor the Intermediate Low scenarios are valid scenarios to use for the future. They both fail to reproduce the observed sea level rise over the past two decades because of significant acceleration from already occurring observed ice melt.

Under NOAA's 2017 projected scenarios, there could be 60 cm (2 feet) of sea level rise by 2046 and 90 cm (3 feet) by 2059. A 2–3 foot rise of sea level will make nearly all of the barrier islands of the world uninhabitable, result in inundation of a major portion of the world's deltas, and make low-lying coastal zones like south Florida and Louisiana increasingly challenging communities in which to maintain infrastructure and welfare and to assure protection of life and property during extreme rainfall events and hurricanes.

NOAA reports that even 0.9 m (3 feet) of sea level rise would permanently inundate 2 million American's homes and communities. Two meters (6.6 feet) of sea level rise would put 6 million U.S. homes underwater (Hauer et al., 2016).

While NOAA's projection of up to 2.5 m (8.2 feet) of sea level rise by 2100 is representative of sea level projections typically made in the scientific literature based on current modeling, including the current rate of accelerated melting in the poles, it does not address other very plausible high-risk scenarios.

Importantly, sea level rise is now accelerating due primarily to the rapid loss of ice on Greenland and Antarctica. This acceleration is occurring faster than any of the climate models predict, because the models currently do not include many of the numerous accelerating feedbacks in ice melt that are now being observed and that the paleo-record documents the reality of. Although not yet in the models, these accelerating feedbacks for ice melt are a reflection of the fact that ice, when destabilized, disintegrates very rapidly resulting in significant pulses of sea level rise such as are documented throughout the past. The historic record of sea level rise clearly establishes that sea level rises in pulses. Our scientific understanding of the historic rapid pulses in sea level rise as ice sheets disintegrate is not incorporated in any U.S. government models, including NOAA's 2017 model, or any of the modeling summarized by the IPCC, the governmental body reporting on the consensus science of climate change. NOAA confirms "the GMSL exceedance probabilities for the scenarios may underestimate future rates of ice melt due to effects such as Antarctic ice sheet instability." (NOAA, 2017).

Dr. James Hansen and co-authors published a peer-reviewed paper in 2016 that attempted to take into account the rapid disintegration of ice sheets that the models have not accounted for and are not yet able to provide for in a numerical model. They used a combination of climate modeling, paleoclimate analyses, and modern observations to incorporate climate feedback processes in an effort to explain the more rapid paleoclimate changes to sea levels. Hansen *et al.* explain the broad scientific understanding that during the late-Eemian, sea level reached +6–9 m (+20–30 feet), due in substantial part from melting in Antarctica at a time when Earth was only slightly warmer than today (Dutton et al., 2015; Hansen et al., 2016). Hansen *et al.* ultimately conclude that while precise predictions of sea level rise are not possible given the uncertainties around how quickly the ice sheets will disintegrate, the authors state with a high degree of confidence that multi-meter sea level rise would become practically unavoidable, probably within 50–150 years, if current emission trends continue.

In June, 2018, 80 leading Antarctic researchers published an article pointing out that in the last decade Antarctica has tripled it rate of ice melt and its contribution to sea level rise (IMBIE, 2018), and they point out that this may well continue (both the melt and its acceleration) and has the potential to produce very serious consequences much sooner than previously anticipated.

Table 1 below summarizes the observed accelerating feedbacks that are speeding up ice sheet melt on Greenland and Antarctica. Most of these are not in the modeled projections of sea level rise, and necessitate consideration that the reality will be much faster than even NOAA’s most recent 2.5 meter (8.2 feet) “Extreme” projection. These accelerating feedbacks that we are now observing are the witness to the reality of a new, probably significant and rapid, pulse of ice sheet disintegration and sea level rise.

From Atmospheric Warming (mostly Greenland at Present)
1. Lowering surface elevation with melt putting surface in warmer climate belt.
2. Surface melt lakes and ponds adsorb more heat than white ice.
3. Dark dirt and soot from within ice concentrates on melting surface adsorbing more heat.
4. Surface melt water pours down moulins (melt sinkholes) to base of ice sheet lifting and detaching ice from rock substrate causing increased lateral movement and ice fracturing.
5. Resulting fracturing lets melt water into ice sheet warming interior ice making it softer and flowier (Bell et al, 2014).
6. Fracturing greatly accelerates overall melt rate as it warms throughout the ice sheet (Scambos et al., 2009).
7. Lake drainage sets up bottom flow causing tensile shock fracturing of ice and then cascading lake drainage (Christoffersen et al., 2018). This large volume of water can accelerate basal ice flow.
8. Melt water is increasing portion of the basal ice sheet that is thawed and flowier (MacGregor et al., 2016). Heat from Earth interior also plays a role in some areas.
9. Increased melt of floating Arctic pack ice creates more open water, adsorbing more heat to warm Greenland's atmosphere and adjacent ocean waters.
10. Cryoconite holes in melting ice sheet surface accelerate surface melt (Fountain et al., 2004).
11. Thick summer surface melt forms thick slush on surface that works downward melting and softening ice.
12. Surface warming has eliminated ability of firn to refreeze meltwater over much of ice sheet, accelerating meltwater production and release (Noel et al., 2017).

From Ocean Warming (Greenland and Antarctica)
13. Intensive intrusion of dense warm ocean water through glacial outlets deep beneath ice sheets causing rapid and irreversible warming (much like estuarine circulation) (Hansen et al., 2016; Kusahara and Hasumi, 2014).
14. Weight of ice produces retrograde slopes (deepening inward) making melting easier and easier inland.
15. Ice, once detached from bottom, can thin by bottom melt and by dynamic thinning (collapse along fractures much like a rack of books splaying out across a table).
16. Inward calving produces higher and higher cliffs which are very unstable above 90 meters height (DeConto and Pollard, 2016; Rignot, 2015). This can result in runaway ice cliff collapse.
17. Surface meltwater can dramatically accelerate ice fracturing of ice cliffs (called hydrofracturing) promoting rapid ice shelf collapse and breakup (Tollefson, 2016; Kopp et al., 2017b*)*.
18. Breakup of floating Ice Shelves (like Larsen A, B, and C) removes the resisting pressure on grounded glaciers and ice sheets and the upstream ice greatly accelerate its velocity of flow to the sea, accelerating sea level rise (Reese et al., 2018).
19. The persistent thickness of the buoyant freshwater outflow isolates the warm water below from seasonal cooling by the cold polar atmosphere thus accelerating the melting power of the warm water penetrating beneath the ice (Silvano *et al*., 2018).

Table 1. Observed Acceleration of Ice Sheet Melt from Atmospheric Warming (mostly Greenland at Present).

Most importantly, Kopp *et al*. (2017) strongly state that "current sea-level observations cannot exclude future extreme outcomes," especially because of hydrofracturing and ice cliff collapse effects that they project to become increasingly important as the century progresses (see also DeConto and Pollard, 2016). These processes, combined with the retrograde bathymetry inward beneath the ice sheet (Rignot, 2015), provide the opportunity and strong likelihood of runaway ice sheet collapse as the century progresses.

In my expert opinion, based on the historic record, the rapid pulses, and current rates of sea level rise acceleration, I project a 4.6 to 9.1-meter (15 to 30-foot) rise in sea level by 2100 if current trends continue, with ever greater rises and acceleration in subsequent centuries until such time as we dramatically reduce the levels of CO_2 in the atmosphere and take steps to cool the upper portion of the ocean. I am not alone in this conclusion. One of the world's eminent glaciologists, Dr. Eric Rignot, predicts that an increase in global temperatures to 1.5–2°C over pre-industrial levels, will commit the planet to sea level rise of six to nine meters, which could occur in the next 100–200 years. In addition, James Hansen has projected 5–10 meters (16–33 feet) this century (Hansen et al., 2016). Thus, only NOAA's extreme sea level rise scenario presents anything close to approximating the real risk we face with sea level rise.

C. Accelerated Sea Level Rise: Regional Influences.

Although Florida has been subjected to basically the global rise in sea level until now, there are two features which indicate that Florida's sea level rise will be significantly greater than the future Mean Global Sea Level rise.

First, the huge masses of ice on Greenland and Antarctica actually have a significant extra gravitational attraction, pulling ocean water towards these areas. This raises sea level near Greenland and Antarctica and lowers sea level elsewhere. As Greenland and Antarctica ice sheet melt is accelerating, the gravitational attraction of that decreasing ice mass is weakening and the pull of water towards these ice masses is less. Lemonick (2010) estimated that this redistribution of mass balance will result in an additional 25-37 percent of ice-melt global sea level rise. More recently, Hsu and Velicogna (2017) estimate that this redistribution of gravitational attraction with continued ice melt will result in southeast Florida's sea level rise being 52 percent greater than the Global Mean Sea Level rise. That could mean that a 1 meter (3.3 foot) global sea level rise would become a 1.52 meter (5 foot) rise in South Florida, or a 3 meter (10 foot) global rise would become 4.5 meters (15 feet). Much of the Atlantic coast of the United States should have a similar response.

Second, it is forecast that the speed of the Florida Current and Gulf Stream will decrease through the century as less water is drawn north around Greenland to replace water that has sunk to form the deep water of the Ocean Conveyer Belt. This Florida Current/Gulf Stream slowdown is predicted in Atlantic Ocean circulation models (Kirtman et al., 2012), and has been documented in recent observations (Park and Sweet, 2015; Rahmstorf et al., 2015). The north-flowing Florida Current is pulled to the right by the Coriolis Force or Effect[2], a force related to the spin of the Earth. In the northern hemisphere, the Coriolis Force acts to turn a moving water current to the right piling up water to the right and creating a slope of the water surface, higher on the right or east side of the Florida Current. Regionally, the Coriolis effect on the Florida Current, Gulf Stream flow and North Atlantic circulation results in water building up on the right side of these currents and being lowered on the landward left side. Sea level averages nearly one meter (3.3 feet) higher at Bimini, Bahamas, than at Miami just across the Florida Current. The Florida current and North Atlantic circulation is driven by a combination of (a) wind (Westerlies to the

[2] The Coriolis Effect or Force is an influence on moving things because of the spin of the Earth. In the Northern Hemisphere, a moving bullet or ocean current will be turned to the right. Because of the clockwise circulation of the North Atlantic gyre, the Coriolis Effect results in water being pulled away from the Atlantic coast and pushed towards and piling up on the right side of the current and in the middle of the ocean. In contrast, westerly winds around Antarctica in the Southern Hemisphere create an easterly moving (counterclockwise) ocean current which is turned to the left. This pulls surface water away from the coast causing upwelling of warmer water from below.

north and Easterlies to the south) and (b) water moving north to replace cold dense water sinking in the vicinity of Greenland to form the North Atlantic Deep Water and the Ocean Conveyor Belt.

As the Arctic has warmed and the Arctic surface water freshened over the past 60 years, the formation of saline, cold dense North Atlantic Deep Water has dramatically decreased (Rahmstorf *et al.*, 2015). If this persists, we can expect the Florida Current/Gulf Stream velocity to slow since less water is being pulled off to replace that which sank. Thus, one of the driving forces maintaining a lower sea level in south Florida than across the Straits in the Bahamas has weakened.

Because of the anticipated slowdown of the Florida Current as this century progresses, the Southeast Florida Regional Planning Council's "Regional Compact" has recommended adding 15 percent to future Global Mean Sea Level rise to account for the anticipated decreasing velocity of the Florida Current and Gulf Stream (Technical Ad Hoc Work Group, 2015)[3].

Adding an additional 20 per cent to the Global Mean Sea Level rise of 1 meter (3.3 feet) discussed above would give an additional 20 cm (0.7 feet). Combining the changing redistribution of mass balance (+52 per cent) and slowing speed of the Florida Current (+20 per cent) would give a total sea level rise of 1 meter (GMSL) plus an additional 72 percent for a total of 1.72 meters (5.6 feet).

By the end of the century the southeast Florida regional sea level, according to the three U.S. Government projections, will be 1.5 to 2.5 meters (5 to 8.2 feet) GMSL plus somewhere between 35 and 72 per cent regional influence for a total regional sea level rise of 2.1 to 4.3 meters (7 to 14.1 feet) (**Figure 6A**).

[3] Another article came out very recently addressing this recent increase (Valle-Levinson *et al.*, 2017. See: https://gizmodo.com/why-are-sea-levels-in-miami-rising-so-much-faster-than-1797733450). The article points out that the recent rapid acceleration in sea level rise has affected Miami to Cape Hatteras, again because of slowdown in the Florida Current/Gulf Stream flow plus El Niño dynamics influences.

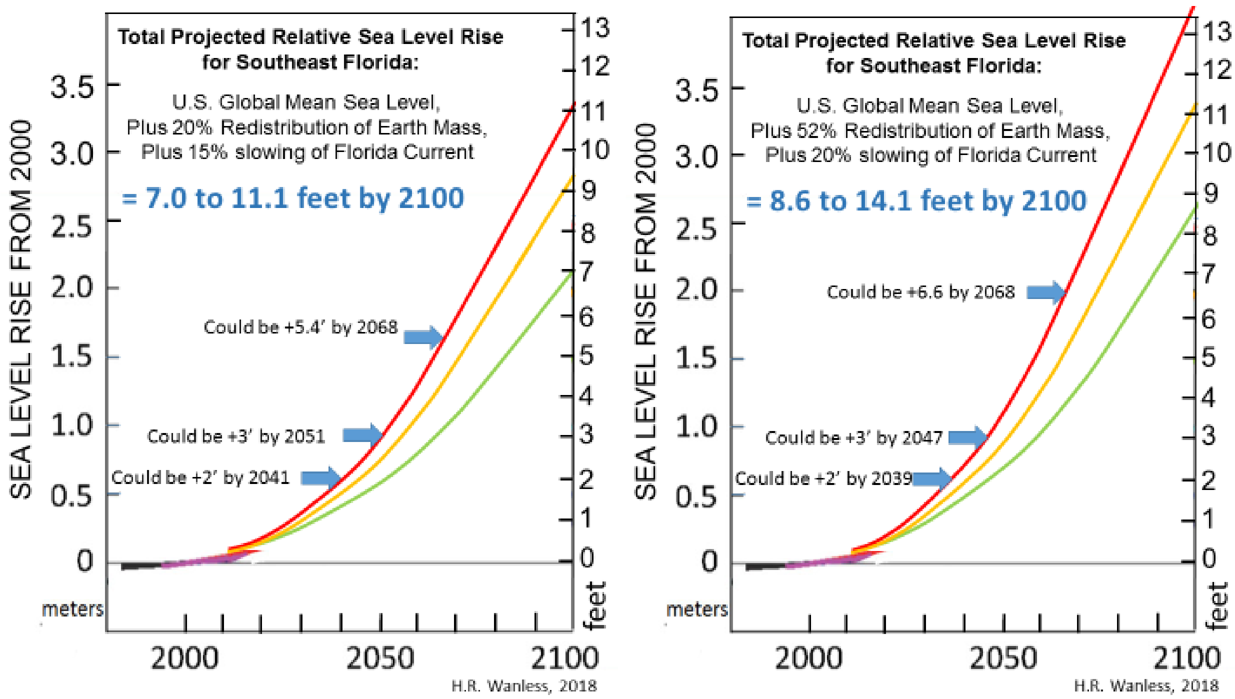


Figure 6A. Low and high projected total relative sea level rise for South Florida based from the three higher U.S. Government Global Mean Sea Level rise projections (Intermediate High, High, and Extreme) shown in Figure 43 plus regional influences. Left: Low projection from adding 20 percent for redistribution of Earth mass and 15 percent for slowing of Florida Current/Gulf Stream. Right: High projection using Global Mean Sea Level plus 20 and 52 percent respectively for regional influences.

Finally on top of that we should add the frequent king tides (strongest full-moon and new-moon tides) affecting southeast Florida. These are about 30 centimeters (12 inches) above normal tide levels. These affect southeast Florida most strongly in October, November and December.

Other Regional Influences on Sea Level. From Savannah north to New York there is regional subsidence as material from deep in the mantle continues to shift back north. The weight of a couple of miles of ice north of New York City squeezed on the Earth below, and the viscous but plastic rock deep in the mantle slowly oozed south in response. This created a 'peripheral bulge' that extended south to about Savannah, Georgia. This deep mantle material is now flowing back north following the melt of the weighty ice sheets further north. This is the 'collapse of the peripheral bulge.' Although ice sheet melt was essentially finished 10,000 years ago, material from the very viscous mantle is still flowing back north. This adds about 15 centimeters (0.5 feet) per century to the global rate of rise for New York and nearly 30 centimeters (1 foot) for areas in Virginia and North Carolina. Florida is south of this influence.

Large cities on deltas have had spectacular subsidence as they withdrew water from the delta substrate, dewatering and collapsing mud and muddy sand substrates. For a time Shanghai had areas that were subsiding at 15 centimeters (6 inches) per decade! They pretty well stopped this by the 1990s because they were greatly shortening the life of their city by self-abuse. More recently they are documenting significant local subsidence beneath and adjacent to massive high-rise buildings. This is as the result of the weight of the building causing dewatering of the underlying sediment and resulting ground subsidence.

There is a dramatic subsidence along the Gulf of Mexico coast from the Mississippi Delta west to the Galveston, Texas area. This subsidence, which is as much as 1 meter (3.3 feet) per century is a complex result of collapse of the peripheral bulge; withdrawal of water, oil and gas; natural progressive dewatering/compaction of rapidly deposited delta sediments, deformation and subsidence from underlying salt deposits and domes; the tectonic effect of gravity faults on the accumulating delta sediments[4]; continued gradual dewatering compaction of deep delta sediments; and near surface dewatering and other water management effects **(**Yuill. *et al*., 2009). The largest of these are the anthropogenic influences: fluid withdrawal and water management. The present rapid relative sea level rise of this Gulf region is resulting in rapid inundation and loss of barrier islands and coastal wetlands – and provide a preview of what is in store everywhere.

Cause for Recent Anomalies. Valle-Levinson *et al*. (2017) studying the causes for times of accelerated relative sea level rise along the Atlantic Coast through "tide gauge records reveal comparable short-lived, rapid SLR accelerations (hot spots) that have occurred repeatedly over ~1500 km stretches of the coastline during the past 95 years, with variable latitudinal position." They conclude that North Atlantic Oscillation determines the latitudinal position of these SLR hot spots, while a cumulative El Niño index is associated with their timing. The North Atlantic Oscillation (NAO) is caused by fluctuations in the difference of atmospheric pressure at sea level between the Icelandic low pressure center and the Azores high pressure center. The NAO affects the strength of the westerly winds of the North Atlantic and thus influences the speed of the Gulf Stream. The El Niños influence the strength of the easterly trade winds and thus the speed of the surface currents moving westerly across the tropical Atlantic. This control of North Atlantic circulation and current speeds and eddies in the currents affects sea level along the Atlantic coast. In the past decade, portions of the coast from Miami north to Cape Hatteras have had 5- to 10-year periods of greatly accelerated sea level rise—at rates of 9 to 20 mm per year (0.35 to 0.79 inches per year) (Wdowinski et al., 2016; and Valle-Levinson et al., 2017). These were three or more times the global average and appear to have been, fortunately, just oscillations, though it is a view of things to come.

Just a 60- to 90-cm (2- to 3-foot) rise of sea level will make nearly all the barrier islands of the world uninhabitable, begin the inundation of a major portion of the world's deltas, and make low-lying coastal zones like Louisiana and southeast Florida increasingly challenging communities in which to maintain infrastructure and assure protection of life and property during hurricanes and other extreme events. Importantly, when governments project several feet of sea level rise by the end of the century, that rise will not be some new fixed end point of sea level at equilibrium. It represents an acceleration of sea level rise because of the ongoing accelerating ice melt. If, for example, we have 1.5 meters (5 feet) of sea level rise at the end of the century, sea level will be

[4] In New Orleans, one can see offsets in roads and fractures in buildings where one of these gravity faults intersects the surface. A gravity or normal fault in this area is where the weight of the delta to the sea ward causes a vertical rip (fault) in the substrate. This rip slants a bit to the seaward and slopes less steeply with depth. The down dropping (seaward) side of the rip has faster subsidence.

rising at a foot per decade and accelerating. If sea level rise accelerates much faster and we have a 2 foot rise by 2041, sea level rise will then also be rising at a foot per decade and accelerating. That will make maintaining coastal infrastructure, such as port facilities, extremely difficult logistically and financially.

III. Sea Level Rise in Southern Florida and Its Barrier Islands

While climate change will be felt globally, the low-lying and heavily-populated coastline of south and central Florida, including its barrier islands, makes it extremely vulnerable to the effects of climate change, particularly sea level rise, amplified by storm surges. Hurricane storm surges will make low-lying south Florida an increasingly risky place to live. The maps in **Figure 7** below show the increased extent and depth of the category 5 Hurricane Andrew (1992) storm with a further three feet of sea level rise. Nearly the entire southern two-thirds of Miami-Dade County will be affected by a deep, powerful, violent onshore storm surge and the seaward barrier islands will be dangerously swept by a strong surge.

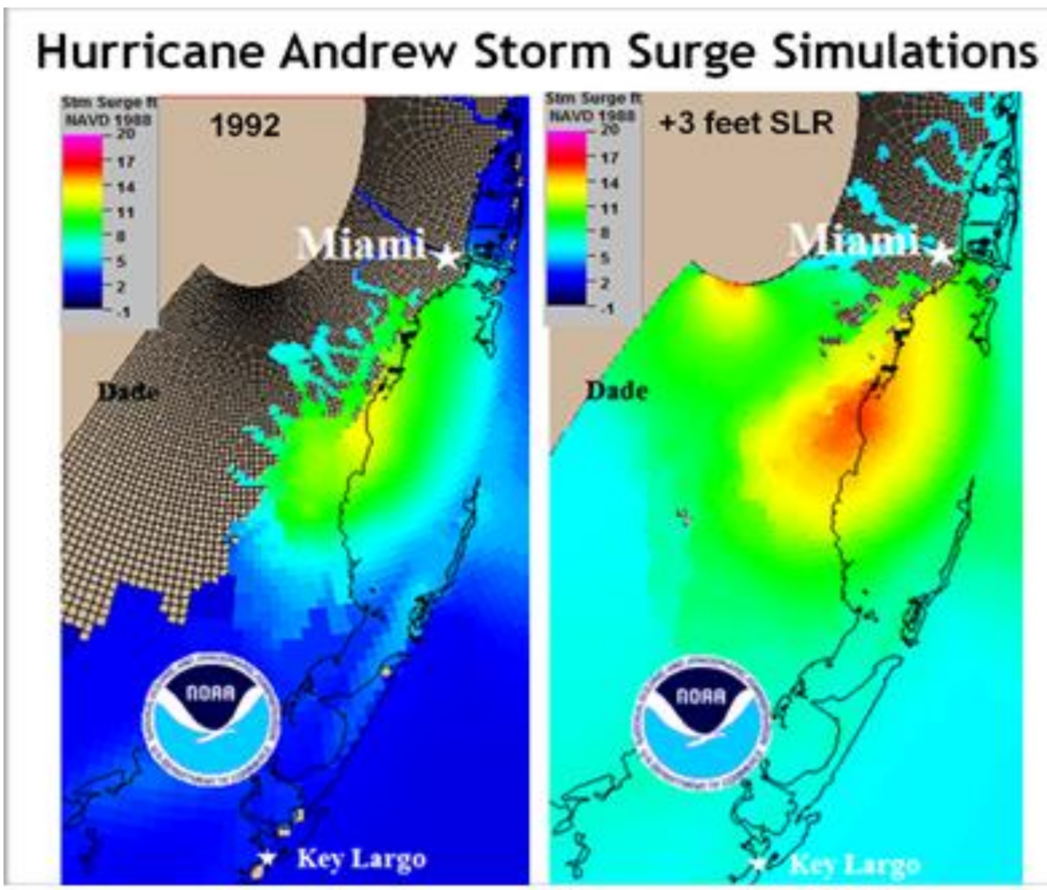


Figure 7. Left: Storm surge of category 5 Hurricane Andrew in 1992. Right: Same Hurricane Andrew storm surge with 90 cm (3 feet) of sea level rise. (Provided by Dr. Brian Soden, University of Miami).

South Florida is not significantly sinking or rising so sea level change in south Florida basically follows the global sea level change, with some potential for enhanced rises. South Florida's sea level has risen about 30 cm (12 inches) since 1930 and is currently increasing at a rate of about 3.5 cm (1.3 inches) per decade; a rate that is approximately 10 times faster than what occurred naturally over the past 2,400 years. If the current trend were to continue at the same linear rate of 1 inch per decade, the oceans along South Florida's coast would rise another 12.5 cm (5 inches) by 2060 and 25 cm (10 inches) by the end of the century. As discussed above, these scenarios are highly improbable and vastly underestimate potential sea level rise given the non-linearity we are observing and that is predicted of ice melt and resulting sea level rise.

In January 2008, the Science Committee (of which I was Chair) of the Miami-Dade Climate Change Advisory Task Force issued a projection of future sea level rise for south Florida, stating:

> With what is happening in the Arctic and Greenland, many respected scientists now see a likely sea level rise of **at least** 1.5 feet in the coming 50 years and a total of **at least** 3-5 feet [90-150 cm] by the end of the century, possibly significantly more. Spring high tides would be at +6 to +8 feet [1.8-2.4 m]. This does not take into account the possibility of a catastrophically rapid melt of land-bound ice from Greenland, and it makes no assumptions about Antarctica. (MDC-CCATF, 2008).

Since issuing this statement, evidence for dramatically accelerating ice sheet melting has increased on both Greenland and Antarctica, again not accounted for in the modeling or in NOAA's latest sea level rise predictions. (Van den Broeke et al., 2009; Velicogna, 2009; Kerr, 2009; Jiang et al., 2010; Rignot et al., 2016, 2017; IMBIE, 2018).

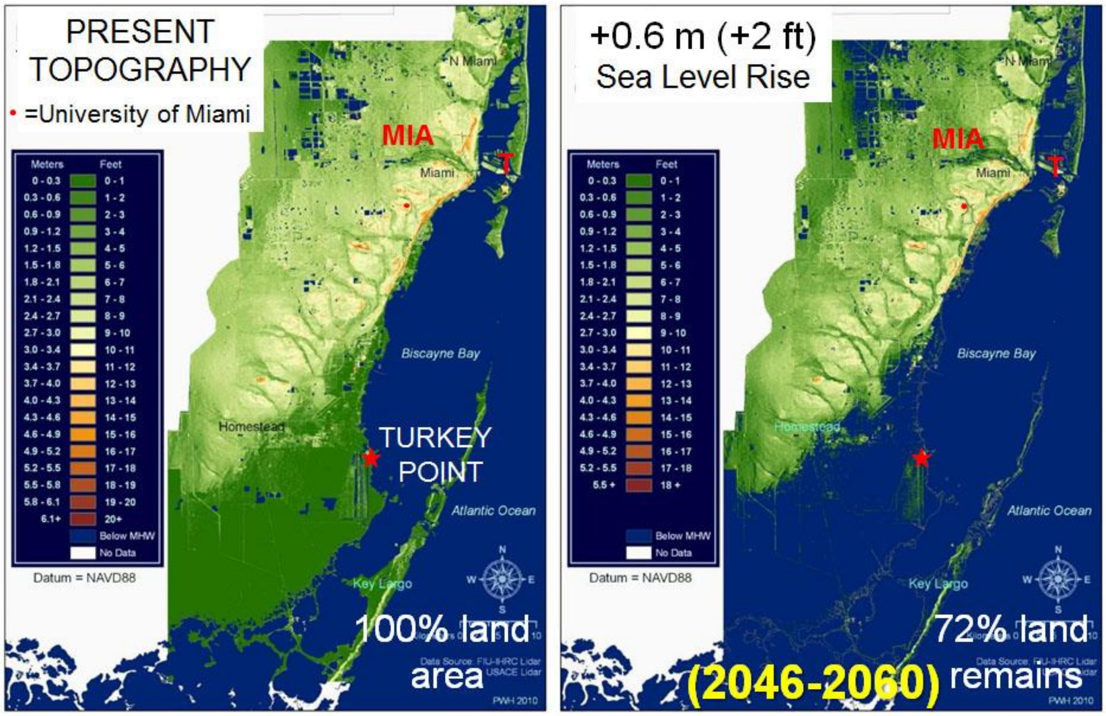
Miami is particularly at risk to the environmental impacts of sea level rise as acknowledged in the 2014 USGCRP Third National Climate Assessment:

> Large numbers of cities, roads, railways, ports, airports, oil and gas facilities, and water supplies are at low elevations and potentially vulnerable to the impacts of sea level rise. New Orleans (with roughly half of its population living below sea level), Miami, Tampa, Charleston, and Virginia Beach are among those most at risk. (Strauss et al., 2012).

Even during the summer and fall of 2017, residents in some areas such as Miami Beach, Key Biscayne, and the Bayshore Drive section of Miami experienced repetitive, serious seawater flooding their streets.

Nearly all climate and sea level assessments agree that ice melt and sea level rise is and will be accelerating well into the next century. This means that coastal cities will not be adjusting to a fixed higher sea level at the end of the century, but one that *continues to rise at an accelerating rate*. Long-term adaptation to sea level rise in low-lying areas of the United States is not realistic under current rates of warming.

Using LiDAR (Light Detection and Ranging) high-resolution elevation mapping from a plane with ground-truthing, the late Peter Harlem and I mapped Miami-Dade County to show the progressive inundation of Miami-Dade County based on U.S. government projections. These are depicted below in **Figure 8**. These LiDAR maps represent mean high tide and do not include king tide or storm surge inundation, which will be substantial. They clearly illustrate the complete and irreversible loss of land and property expected this century. With NOAA's 'Highest' sea level rise scenario (again, which is conservative), we would see a Global Mean Sea Level rise of 60 cm (2 feet) of sea level rise by 2046, 90 cm (3 feet) by 2059, 1.2 m (4 feet) by 2069, 180 cm (6 feet) by 2084, 2.4 m (8 feet) by 2098, and 3.0 m (10 feet) by 2110. When regional influences (**Figure 6A**) are added this will be much, much faster and greater.



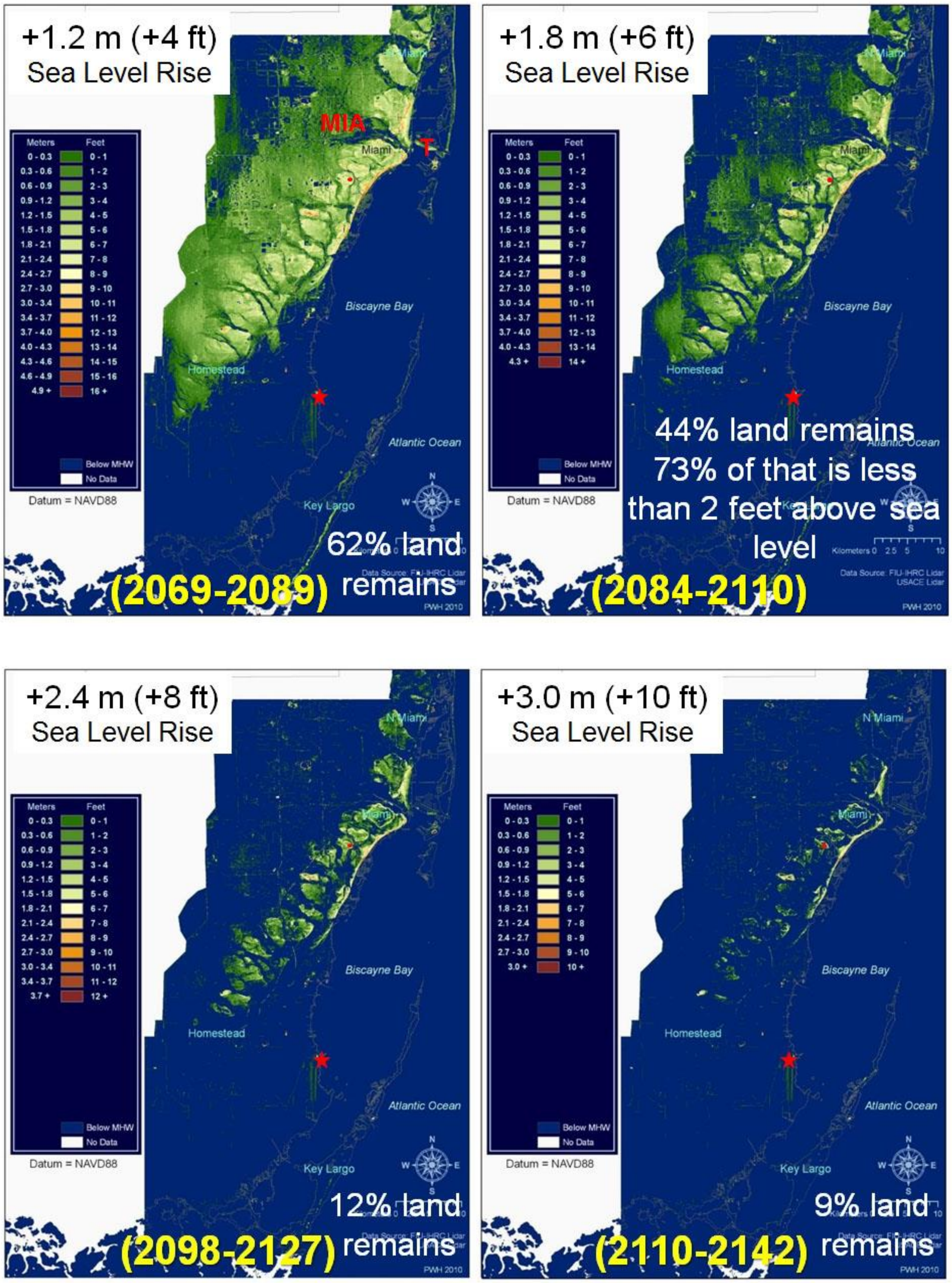


Figure 8. LiDAR elevation maps of Miami-Dade County showing areas above mean high water at present and with 0.6 m (2 feet), 1.2 m (4 feet), 1.8 m (6 feet), 2.4 m (8 feet) and 3 m (10 feet) of further sea level rise. Possible timing of these inundation levels is indicated using only those U.S. Government Mean Global Sea Level rise projections that incorporate significant acceleration in polar ice melt. Adding in the 35 to 72 per cent increase because of

regional influences on sea level rise (changing speed of the Florida Current and redistribution of Earth's mass), these dates will be: +2 feet (2039-2041), +4 feet (2053-2074), +6 feet (2083-2090), +8 feet (2072-2107) and +10 feet (2081-2119). Maps were created by the late Dr. Peter Harlem of Florida International University using LiDAR data flown by the State of Florida. MIA= Miami International Airport; T = new tunnel to shipping/cruise port; star = Turkey Point Nuclear Power Plant.

Sandy barrier islands along tectonically passive margins, such as southeast Florida, are on a gently sloping continental shelf setting and tend to shift dramatically landward with rising sea level. In this setting, a one-foot rise in sea level will commonly result in a landward migration of a barrier island of 500 to 2,000 feet. This occurs as sand overwashes the island or is swept through inlets or to the offshore during storms.

Rising sea level will significantly change the coastal environments, interactions of land and water (including salinity), base-level elevations, tidal current patterns and strengths, and storm surge patterns and strengths. With even a two-foot rise in sea level, saltwater will intrude into Florida's southern and southeastern aquifers. For instance, saltwater intrusion is already affecting the Biscayne Aquifer, and this will become a rapidly increasing problem (Heimlich et al., 2009), diminishing and then eliminating sources of freshwater (Science Committee, 2008; Heimlich et al., 2009).

In addition to harming private and public property, rising sea level will also harm the viability of infrastructure like wastewater treatment facilities, nuclear power plants, roads, and landfills, which will become vulnerable to disruption or destruction by storms, potentially leading to vast contamination of lands and waters as other pollutants are released. There is no planning in southern Florida for cleaning the land before inundation even though many of the waste disposal sites, sewage treatment plants, industrial sites, nuclear power plant, and superfund sites are in low-lying coastal zones. For example, with only 45 to 90 cm (1.5 to 3 feet) of further sea level rise, the Central Sewage Treatment Plant and the adjacent abandoned unlined dump of Virginia Key, Florida will be all that is left of the ocean-facing sandy barrier island. Those pollutant-filled facilities will be exposed to the full force of the oceans tides, waves and storm surges. For those areas on septic tank systems, increasingly frequent sunny day flooding will flood neighborhoods and roads with fecal pollution.

Southeastern Florida and its barrier islands will experience at least two feet of sea level rise in the next 30–50 years. This rise, combined with king tides and storm effects, will eliminate the habitability of most of Florida's barrier islands. Sweet *et al.* (2018) have taken the future frequency of high-tide floods that an area will experience for the different U.S. Government sea level rise projections (Sweet, 2017). They based 'flood' as 'when water levels exceed about 0.5 m, 0.8 m and 1.17 m above a height slightly higher (3–4%) than the local tide range," because that is when they found "minor, moderate and major flooding will occur" (Sweet et al., 2018). **Figure 9** below shows the projected future flooding frequency for those levels for New York City, Miami, and San Francisco.

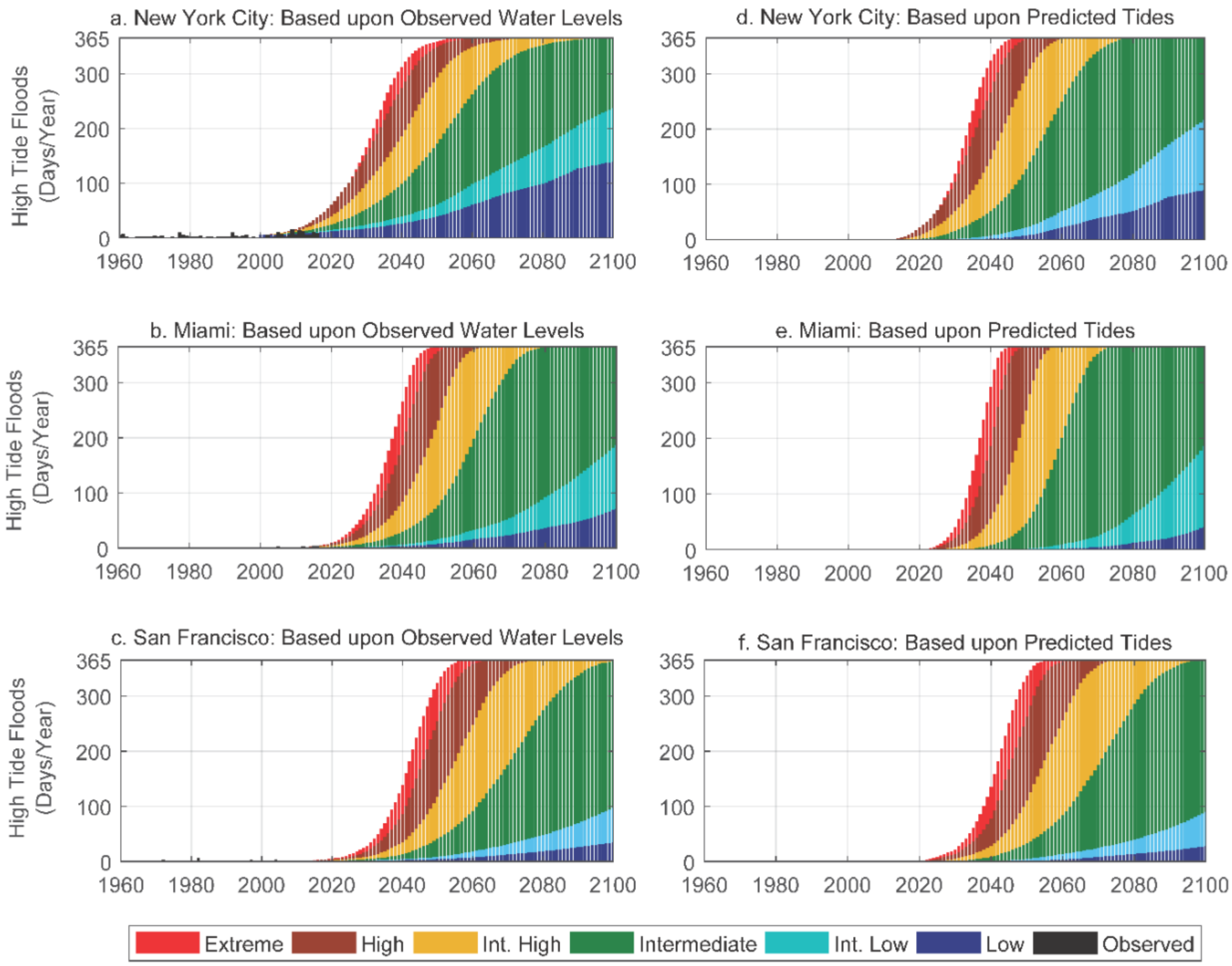


Figure 9. Projected annual frequencies of high tide flooding in response to scenarios of global sea level rise (Sweet et al., 2017) estimated at NOAA tide gauges in a) New York City (The Battery), b) Miami (Virginia Key), Florida and c) San Francisco, California considering observed patterns (combined tidal and nontidal water level components) and d), e) and f) at the same locations but assuming predicted tide forcing only. Derived high tide flood levels are 0.56m, 0.53 m and 0.57 m, respectively.

Plaintiff Levi lives in Satellite Beach on a southeastern Florida barrier island, much of which is less than 6 feet above sea level. Levi's home is at 0.9 m (3 feet) above sea level. His island is already facing sea level rise and increased inundation during storms. At 90 cm (3 feet) of sea level rise, Levi's home will be in the sea. That is likely to happen between 2065 and 2083. But long before 3 feet of sea level rise, Levi and his family will have been forced out because of increasing frequency and depth of flooding and infrastructure failure in their home and community from sunny day flood events (king tides and heavy rainfalls) and storm surges from tropical storms and hurricanes.

A. 2017 Hurricane Season and Sea Level Rise

As described above, human-induced climate change can also cause more intense hurricanes. In September 2017, we experienced this firsthand when the state of Florida was hit by Hurricane Irma as a huge category 1 to 4 storm that blanketed the state in wind damage and in heavy rains and storm surges, which caused significant flooding, even where it only reached category 1 intensity (Miami). In addition, two other hurricanes (Harvey and Maria) reached category 5 status and caused catastrophic damage in Texas, Puerto Rico (a U.S. territory) and elsewhere throughout the Caribbean.

Although the timing and landfall of storm events like these hurricanes cannot be specifically attributed to human-induced global warming, there are a number of trends predicted from global warming that contributed to the 2017 hurricane season's impacts on the United States and its territories. First, a warmer ocean fueled three category 4–5 hurricanes. Irma in particular was an unusually large storm as a category 5 storm and when it diminished in intensity, it spread out to become a spatially huge storm (much like a spinning figure skater spreading her arms). Second, the warmed ocean has a thicker warm layer than in the past, and this was especially true in the southern Gulf of Mexico where the thick warmed ocean fueled intense rain for days in and around Houston alongside Hurricane Harvey. In the past, turbulence in the upper ocean as a hurricane passed brought up cooler water from below thereby weakening the hurricane. Third, as global warming shifted the summer Jet Stream further north than in the past, its strong influence on picking up and moving on hurricanes was diminished, and hurricanes Harvey and Irma lingered on their north and northeastern passage resulting in prolonged intense rainfall (Harvey) and prolonged coastal erosion (Irma on the Atlantic Coast). Normally, as a hurricane approaches the Jet Stream, it is pulled in and swept eastward and northward. And fourth, because of the relative 30 to 75 cm (1 to 2.5) feet of relative sea level rise that the Atlantic and Gulf coasts have experienced in the past century, storm surges were more severe since they could reach higher, further inland and with more velocity than in the past without this sea level rise.

IV. Sea Level Rise and Loss of Infrastructure

As a resident of South Florida, it is truly amazing to me to watch the very aggressive building boom underway, on beaches and barrier islands, throughout downtown and in the low western areas bordering the Everglades. Even with the current, likely underestimated, projections of sea level rise by the end of the century in NOAA, 2017, it is beyond sobering to consider the risk in the present investments and safety that young people, including Plaintiffs, face.

With a further 60 cm (2 feet) of rise (possibly before 2046) most of the barrier islands (of South Florida and the world) will be abandoned and the people relocated; at the same time low places like Sweetwater and Hialeah bordering the Everglades will become more and more frequently flooded and difficult places to live, as illustrated by Hurricane Irma in September 2017. We are on a path towards losing our freshwater resources, living in a community with a failing and disconnected infrastructure, and facing increasing risk from catastrophic storm surges and from hurricanes and flooding from extreme rainfall events.

Based on what we know about sea level rise, governments should be aggressively and transparently planning for young people's future, working with elevation and infrastructure maps to determine the timing, costs and economic feasibility for maintaining a functional infrastructure, a viable insurance industry, and human health and safety. In South Florida, there are already areas that will be unlivable and properties that will be unsellable within a 30-year mortgage cycle.

On January 30, 2015, then-President Barack Obama issued Executive Order 13690, establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input. This order was designed to improve the Nation's resilience to current and future flood risks, which "are anticipated to increase over time due to the effects of climate change and other threats." The sea level rise scenarios and tools set forth in the 2017 NOAA Technical Report, Global and Regional Sea Level Rise Scenarios for the United States (NOAA, 2017), referenced above, were "intended to serve as a starting point for on-the-ground coastal preparedness planning and risk management processes," including compliance with Executive Order 13690. NOAA recognized:

> In this context, there is a clear need – and a clear call from states and coastal communities (White House, 2014) – to support preparedness planning with consistent, accessible, authoritative and more locally appropriate knowledge, data, information, and tools about future changes in sea level and associated coastal risks.

I agree with that statement and have been involved in this kind of work with local governments in South Florida for the past decade, including the 4-County Compact on climate change in Southeast Florida. The lack of current federal government support for sea level rise adaptation and preparedness planning is notable. For example, on August 15, 2017, President Trump revoked Executive Order 13690. In addition, the federal Flood Insurance Rate Maps established by the Federal Emergency Management Agency to help determine the cost of the National Flood Insurance Program flood insurance rates are based on past patterns of flooding.[5] Present and future sea level rise is not factored into the Flood Insurance Rate Maps and thus the maps do not accurately communicate the risk to residents who live in coastal areas.

Nonetheless, as I explain above, no amount of preparedness or adaptation planning will make people like Levi safe from the rising seas and increasingly dangerous storm events if mitigation through urgent emission reductions is not planned for and carried out by Defendants. We cannot adapt our way out of increasingly warm oceans and the planet's ice that will melt.

V. The Loss of Coastal Wetlands

Both Florida and Louisiana are losing vast amounts of wetland because of accelerating sea level rise and poor management. In Louisiana, through the last century, a continuous line of levees was built essentially to the outlet far out on the edge of the continental shelf. This prevented both sediment and freshwater from building and maintaining the Delta. Louisiana has lost more than

[5] National Research Council, Tying Flood Insurance to Flood Risk for Low-Lying Structures in the Floodplain (2015); FEMA Technical Mapping Advisory Council Annual Report (Dec. 2016).

5,000 square kilometers of wetlands over the past century (Jankowski et al., 2017) and will lose another 10,000 to 13,500 square kilometers by the end of this century because of subsidence and sea level rise (Blum and Roberts, 2009). Blum and Roberts (2009) conclude that, because of upstream dams, there is no longer enough sediment coming down the Mississippi River to significantly offset this loss. Nearly all of the Mississippi River Delta is less than 1.5 meters (5 feet) above sea level and extremely vulnerable to the coming accelerating sea level rise as depicted in **Figure 10**, below.

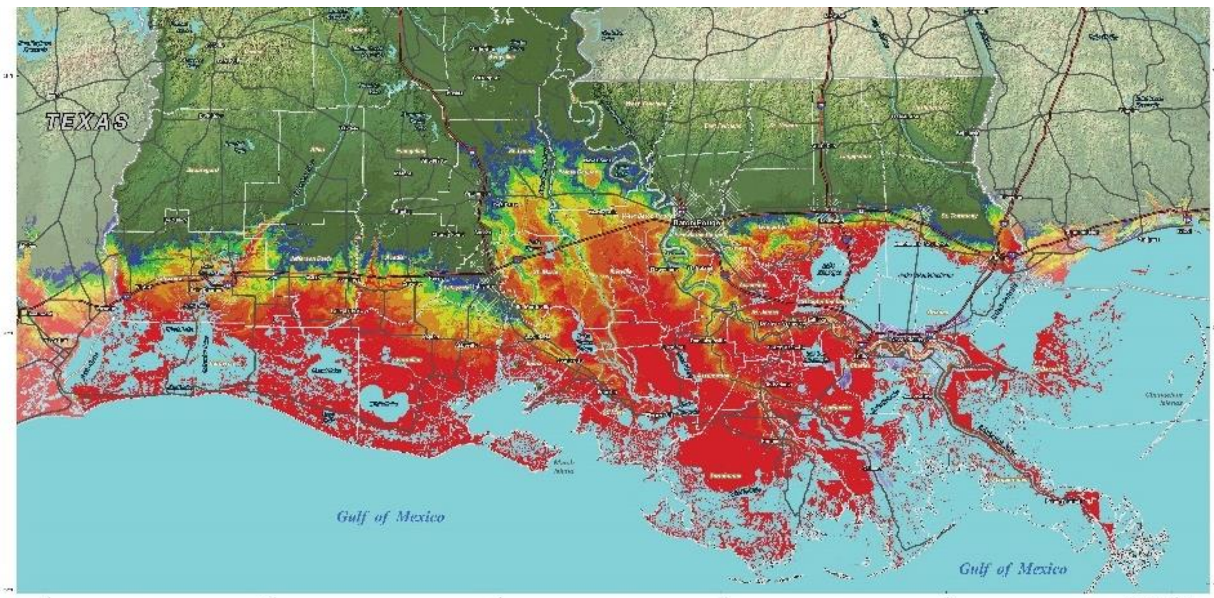


Figure 10. Low lying areas associated with the Mississippi River Delta. Red areas are less than five feet elevation; dark orange is 5 to 10 feet. The large gaps in the delta plain (G) are areas largely lost since World War II as increased blockage by levees forced deterioration. NO is New Orleans. Chenier Plain is a coast of sand beach ridges, mud and wetlands built by the western drift of sediment eroded from the main Delta and then washed to shore. Digital Elevation Data map by the U.S. Geological Survey (Kosovitch, 2008).

A part of Louisiana's wetland and coastal barrier island loss is because of subsidence brought on primarily because of the withdrawal of oil, gas, and water. Current relative sea level rise is a rate of about 12 mm per year (Jankowski, 2017) of which 3.5 mm per year is global sea level rise and 8.5 mm per year is land subsidence. That is an overall rate of relative sea level rise of 1.2 m (4 feet) per century of which 36 cm (1.2 feet) per century is global and 86 cm (2.8 feet) per century is from subsidence. Basically, no coastal sandy barrier island or coastal wetland can persist with that rate of relative sea level rise. Already the U.S. Government has had to remove 35 place names from the Louisiana Coastal Charts because they no longer exist as a result of relative sea level rise and erosion.[6] Florida is also rapidly losing coastal wetlands through a combination of rising sea levels, storm surge damage and saline intrusion.

[6] NOAA, Office of Coast Survey, Historical Geographic Place Names Removed from NOAA Charts (updated Aug. 4, 2014), at

VI. The Unprecedented Urgency of Reducing Greenhouse Gas Emissions

The U.S. government has long known that burning fossil fuels would cause global warming and ultimately sea level rise. In 1983, I attended my first meetings with EPA where they were discussing accelerating sea level rise. I have been speaking about the threat of accelerating sea level rise since 1981 and became certain by the mid-1990s that human burning of fossil fuels was the cause.

The last time in the geologic record that atmospheric CO_2 was at present levels, the seas were 21–27 meters (70–90 feet) higher (Miller et al., 2012; Dutton at al., 2015). Several recent papers, including one from the National Science Foundation, have pointed out that we now have greenhouse gas levels sufficient to cause a 21-meter (70-foot) sea level rise (Miller et al., 2012) and be sufficient to affect or displace 70 percent of the world's population (National Science Foundation, 2012).

In my expert opinion we need to return from over 400 ppm to 350 ppm as recommended by Hansen et al. (2008) and then towards 300–325 ppm to prevent further ocean warming and eventually attempt to return to the levels of the Holocene. Even if we do that, the immense heat that is now in the ocean is only very, very slowly going to revert back to the atmosphere. It's going to stay in the oceans for centuries continuing to expand the ocean and melt polar ice. And this is why we so urgently need to stop burning fossil fuels, aggressively sequester more carbon into our lands and forests, and actively reduce carbon dioxide levels in the atmosphere.

We are headed to catastrophic sea level rise a lot faster than we have anticipated. If we act now, we may not be able to save Naples, Miami, our sandy barrier islands, the Mississippi Delta coast, and other low-lying regions. But if we do not act now, we have no chance to protect Plaintiff Levi's barrier island, and we will also be heading towards losing Orlando, Baton Rouge and many other places presently above any officially projected sea level rise.

As the ocean warms, we are also causing the release of huge amounts of methane and CO_2 from permafrost and methane hydrates from the Arctic tundra and Arctic Ocean floor. This stands to become a runaway warming contributor to catastrophic warming later this century unless we rapidly stop forcing atmospheric warming. This will very significantly affect sea level rise in the future.

Already, our local governments in southern Florida must plan for 1.5–2.4 meters (5–8 feet) of sea level rise by century's end according to the U.S. Government projections. Although I consider 4.6–9.1 m (15–30 feet) by century's end to be more likely, 1.5–2.5 m (5–8.2 feet) will be enough to basically eliminate habitation of south Florida's barrier islands and low mainland areas.

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https://historicalcharts.noaa.gov/pdfs/HistoricalPlacenames_Louisiana.pdf; Meredith Westington, NOAA, Office of Coast Survey, *Geographic Names Disappear from Charts, But Not from History*, at https://noaacoastsurvey.wordpress.com/2014/03/21/geographic-names-disappear-from-charts/ ("Some of these places have appeared on NOAA's nautical charts of Louisiana since the 1800s, so their removal raises concerns about a loss of cultural identity on the landscape.").

At times, the hard facts of science do not convey the grave danger we face, particularly when the consequences of invisible CO_2 pollution are locked in long before we physically see them. I express the urgency in this way: As we continue burning fossil fuels today, tomorrow, next month and into next year, a significant portion of the resulting CO_2 pollution is going to remain in the atmosphere for 4,000 years. Every ton of fossil fuels the U.S. government grants private companies permission to extract, when burned, adds more heat and energy to the oceans, and our oceans will hold that heat for hundreds to thousands of years, leading to more and more ice melt.

For hundreds of thousands of years, CO_2 has fluctuated up and down about 100 ppm, between 180–280 ppm, during which time sea level has been going up and down by about 100 meters in response. In the flash of time since the industrial revolution, we have tipped the CO_2 scale over 410 ppm, an increase of 130 ppm, and that rapidly warming atmosphere has already heated the ocean enough to initiate rapid melting of the ice on both Greenland and Antarctica and to initiate destabilization of the Arctic Pack Ice, permafrost, and methane hydrates. It is important to note that the natural 100 ppm rise, from 180 to 280 ppm, occurred over about a 12,000 year period. The human induced CO_2 increase of 130 ppm, from 280 to 410 ppm, has occurred in the last 120 years. This is a rate about 100 times faster than the natural geologically very rapid rate of climate change. Note that, although the industrial revolution began in the 1700s, it was not until the 20th century that burning of fossil fuels had a significant impact on climate. In 1900, only about 500 metric tons of carbon were introduced into the atmosphere by burning fossil fuels per year. By 1950, this had increased to about 1,800 metric tons per year, and by the year 2000 humans were introducing over 6,600 metric tons of carbon per year—a 13-fold increase. Progressive global industrialization and population growth have turned burning fossil fuels from a small influence to an overwhelming control on climate.

To stay at this high level for long or to further increase atmospheric CO_2 levels will wreak havoc on our oceans, our coastal lands within 100 feet of sea level, our arid areas, human civilization, and the productivity and diversity of life on earth.

Dr. Hansen et al., concluded their 2016 paper, "Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2°C global warming could be dangerous," by saying:

> We understand that in a system that is out of equilibrium, a system in which the equilibrium is difficult to restore rapidly, a system in which major components such as the ocean and ice sheets have great inertia but are beginning to change, the existence of such amplifying feedbacks presents a situation of great concern. There is a significant possibility, a real danger, that we will hand young people and future generations a climate system that is practically out of their control. We conclude that the message our climate science delivers to society, policymakers, and the public alike is this: we have a global emergency. Fossil fuel CO_2 emissions should be reduced as rapidly as practical.
>
> Social disruption and economic consequences of such large sea level rise, and the attendant increases in storms and climate extremes, could be devastating (Hansen, 2016).

Along similar lines, NOAA concludes that a strategy for decisions and planning processes where *long-term* risk management is paramount is to:

> Define a scientifically plausible upper-bound (which might be thought of as a worst-case or extreme scenario) as the amount of sea level rise that, while low probability, cannot be ruled out over the time horizon being considered. Use this upper-bound scenario as a guide for overall system risk and long-term adaptation strategies (NOAA, 2017, p. 34).

Given all of the above, it is my opinion, stated to a reasonable degree of scientific certainty, that these Plaintiffs face ongoing long-term harm, and any delay in massive reductions of greenhouse gas emissions will only increase the very dangerous situation they already face. For Plaintiff Levi, it may very well be too late to save his barrier island from the rising seas over the course of the century, but to have any reasonable possibility of avoiding irreversible harm to his home island and State, we must aggressively work to limit any additional warming of the oceans and slow the risk of rising ocean levels.

In my expert opinion, we are in the danger zone in southern Florida, and any delay in a judicial remedy for Plaintiff Levi poses clear and irreversible harm to his interests and his future. However, it is not just Plaintiff Levi and his island that are at risk. All of the children of the barrier islands, deltas, and low-lying coastal zone of the Atlantic and Gulf coasts are at risk of inheriting a life of migration further inland. And even on soft-cliffed shorelines, such as are found in portions of California, Oregon, Washington and Hawaii, very significant coastal erosion will occur as ocean waves and currents attack these weak cliffs at a higher level.

In closing, I am sometimes asked by adults about how I give hope to young people given the dire projections for their future. I tell them "I hope *you* are listening." It does a disservice to young people for adults in positions of power and governmental leadership to sugarcoat or deny the very real irreversible harms that are already occurring and are now committed to because of warming already realized. Without transparent and honest planning to urgently mitigate climate change, we are betraying young people and all citizens. We cannot have government disregard for this or have planning regarding our citizen's survivability behind closed doors. The purpose of government is not to do business with and for the coal, oil and gas industry and others who benefit in the short-term by ignoring this serious problem, to the detriment of the broad public interest and certainly the public interest in protecting our children. The public interest is fundamentally harmed by ongoing fossil fuel combustion, which urgently needs reparation.

CONCLUSION

As a geologist and marine geologist with 46 years of experience, and with over 100 peer reviewed publications, largely concerning sea level rise and coastal environmental evolution, it is my expert opinion that young people, including the Plaintiffs, are experiencing sea level rise from already occurring observed and measured ocean warming and polar ice sheet melt. This sea level rise is happening faster than the climate models predict because the models do not include many of the numerous accelerating feedbacks in ice melt that are now being observed consistent with the paleo-record. If we continue to inject even more CO_2 into the atmosphere, the results will be even more dire for these Plaintiffs and future generations. The fact of the matter is that we have warmed the atmospheric and oceanic climate and future atmospheric warming is unavoidable for some 30 years after we stop putting further greenhouse gases into the atmosphere. However, how much more climate forcing humans put into the system through CO_2 and other greenhouse gas emissions in the near-term, and how much carbon we sequester, will dictate the severity of the warming and whether these young Plaintiffs and future generations can thrive, or even survive.

The need to move quickly to stop using the burning fossil fuels as our primary energy source is in large part because, through scientific study of the geologic record, we have learned that sea levels did not rise in a sluggish, gradual linear manner in response to gradually increasing natural warming and carbon dioxide levels as we came out of the last glacial period. Rather, global sea level rose to the present level as a series of rapid pulses of rise, followed by pauses as warming initiated one pulse of ice sheet collapse after another. These historical pulses of sea level rise each caused a 1- to 10-meter rise over a relatively short period of time (within a century or so) and each reflects the rapid disintegration of some ice sheet sector.

We are most likely witnessing the onset of one of these rapid pulses of sea level rise, this time in response to human-induced CO_2 build up and warming. Through the 20^{th} Century, atmospheric warming progressively warmed the oceans causing their expansion, and this was the reason for an initial increase in the rate of global sea level rise to some 2.3 mm/year, a rate some 8 times that of the past 2,000 years. Then in the 1990s, these warmed ocean waters initiated ice sheet melt of Greenland and Antarctica, and this is dramatically accelerating. Current models only incorporate a few of the 15 or so accelerating feedbacks that have been documented to be accelerating polar ice melt. It is these accelerating feedbacks, which are the current visual display of the nature of pulses of ice melt and resulting sea level rise that characterized the paleo-sea level record in the 18,000 years following the past ice age. All of the accelerating feedbacks recently documented are features of ice melt that are anticipated to maintain ice melt acceleration and sea level rise acceleration through this century and beyond.

For the first time in Earth's climate record, human-induced climate change has caused CO_2 levels to rise more than 125 ppm in a period of only 150 years, some 100 times faster than the increase following the last ice age. This pace and extent of CO_2 increase and associated warming is unprecedented and should serve as an emergency warning that the Earth will now respond in dire ways, including very significant sea level rise above and beyond what has already been experienced. The last time CO_2 levels were above 400 ppm, over one million years ago, sea level was some 21–27 m (70-90 feet) higher than today (Miller et al., 2012; Dutton at al., 2015). That is where we are headed.

Specifically, I project near certainty of a sea level rise of 1.5–2.5 m (4.1 to 8.2 feet) by 2100 and a strong likelihood that this could be 4.5–9 m (15–30 feet) by 2100 if current trends continue, with ever greater rises and acceleration in subsequent centuries until such time as we aggressively begin to dramatically reduce the levels of CO_2 in the atmosphere and take steps to cool the upper portion of the world's ocean. This amount of sea level rise, combined with other factors, such as hurricane storm surges, would make many parts of the coastal United States uninhabitable. Given the pulses of sea level rise documented in the paleo climate record, this amount of future sea level rise is likely to occur in a relatively short timeframe, making adaptation difficult or impossible.

To protect these Plaintiffs and future generations from the serious and significant harms associated with sea level rise, I recommend that the Federal Defendants be ordered to drastically reduce greenhouse gas emissions and initiative massive carbon sequestration efforts. The prescription set forth by Hansen, et al. in 2013 and 2016, i.e. achieving atmospheric CO_2 concentrations of at most 350 ppm before 2100, should be required. Our children and theirs and future civilization deserve much better than we are presently doing.

Signed this 4th day of April, 2018 in Miami, Florida.

Dr. Harold R. Wanless

Report supplemented this 11th day of September, 2018 in Miami, Florida.

Dr. Harold R. Wanless

EXHIBIT A: CURRICULUM VITAE

UNIVERSITY OF MIAMI
Curriculum Vitae

1. **Date:** March 2018

PERSONAL

2. **Name:** Harold R. Wanless

3. **Home (cell) Phone:** (305) 798-6735

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5. **Home Address:** 1231 Genoa St. Coral Gables, FL 33134

6. **Academic Rank:** Professor

7. **Primary Department:** Department of Geography and Regional Studies, School of Arts and Sciences, University of Miami, P.O. Box 249176, Coral Gables, Florida 33124

   Secondary Department: Department of Marine Geoscience, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami

8. **Citizenship:** U.S.

9. **Date of Birth:** 14 February 1942

HIGHER EDUCATION

10. **Institutional:**

    Johns Hopkins University; Ph.D. 1973 (Dr. L.A. Hardie, Dissertation Advisor)

    University of Miami: M.S. 1968 (Dr. A. Conrad Neumann, Thesis Advisor)

    Princeton University: A.B. 1964 (Dr. A.G. Fischer, Thesis Advisor)

11. **Non Institutional:** NONE

12. **Certification:** Registered Professional Geologist, State of Florida, #985, 1989 to present.

EXPERIENCE

13. **Academic:**

    Geological Assistant; Scripps Institution (for Dr. Francis P. Shepard); 1962-63

    Geological Assistant; University of Illinois (for Dr. Harold R. Wanless); 1964

Research Assistant; University of Miami (for Dr. A. Conrad Neumann); 1965-67

Graduate Fellow; Johns Hopkins University; 1967-71

Research Scientist; University of Miami; 1971-73

Assistant Professor; University of Miami; 1973-81

Associate Professor; University of Miami; 1981-1993

Professor, University of Miami; 1993-present

Chairman, Department of Geological Sciences, University of Miami 1998-2017

Elected Interim Director, Institute for Interdisciplinary Tropical Science, University of Miami, 2003-2004

Cooper Fellow of the College of Arts and Sciences, University of Miami, 2010-2013.

14. **Non-Academic Employment:** Private consultant: petroleum, coastal and environmental, forensic and educational, climate change and sea level rise.

15. **Military:** NONE

PUBLICATIONS

16. **Books and Monographs Published:**

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2018 Dravis, J.J. and Wanless, H.R. Reflux dolomitization–A Holocene example beneath a coastal salina, West Caicos Island, Turks and Caicos Islands. *Marine and Petroleum Geology*, *97*, pp. 311-322.

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2010 Wanless, H.R., and Harlem, P. Accelerating sea level rise – projections and implications. 2010 Geological Society of America Annual Meeting and Exposition; Abstracts with Programs, p. 489.

2011 Wanless, H.R., and Harlem, P. Accelerating sea level rise – projections and implications. Sea Level Rise Adaptation in the Florida Keys: Conserving Terrestrial and Intertidal Natural Areas and Native Species. May 10th – 12th, 2011, Hawks Cay Resort, Florida Keys

2012 Wanless, H.R. Carbonate Depositional Systems in the Context of Previous, Current, and Anticipated Global Change, in Gerace Symposium on Rapid Pulses of Sea Level Rise and Their Effect on Past, Present, and Future Coastal Environments and Sequences. 2 page Abstract in Abstract Volume.

Wanless, H.R. Pulses of Rapid Sea Level Rise: Their Effect on Past, Present and Future Coastal Environments and Sequences. Invited presentation in session on 'Rapid Sea Level Rise and Its Impacts: Past, Present and Future.' Geological Society of America Annual National Meeting and Exposition Abstracts with Programs, Vol. 44. No. 7, p 53.

"Role of Storms, Oceanic Swells, Prevailing Energy and Sea Level in Defining Sediment Body Geometry, Composition and Texture on Caicos Platform, Turks and Caicos Islands." Keynote Presentation in session on 'New Insights on the Geology, Karst, and Paleontology of Carbonate

Systems of the Bahamian Archipelago.' Geological Society of America Annual National Meeting and Exposition Abstracts with Programs, Vol. 44. No. 7, p 67.

2013 "Pulses of Rapid Sea Level Rise – Past, Present and Future", Penrose/Chapman Conference on Coastal Processes and Environments Under Sea-Level Rise and Changing Climate: Science to Inform Management, jointly sponsored by the Geological Society of America and the American Geophysical Union. Abstracts. Galveston, TX. April 15-19, 2013.

"Need for Orderly Planning for Barrier Island Inundation", in Session 107, The Sandy Beaches of Atlantis: Success Stories and Cautionary Tales for Coastal Development. Geological Society of America Annual National Meeting and Exposition Abstracts with Programs, Vol. 45. No. 7, p 273.

2014 "The Coming Reality of Sea Level Rise: Too Fast Too Soon", Illustrated Abstract for National League of Cities Conference. September 20, 2014.

"The Coming Reality of Sea Level Rise: Too Fast Too Soon", Illustrated Abstract for Best Practices Conference, Miami-Dade County League of Cities, Miami, FL. October 24, 2014.

2015 "Thriving *Acropora* in Caicos – a Refugia?" Invited presentation GSA 193-11in session T148 on.' Geological Society of America Annual National Meeting and Exposition Abstracts with Programs, Baltimore, MD, Vol. 47, No. 7, p. 489-490.

"The Coming Reality of Sea Level Rise: Too Fast Too Soon." A 4-10 page illustrated summary of the seriousness and urgency of climate change and sea level rise; revised and updated monthly and provided at all my invited lectures, interviews and other events.

2016 "The Coming Reality of Sea Level Rise: Too Fast Too Soon." A 4-10 page illustrated summary of the seriousness and urgency of climate change and sea level rise; revised and updated monthly and provided as handout at all my invited lectures, interviews and other events.

"Anaerobic Bottom Waters Need Not Be Deep." Geological Society of America Annual National Meeting, Abstracts with Programs V. 48, No. 7. Session T296. Carbonate Sediments Session. Paper 12. https://gsa.confex.com/gsa/2016AM/webprogram/Paper283809.html

2017 "The Coming Reality of Sea Level Rise: Too Fast Too Soon." A 10-12 page illustrated summary of the seriousness and urgency of climate change and sea level rise; revised and updated for each lecture/event and provided as handout at all my invited lectures, interviews and other events.

Evanoff, Emmett, and Wanless, Harold R., Geologic and Paleontologic Significance of Historic Photographs in Badlands National Park, South Dakota. Paper 316-1, Geological Society of America Abstracts with Programs. Vol. 49, No. 6, ISSN 0016-7592
doi: 10.1130/abs/2017AM-302051

Wanless, H.R., 2017 *Expert Report of Harold R. Wanless*. For Case No.: 6:15-cv-01517-TC in the United States District Court, District of Oregon. Kelsey Cascadia Rose Juliana; Xiuhtezcatl Tonatiuh M., through his Guardian Tamara Roske-Martinez; et al. Plaintiffs, v. The United States of America; Donald Trump, in his official capacity as President of the United States; et al., Federal Defendants. 32 pages. Filed October 12, 2017.

Book Reviews:

1980 The North-West European Shelf Seas: The Sea Bed and the Sea in Motion. I. Geology and Sedimentology. (F.T. Banner, and M.B. Collins, and K.S. Massie, Eds.), Bull. Mar. Sci., 30(3): 746.

1981 Barrier Islands from the Gulf of St. Lawrence to the Gulf of Mexico. (S.P. Leatherman, Ed.), Academic Press, New York.

1983 "Tempestites", review of Cyclic and Event Stratification, 1980, G. Einsele and A. Seilacher, Eds., Science, v. 220, #4564: 296-297.

1987 An Introduction to Carbonate Sediments and Rocks (Terence P. Scoffin), Bull. Mar. Sci. 41(3): 909-910.

19. **Other Works Accepted for Publication:**

Refereed Articles Accepted and in Press:
Tedesco, L.P., and Wanless, H.R. Fabric selective dolomitization and porosity enhancement in fine-grained shelf and bank facies. Proceedings of the International Symposium on the Exploration and Development of Low Permeability Oil and Gas Reservoirs, Xian, China [12 msp, 12 figs.; in English and Chinese].

Wanless, H.R. Porosity and permeability destruction and enhancement in limestones during burial and tectonic stresses. Proceedings of the International Symposium on the Exploration and Development of Low Permeability Oil and Gas Reservoirs, Xian, China [19 msp., 15 figs.; in English and Chinese].

PROFESSIONAL

20. **Funded Research Performed**, H.R. Wanless, Principal Investigator. (Since 1978):

Role and Record of Storms on Sedimentation in Subtropical Lagoons, National Science Foundation (Geology), 1978-1980.

Pressure Solution and Dolomitization, National Science Foundation (Geology), 1978-1980.

Sedimentation History of Loxahatchee River Estuary, Florida. U.S.G.S., 1981-1982.

Sources and Circulation of Turbidity in Biscayne Bay, Florida. Dade County, 1982-1984.

Sources and Circulation of Turbidity in Biscayne Bay, Florida. Sea Grant, 1982-1984.

Limestone Diagenesis and Porosity Modification Associated with Exposure Surfaces: Influence of Climate, Depositional Fabric and Topography, Exxon Production Research Co., Tenneco Oil Co., and Union Oil of California, 1985-1986.

Effect of Hurricane Kate on Carbonate Sedimentation, Caicos Platform, B.W.I. National Science Foundation (Surficial Processes) 1986.

Carbonate Mud Mound Facies Evolution. Champlain Oil, 1987.

Carbonate Facies on Caicos Platform. Union Oil of Calif., and ARCO, 1987, 1988 and 1989.

Facies Generation, Transformation and Destruction by Repetitive Excavation and Infilling of Burrow Networks, National Science Foundation, 1990-1991.

Carbonate Facies and Shallow Seismic Signature on Caicos Platform. Texaco, BP and UNICAL, 1991.

Dynamics and Historical Evolution of the Mangrove/Marsh Fringe, Southwest Florida, in Response to Sea-level History, Biogenic Processes, Storm Influences, and Climatic Fluctuations. Department of Interior, National Park Service, June, 1992 to June, 1996.

Post-Hurricane Sediment Redistribution and Benthic Community Response and Evolution within Bicayne Bay, the Coral Reef Platform and the Southwest Florida Coast. Department of Interior, National Park Service, November 1993 to October 1996.

Sediment Dynamics and Substrate Characterization Legare Anchorage, Mid-Reef-Tract Shelf, Biscayne National Park. National Park Service, April 1995 to December 1995.

Historical Changes in the Coastal and Shallow Marine Environments in and Proximal to Florida Bay, Florida: a Retrospective analysis using sedimentologic parameters. Department of Commerce, National Oceanic and Atmospheric Administration, April 1994 to June 2001.

Project SUCCEED: School University Community Coalition for Excellence in Education. Co-geology leader, working with members of Biology, Chemistry and Physics to develop an integrated curriculum for middle school science and for undergraduate education majors. U.S. Department of Education (5 years: 2000-2004; discontinued participation 2002)

Experimental coral/coralline algae transplanting on carbonate banks in Biscayne Bay. Oil Spill Research Fund, subcontract of sea grass planting program (April 2001-April 2002).

"Coastal landscape, wetland and tidal channel evolution affecting critical habitats of Cape Sable, Everglades National Park, Florida." National Park Service, August 2002-June 2005.

"Detection, Mapping, and Characterization of Groundwater Discharges to Biscayne Bay" State of Florida, Biscayne Bay Regional Restoration Coordination Team, as sub-contract with National Oceanic and Atmospheric Administration through CIMAS. With Dr. John R. Proni, NOAA, AMOL. March 2003- December 2004

21. **Editorial Responsibilities:**

Reviewer for numerous journals.

Co-Chair Biscayne Bay Initiative Science Survey Team, responsible for preparation of

Synthesis, critical issues and recommendation to the Florida Legislature, 1999-2001.

Invited member of Core Group for evaluating and prioritizing research and monitoring research (RECOVER) associated with the Comprehensive Everglades Restoration Plan 2004-2005.

National Science Foundation Panel on the Coastal SEES Program (SEES a new program within NSF's "Science, Engineering and Education for Sustainability." – 2012 - 2015.

22. **Professional and Honorary Organizations:**

Society of Economic Paleontologists and Mineralogists
International Association of Sedimentologists
Gulf Coast Section; Society of Economic Paleontologists and Mineralogists
Geological Society of America, elected Fellow
American Association of Petroleum Geologists
Board of Directors: The Conservancy, Inc. (Collier County) (1983-1987)
Miami Geological Society
Board of Directors, CLEO Institute, Miami, (2011-present)

23. **Honors and Awards:**

1976 American Association of Petroleum Geologists General Chairman's Award for Best Paper in Poster Session at 61st Annual Meeting in New Orleans.

1980 Best paper for 1979 in Journal of Sedimentary Petrology. ("Limestone Response to Stress: Pressure Solution and Dolomitization") from the Society of Economic Paleontologists and Mineralogists. Presented at May 1981, San Francisco Mtg.

1986 Society of Economic Paleontologists Mineralogists Excellence of Presentation: AAPG-SEPM Annual National Meeting, Atlanta. "Burrow-Generated False Facies and Phantom Sequences." Presented at June 1987, Los Angeles Mtg.

1993 Awarded Undergraduate Course Enhancement Grant, College of Arts and Sciences, University of Miami.

2001 Earth Trustee, Presented at the United Nations by the Earth Society, March 21, 2001.

2002 Environmental Leadership Award for 2001, Sierra Club, Miami Group.

2004 Honorary Member Board of Directors, Montgomery Botanical Center, Miami-Dade County.

2007 Sabbatical, Spring 2007 – College of Arts and Sciences, University of Miami.

2010-2013 Cooper Fellow, College of Arts and Sciences, University of Miami.

2011. Named by Poder Hispanic Magazine as one of the 100 Most Influential Persons in Miami.

2012. Named by Poder Hispanic Magazine as one of The Most Influential People in Miami.

Keynote Speaker and honoree at Gerace Geology Symposium, San Salvador, Bahamas, June, 2012.

Keynote Speaker at Bahamian Symposium, Geological Society of America Annual National Meeting, Charlotte, NC, November, 2012.

Inducted into CLEO Leadership Circle, CLEO Institute (Department of Geological Sciences also received award for Sponsoring ‘Empowering Capable Climate Communicators’ climate training series), December, 2012.

2013 Written up as a “Gables Great” in an article entitled ‘Dr. Hal Wanless Easily Mixes Science and Fun’ in ***Coral Gables News***, January 8-12, 2013.

2015 "Founders Award." Earth Web Foundation, Orlando, Earth Day 2015 (April 18).

2016 Featured in "10 by 10" in ***Malibu Magazine***, April 2016.

Named one of ***Politico Magazine's*** 50 plus 'thinkers, doers and visionaries who are transforming American Politics in 2016.'

Lifetime Achievement Award for leadership work with youth and climate change, Adams Family.

2017-18 One year Sabbatical from the University of Miami.

24. **Post-Doctoral fellowships:** NONE

25a. **Other Professional Activities - Invited Lectures** (see #18 for papers presented at scientific meetings and symposiums):

1981 Sediment Diagenesis, a NATO Advanced Study Institute at Reading University, U.K., 12-25 July, 1981. Specific Topic: "Late Stage Diagenesis in Carbonates".

"Dynamics of Carbonate Sedimentation in Florida Bay". Invited lecture at Univ. of South Florida, October, 1981.

1982 "Modern Carbonate Sedimentation and Early Diagenesis". Invited lecture and field study, University of Kansas, March, 1982.

"Sea Level Rise: Evidence and Implications". TV Channel 17, Miami, March, 1982.

"Sea Level Rise: Evidence and Implications". Invited Lecturer at Florida Department of Environmental Regulation, Tallahassee, Florida, March, 1982.

"How Biscayne Bay Works". Invited Lecturer and Techn. Coordinator, October, 1982, RSMAS and Dade County sponsor.

1983 Invited Lecture series, University of Tubingen, West Germany, I. "Pressure Dissolution"; II. "Facies Reconstruction of the Cambrian of Grand Canyon", November, 1983.

"Styles of Pressure Dissolution", Abu Dhabi Reservoir Research Foundation, Abu Dhabi, U.A.E., November, 1983.

1984 "Understanding and Managing Florida's Estuaries", Keynote speaker at St. Lucie Estuary Coordinating Conference, Jensen Beach, Fl., March, 1984.

"Biscayne Bay Problems and Solutions". Baynanza Symposium RSMAS, October, 1984.

1985 "Environmental Implications of Sea Level Rise". The Conservancy, January, 1985.

1986 "Storm Sedimentation and Burrow Dynamics". Department of Geology, Cambridge University, February, 1986.

"Coastal Dynamics and Trends: A Necessary Background for Beach and Shore Management". Keynote speaker, 1986 Coastal Management Conference-Florida's Coastal Future: The Challenge Remains. State of Florida. Department of Environmental Regulation, Miami Beach, September, 1986.

"The Geology of Hurricanes", Distinguished Lecture Series, in celebration of the 60th Anniversary of the University of Miami, October, 1986.

"Hurricanes and Sea Level Rise; Effect on Coastal Environments", Fairchild Tropical Gardens, Annual Mtg. Native Plant Society, October, 1986.

"Influence of Sea Level Rise on Coastal Mangrove Communities", Naples City Council, December, 1986.

1987 "Biogenic Facies Destruction, Modification and Generation", Champlain Oil Co., Denver, June, 1987.

1988 "Will Our Rising Sea Level Cause Disaster in South Florida?" American Littoral Society, South Florida Chapter, Key Biscayne, Florida, March 1988.

Evolution of Coastal Environments in Response to Increased Rate of Sea Level Rise", Admirals of the Fleet of Florida, October, 1988.

"The Role of Excavating Burrowers in Generating, Transforming and Destroying Sedimentary Facies", Kansas Geological Survey and University of Kansas, October, 1988.

1990 Invited Lecture series, National Taiwan University, Taipei, Republic of China, I. "New Models of Carbonate Platform Sedimentation"; II. "Burrow Generation and Modification of Sedimentary Facies", March, 1990.

Invited Lectures series, East China Petroleum University of Beijing, Peoples Republic of China, I. "New Models of Carbonate Platform Sedimentations"; II. "New Models of Ooid Sedimentation"; III. "Carbonate Reefs and Leeward Margin Evolution"; IV. "New Models of Carbonate Tidal Flat Sedimentation"; V. "Seagrass/Crinoid Influence on Sedimentation"; VI. "Origin and Growth of Modern Carbonate Mud Mounds"; VII. "Porosity Evolution During Karst and Calcrete Development"; VIII. "Holocene Evaperite and Dolomite Sedimentation"; IX. "Cambrian Cyclic Sedimentation"; X. "Pressure Dissolution and Dolomitization in Carbonate Rocks", April, 1990.

"New Models of Carbonate Platform Sedimentation", Chengdu College of Geology, Chengdu, Sichian, Peoples Republic of China, April, 1990.

Invited Lectures series, Changying Petroleum Exploration Gen. Co. of China National Petroleum Corp., Qinayang, Gansu, Peoples Republic of China; I. "New Models for Ooid Sedimentation"; II. "Reefs and Leeward Margin Evolutions"; III. "Carbonate Tidal Flat and Evaperite sedimentation and Holocene Dolomitization"; IV. "Origin and Facies Development of Modern Carbonate Mud Mounds"; V. "Porosity Evolution During Karst and Calcrete Development"; VI. "Pressure Dissolution and Dolomitization in Carbonate rocks", April, 1990.

Invited Lectures series, East China Petroleum University at Dangyang, Shengdong, Peoples Republic of China, I. "New Models of Ooid Sedimentation"; II. "Reefs and Leeward Margins Evolution of Carbonate Platforms"; III. "Carbonate Tidal Flat Sedimentation"; IV. "Origin and Facies Development of Modern Carbonate Mud Mounds"; V. "Pressure Dissolution and Dolomitization in Carbonate Rocks", April, 1990.

"Observations of Changing Sea Levels and Storms on Coastal Environments", Astronaut Office Colloquium on Earth: a Changing Planet, Johnson Space Center, Houston, Texas, July 25, 1990

"New Models of Carbonate Platform Sedimentation". Royal Dutch Shell, Den Hague, The Netherlands, August 1990.

"New Models of Carbonate Platform Sedimentation". British Petroleum, London, August, 1990.

"Biscayne Bay's Response to Urbanization and Rising Sea Level", Baynanza 90 and Sierra Club, Miami, FL, Oct., 1990.

"Sea Level and Hurricanes: Their Effects on Our Coastal Environments". RSMAS School Council Staff Seminar Series, December, 1990

1991 "Porosity and Permeability destruction and Enhancement in Limestones during Burial and Tectonic Stresses." International Symposium on the Exploration and Development of Low Permeability Oil and Gas Reservoirs, Xian, China, May, 1991.

"Differentiating Porosity Development Resulting from Karst Versus Late-stage burial Dissolution in Limestones", Changying Petroleum Exploration Co. of China National Petroleum Corp., Qinayang, Gansu, China, June, 1991.

"Origin and Evolution of Holocene Sedimentary Environments in Florida Bay". Indiana University Purdue University at Indianapolis, Indiana, November, 1991.

1992 "Plio-Pleistocene stratigraphy of Caicos Platform based on high-resolution Seismic profiles and core borings." Texaco Research and Exploration, Houston, February, 1992.

"Recommendations for the Future Management of Key Biscayne's Beaches and Coastline," Village of Key Biscayne Public Lecture Series in Conjunction With Master Plan Development, April 1992.

"Hurricane Andrew: the Geological Implications." Special evening symposium at the 1992 Annual Meeting of the Geological Society of America, Cincinnati. Organizer and one of four speakers.

"Physical and Biological Effects of Hurricane Andrew: a Summary. Hurricane Andrew Session of the 1992 Symposium on Florida Keys Regional Ecosystem. NOAA and University of Miami, RSMAS Conveners, Miami, November, 1992.

1993 "Hurricane Andrew: the Short and Long Term Impacts." Sigma XI Lecture series, Tallahassee, April 1993.

1994 "The Impact of Hurricane Andrew on the Terrestrial, Wetland, Coastal and Shallow Marine Environments of Florida" Environmental Lecture Series, The Conservancy, Inc., Naples, FL; February, 1994.

"Sea Level Rise and Mangrove Forests" Department of Environmental Protection Coastal Zone Resource Management Workshop, Rookery Bay National Estuarine Research Reserve, Naples, FL; February, 1994.

1995 "Coastal changes resulting form Hurricanes and Global Warming" NOVA University, September, 1995

"Geology of Western Cuba" Miami Geological Society, September, 1995.

"How Hurricanes and Sea-Level Rise Are Changing Our Coastal Environments" Science Expo '95, Univ. Miami, September, 1995.

1996 "Land from the Sea: the Geological Origins of south Florida;" Lecture #2 of the Miami Centennial Celebration Lecture Series, January, 1996.

Past and Future Sea-Level Rise.

1997 "The Geologic Wonders of Newfoundland," Miami Geological Society, February, 1997.

"Hurricanes and Sea-Level Rise: Effectors of Coastal Evolution," Florida Tech, Melbourne, FL, February, 1997.

"Anticipated Sea Level Change and Effects" and Panelist at 'Impacts of Climate Change in South Florida's Growing Urban Area' a regional teleconference in conjunction with 'President Clinton Speaks Out on Climate Change', Florida international University, October, 1997.

"Beach Dynamics and Coastal response to Sea Level Rise an Hurricane Events," Rookery Bay National Estuarine Research Reserve, November, 1997

1998 "Geological History, Evolution of Modern Environments and Processes Controlling the Coastal Systems of Southwest Florida". A lecture and field seminar for Faculty of the Keck Consortium of Undergraduate Geoscience Departments. Naples, FL January 7-10, 1998.

"Mud Banks of South Florida: Stratification Type and the Contained Paleoenvironmental Record." Workshop on Paleoecology and Ecosystem History of Florida Bay and the Lower Everglades. Sponsored by the Florida bay Program Management Committee, Key Largo, January, 1998.

"A Summary and Perspective on What We Know and need to Know" Workshop on Paleoecology and Ecosystem History of Florida Bay and the Lower Everglades. Sponsored by the Florida Bay Program Management Committee, Key Largo, January, 1998.

(poster) Stratification types of Florida Bay. Workshop on Paleoecology and Ecosystem History pf Florida Bay and the Lower Everglades. Sponsored by the Florida bay Program Management Committee, Key Largo, January, 1998.

"Natural and Geological Wonders of Newfoundland." Miami Geological Society, February 28, 1998.

"Geological Influences on the Big Cypress Basin." Workshop II of the Big Cypress Basin Science Plan Steering Committee, Department of Environmental Protection. February 26, 1998.

"The Impact on Florida of Global Warming." 1st Orlando Earth Day Symposium, sponsored by Orange County Medical Society Environmental Committee., Orlando Regional Medical Center, April 25, 1998.

1999 "The Geologic Dynamics of Everglades National Park." Everglades National Park Interpreter's Training Workshop. January, 1999.

"Life as a Geoscientist." Centennial Middle School, Miami-Dade County, April, 1999.

"The Future of South Florida." Friends of the Everglades, April 1999

"South Florida in the Face Of Global Warming." Miami Marine Council. Coral Gables, FL, May, 1999.

"Sea Level Rise Adaptation Options for South Florida." Environmmental Protection Agency Conference: *Climate Change: What Does It Mean for South Florida?* Miami, FL, May 26, 1999.

"Sea Level Rise Adaptation for the Florida Keys." Environmental Protection Agency Conference: *Climate Change: What Does It Mean for the Florida Keys?* Marathon, FL, May 27, 1999.

"Harold Rollin Wanless – a Son's View." 8th International Carboniferous Congress, Session on Cyclothems dedicated to Harold R. Wanless. Calgary, Alberta, Canada, August 18, 1999.

"The origin and dynamics of intertidal sand and mud flats." Rookery Bay National Marine Estuarine Reserve Conference on biodiversity of intertidal environments, Naples, FL, November 1999

"South Florida Environments in the Face of Rising Sea Level." Sierra Club, Miami Chapter, Coral Gables, FL, November, 1999.

2000 "South Florida-- the Next 100 Years." South Florida Audubon Society, January, 2000

"Evolution of Biscayne Bay -- Past and Future." Biscayne Bay Partnership Initiative, Science Survey Team Working Session, Miami, FL, January 28, 2000

2001 "Aquifer Storage and Recovery: lessons from failing injection wells." Everglades Coalition Annual Meeting invited breakfast speaker, Stewart, Fl. January 2001.

"The Evolution of the Florida Keys and Reefs over the next 100 years in the face of global warming." John Pennecamp State Park, Key Largo, Fl. February 2001

The Risk of Injection Wells and impure ASRs." LEAF meeting on Aquifer Storage and Recovery, Winter Park, Fl. May 2001.

"You're a Scientist Now – Don't Believe a Word You Hear." INQUIRY, University of Miami, November, 2001.

"The Risks to South Florida over the next 100 Years from Global Warming: Need for Council Action." South Florida Regional Planning Council, Hollywood, Fl. December 3, 2001

"The Risks to South Florida over the next 100 Years from Global Warming: need for Coalition Action." Florida Gold Coast Clean Cities Coalition meeting, Hollywood, Fl. December 3, 2001.

2002 "Aquifer Storage and Recovery" – a panel on questions and feasibility. The Everglades Coalition annual meeting, Ft. Lauderdale, Fl., January 2002.

"Biscayne Bay in the Face of Global Warming" National Park Service Discovery Series Lectures, Miami, FL, April 2002.

Wanless, H.R. "Sediment Stability in Tropical Carbonate and Organic Environments". U.S. Army Corps of Engineers sponsored *Sediment Stability Workshop*, New Orleans, LA, Jan 22-24, 2002. (Invited presenter and panelist)

Wanless, H.R., "An Evaluation of Cape Sable Canals, Everglades National Park, Florida." Invited presentation to Superintendent and staff, Everglades National Park, October, 2002.

Wanless, H.R., "Rapid Ecosystem and Coastscape Evolution of South Florida, in response to Sea Level Rise, Hurricane Events, and Human Stresses", National Oceanic and Atmospheric Administration, National Ocean Service, Coastal Oceans Division. Rockville, MD, (with synchronous feed to regional centers), October 2002.

Wanless, H.R., "The Nature of Transgression: Cape Sable, Florida." Geological Society of America Annual National Meeting, Denver, October, 2002

2003 "Inundation of South Florida: Past, Present and Future." Invited paper at 13th South West Florida Water Research Conference: The Rising Tide: Emerging Coastal Issues, Gulf Coast University, November 2003.

"Aquifer Injection and Storage Wells – Opportunity or Disaster?" invited paper at the National Groundwater Association meeting: Groundwater in Coastal Zones, Availability, Sustainability and Protection, Orlando, December, 2003.

2005 South Florida Coastal Response to anticipated Sea level Rise" invited presenter and panelist, Everglades Coalition Annual Meeting, Naples, January, 2005.

"With Global Warming – Comes the Sea" invited lecturer and panelist, 11th Annual Public interest and Environmental Conference, University of Florida, Gainesville, FL, February, 2005

"Regional Impacts of Climate Change: Hurricanes and Sea Level Rise" and panelist South Florida Parks and Preserves, Climate Friendly Parks Workshop, Environmental Protection Agency and National Park Service. Everglades National Park, Florida, June, 2005

"Welcome to the Tropics: Where the Canadian Rockies Were Made" Canmore Geoscience Museum Open House, Canmore, Alberta, June, 2005.

2006 Climate Change Workshop, Florida Atlantic University, January, 2006.

"Impact of Climate Change on South Florida" on *Topical Currents* on WLRN Radio, January 19. 2006.

"Coastal Systems and Climate Change – It is real – It is Now – Change Your Ways – Change Your Plans" South Florida Association of Environmental Professionals Conference on Global Climate Change: Implications for South Florida's Future, Florida, January 20, 2006.

"The Everglades in the Next 100 Years" and panelist discussing 'Global Warming's Threats to Florida's Everglades, Economy and Way of Life.' Everglades Restoration: Are We Making Progress? Everglades Coalition 21sat Annual Conference, Stuart, FL, January, 2006.

"Providing Water for a Viable Everglades Restoration" and Panelist discussing 'Deep Concern for ASR Wells and Everglades Restoration.' Everglades Restoration: Are We Making Progress? Everglades Coalition 21sat Annual Conference, Stuart, FL, January, 2006.

"Towards Effective Everglades Restoration and south Florida Resource Management" 5th Annual Environmental Ethics Conference, Ft. Lauderdale, Florida, February 17, 2006.

"Beach Renourishment is Becoming an Economic and Environmental Disaster in Florida" Invited workshop with Regional Environmental Protection Agency heads preliminary to a regional workshop and new regulations. Palm Beach, Florida, February 22, 2006.

"How We Know Global Warming is Human Induced and Real" League of Women Voters, Broward County, Florida, February 25, 2006.

"With Warming Comes the Sea – Global Warming's Effect on South Florida", Broward County Audubon Society, Ft. Lauderdale, FL. April 20, 2006.

"We have Made a Mess of Earth and Earth is Responding" Earth Day Miami. Miami, FL April 22, 2006

"Saving America's Wetland's – Alternatives for Action" A presentation to the State of Louisiana'a Governor's office based on recommendation of an international workshop held in April in Louisiana. New Orleans, LA. June 1, 2006.

"Anticipating and Managing Climate Change – a Conservation View", The Nature Conservancy annual Florida Meeting St. Petersburg Beach. September 17, 1006.

"Global Warming and its Implications for Managing South Florida" Broward County Water Advisory Board, Ft. Lauderdale, September 21, 2006

"Global Warming and Coastal Architecture" University of Miami, November 11, 2006

"Anticipating and Managing Global Warming in Florida – A Conservation View", to the Florida Board of Directors, The Nature Conservancy./ November 16, 2006.

2007 "Global Warming: Its Effect on Southeast Florida" VisionBROWARD Leadership Community Forum, Ft. Lauderdale, FL. February 9, 2007

"Rising Sea Level and its Anticipated Effect on Southwest Florida" Gulf Coast Alliance Workshop on Water. Rookery Bay, Naples, FL, February 20, 2007.

"Comes the Sea – Global Warming's Anticipated Effect on South Florida" Miami Rotary Club, Miami, FL, February 22, 2007.

"Comes the Sea – Global Warming and Sea Level in South Florida" Dade Native Plant Society, Fairchild Gardens, September 25, 2007.

"Water Resources and 'Re'Sources and Potential Losses – South Florida's Diminishing Freshwater Future" Legal Symposium - Partnering With Water and Sewer Agencies: The Key to Future Development in Florida, Miami, October 26, 2007.

"Florida's Diminishing Coastal Future" Florida Legislature, Energy and Environmental Council – Symposium on the Science and Economics of Climate Change, Tallahassee, November 6, 2007.

"Florida's Diminishing Coastal Future" Symposium on Global Warming in honor of Dr. Jack Parker, Florida International University, November 29, 2007.

"Florida's Diminishing Coastal Future" South Florida Association of Environmental Professionals, Workshop and Symposium for Wetland Professionals in South Florida, Miami, November 29, 2007.

2008 "Rising Seas: Will the Everglades and Coastal Areas Survive?" Keynote Address, Everglades Coalition Annual Conference, Captiva, FL, January 12, 2008.

"Rising Seas: Will the Everglades and Coastal Areas Survive?" Miami-Dade College, sponsored by Earth and Environmental Ethics Institute, Miami, January 31, 2008.

"Comes the Sea" Global Warming Teach-In, University of Miami, January 31, 2008.

"Rising Seas: Will the Everglades Survive?" Climate Change Discussion/Mini-Workshop, Greater Everglades Ecosystem Restoration, Florida Atlantic University, February 6, 2008.

"Managing the Everglades in a Time of Rapidly Rising Sea Level" State of Florida Legislative Committee on Everglades Restoration, Tallahassee, February 18, 2008.

"Rising Sea Level and Implications for Future Development in Miami-Dade County." Hold The Line Meeting, South Miami, Florida. February 20, 2008.

"Rising Seas: Realities for our South Florida Coastlines." Climate Protection and Greenhouse Gas reduction Workshop for Local Governments, Palm Beach, FL, February 21, 2008.

"Rising Seas: Realities for Our South Florida Coastlines." Kiwanis Club of Coral Gables, FL, March 11, 2008.

"Rising Seas: Realities for the Everglades and Our South Florida Coastlines." Ecosystem Science Seminar, University of Miami, FL, March 19, 2008.

"Sea Level Rise in South Florida." Faiths United for Sustainable Energy (FUSE), Beth Ann Synagogue, Miami Beach, FL, March 31, 2008.

"Comes the Sea: Earth's Changing Coastal Future." Quantum Leap – 1st Annual Meeting of the Climate Group, Miami, FL, April 1, 2008.

"Rising Seas: A Challenge to the Everglades' Survival – Realities and What We Have to Do."

Friends of the Everglades – Founder's Day Celebration, April 13, 2008.

"Key Biscayne – Past, Present and Future." Key Biscayne / RSMAS Lecture Series, Key Biscayne, FL, April 15, 2008.

"Comes the Sea: South Florida in the Face of Global Warming." Friends of Forest Hill Environmental Academy – 8th Annual Nicolas Megrath Dinner, Palm Beach, FL, April 17, 2008.

"Statement on Sea Level in the Coming Century" from the Science Committee of the Miami-Dade County Climate Change Advisory Task Force for the Board of County Commissioners, Miami, FL, April 22, 2008.

"Comes the Sea: Earth's Changing Coastal Future." Scripps Howard Institute on the Environment (a National Workshop for Journalists), Florida Atlantic University, Jupiter Campus, May 12, 2008.

"Implications of Rising Sea Level on Everglades Restoration." American Geophysical Union Annual Meeting, Ft. Lauderdale, FL, May 28, 2008.

"Comes the Sea: Earth's Changing Coastal Future." One-on-one presentation and discussion with Presidential Candidate and U.S. Senator John McCain and Florida Governor Charlie Crist, in the Everglades, FL, June 6, 2008.

"Ocean Effects of Rising Sea Level on Coastal Environments." Florida Wildlife – on the Front Line of Climate Change, Orlando, FL, October 1, 2008.

"Comes the Sea: Earth's Changing Coastal Future." University of Miami URB 201 – Metropolitan Miami, Coral Gables, FL, September 9, 2008.

"Climate Change and Sea Level Rise – Impacts on Florida in the Coming Century." Florida Shore and Beach Preservation Association Annual Meeting, Captiva Island, FL, September 12, 2008.

"Ocean Effects of Rising Sea Level on Coastal Environments – Biscayne Bay." Miami, FL, October 10, 2008.

"In Future of the Environment and the Nation: A Forum on Sustainability." A Dialogue for Democracy, University of Miami, Coral Gables, FL, October 22, 2008.

"Ocean Effects of Rising Sea Level on Coastal Environments." University of Miami Oceans and Human Health Graduate Course, RSMAS, Miami, FL, November 3, 2008.

"Rising Seas: Realities for the Southwest Coast of Florida." A Sustainable Southwest Florida: Creating a vision. Ft. Myers, FL, November 6, 2008.

"Rising Seas: Realities for the Coming Century." University of Miami ECS201 (Contemporary Environmental Issues), Coral Gables, FL, November 13, 2008.

"Rising Seas: Coastal Realities for the Coming Century." University of Miami, RSM-581 (Carbon and Climate), Virginia Key, FL, November 21, 2008.

"South Florida and Global Warming." Miami-Dade County League of Cities Dinner Meeting, Miami, FL, December 3, 2008.

2009 "Climate Change and Sea Level Rise – The Coming Century." Broward County Climate Change Task Force, Ft. Lauderdale, Florida. January 22, 2009.

"Effects of Rising Sea Level on the Florida Keys and Reef Tract." Federal Regional Management Meeting. Marathon, Florida. January 27, 2009.

"Climate Change and Sea Level Rise – the Coming Century." Gumbo Limbo Eco Center Evening Lecture Series, Boca Raton, Florida. January 27, 2009.

"Climate Change and Sea Level Rise – the Coming Century." Miami-Dade College, Kendall Campus, Miami, Florida. February 5, 2009.

"Climate Change and Sea Level Rise – the Coming Century." Space Coast Climate Change Initiative, Melbourne, Florida. February 9, 2009.

Climate and Ecosystem workshop, invited panelist. Washington D. C. February 17-19, 2009.

Beach Restoration Panelist. Ocean Awareness Week. University of Miami, Coral Gables, Florida. February 24, 2009.

"Sea Level Rise on the Southern Florida Coast: Past, Present, and Future Trends." In Session: Navigating Terra Incognita: New Management Strategies in an Era of Climate Change II • Confronting Climate Change in Everglades and South Florida. Rethinking Protected Areas in a Changing World, The 2009 George Wright Society Biennial Conference on Parks, Protected Areas, and Cultural Sites, Program and Abstracts. Portland, Oregon. March 3, 2009, P. 60.

"Climate Change and Sea Level Rise – the Coming Century." EPH 541, Environmental Health, University of Miami Medical School, Miami, Florida. March 24, 2009.

"Effects of Sea Level Rise in South Florida in the Coming Century." The Impact of Climate Change on South Florida. Florida Atlantic University. April 3, 2009.

"Climate Change and Sea Level Rise – the Coming Century." Gateway To Green Symposium, Parrot Jungle venue, Miami, Florida. April 8, 2009.

"Climate Change and Sea Level Rise – the Coming Century." City of Plantation Climate Change Task Force, Plantation, Florida. April 15, 2009.

"Climate Change and Sea Level Rise – the Coming Century." Broward County Directors and Managers Quarterly Meeting, Ft. Lauderdale, Florida. April 17, 2009

"The Influence of Sea Level Change on Florida's Ecology." Florida Native Plant Society, 29th Annual Conference. West Palm Beach, Florida. May 23, 2009

"Rising Sea Level and Florida's Tenuous Future." PCB 3352 – Issues in Human Ecology with a focus on South Florida. Florida Atlantic University, Davie Campus, Florida. October 5, 2009.

"Accelerating Predictions for Rising Sea Level: Florida's Tenuous Future." Southeast Coastal and Ocean Stewardship Workshop: Challenges in a Changing Environment. Mandarin Oriental Hotel, Miami, Florida. November 2, 2009.

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." Oxbow Eco-Center Lecture Series. Port St. Lucie, Florida. November 7, 2009.

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." Executive Committee, South Florida Builders Association. Miami-Dade Water and Sewer building, Miami, Florida. November 12, 2009.

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." Harbor Branch Evening Lecture Series, Ft. Pierce, Florida. November 18, 2009.

"Coral Gables, A Jewel From the Sea – Will It Return?" Coral Gables Museum, Coral Gables, Florida. November 7, 2009.

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." Managing Climate Change with Sustainable Initiatives. Lee County, Florida. December 4, 2009.

"Be Bold or Start Packing up the Shop – Recommendation to move the Mississippi River Outlet from the Scientists of the 'Envisioning the Future of the Gulf Coast Workshop." White House Council on Environmental Quality, Washington D.C., December 1, 2009.

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." Florida Natural Resources Leadership Institute. Preparing for Sea Level Rise: Local Government Planning and Community Management, Deauville Hotel, Miami Beach, Florida, December 10, 2009.

2010 "Sea Level Rise and the Everglades Through the Century: the Need for More Proactive Management of the Everglades." Global Climate Change and the Changing Role of Everglades Restoration. Everglades Coalition Conference, Palm Beach Gardens, Florida. January 8, 2010.

"Rapid Sea Level Rise Steps Are the Norm in Post-glacial Rise." Predicting Climate of the Coming Decades: Paleo-perspective on decadal variability. Rosenstiel School of Marine and Atmospheric Science, University of Miami, Virginia Key, Florida. January 13, 2010.

"Capstone Address - Summary of Challenges and Opportunities." Keeping out Heads Above Water: Surviving the Challenges of Sea Level Rise in Florida. Archbold Biological Station, Lake Placid, Florida. January 13, 2010.

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future". Dagny Johnson Key Largo Hammock Botanical State Park Lecture Series, John Pennecamp Coral Reef State Park, Key Largo, Florida, January 27, 2010.

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." ECS 310 – Sustainable Living (but maybe not in south Florida. University of Miami, Coral Gables, Florida. January 28, 2010.

"Sea Level Rise in the Coming Century – How Much and How Do We Prepare?" NOAA sponsored Community Conversations on Climate Change and Sea Level Rise, Ft. Lauderdale, Florida. February 27, 2010.

"Anticipated Global Warming and Sea Level Rise – What They Mean for Your Career Opportunities?" ULecture Series, University of Miami. April 7, 2010

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." FNS 199 – Global Warming. University of Miami, Coral Gables, Florida. April 13, 2010.

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." Science Café Series: Eat, Think and be Merry, Bookstore in the Grove, Coconut Grove, Florida, April 19, 2010

"Accelerating Sea Level Rise and Florida's tenuous Coastal Future," University of Florida Everglades conference at FIU North Campus. May 18, 2010

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." US State Department International Visitor Leadership Program, Sustainable Development and Environmental Projections to Chinese Delegation, August 11, 2010.

"Recovery of An *Acropora* Reef Following Hurricane Ike Devastation, SE Caicos Platform." 2nd Annual NCORE University-wide Coral Reef Forum, University of Miami, Virginia Key, Florida. August 23, 2010

"Emergence of Modern reefs and Their Dynamics in Times of Major Sea Level Fluctuations – Past and Future. Graduate Marine Biology and Fisheries course in Reef Systems, RSMAS, University of Miami, August 26, 2010.

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." ESC Sustainability program, RSMAS, Coral Gables, Florida. September 13, 2010.

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." Distinguished Lecturer Series, Florida Atlantic University, September 17, 2010.

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." Osher Lifelong Learning, University of Miami, Coral Gables, Florida. September 21, 2010.

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." Lecture Series, RSMAS, University of Miami, Florida. November 10, 2010.

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." MSC 220 – Global Climate Change, University of Miami, Coral Gables, Florida. November 23, 2010.

With Peter Harlem: "Accelerating Sea-Level Rise – Projections and Implications. Geotopics, Division of Marine Geology and Geophysics, RSMAS, University of Miami, Florida. November 29, 2010.

2011 "Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." ECS 310 Sustainable Living, University of Miami, Coral Gables, Florida. January 27, 2011.

"Accelerating Sea Level Rise and Earth's Tenuous Coastal Future." Distinguished Lecrure Series, NOVA Southeast University, Ft. Lauderdale, FL, February 8, 2011.

"Accelerating Sea Level Rise and Earth's Tenuous Coastal Future." Distinguished Lecture Series, Indian River State College Institute for Lifelong Learning, Vero Beach, Florida, February 10, 2011.

"Accelerating Sea Level Rise and Earth's Tenuous Coastal Future." Distinguished Lecture Series, Indian River State College Institute for Lifelong Learning, Stuart, Florida, February 10, 2011.

"Accelerating Sea Level Rise and Earth's Tenuous Coastal Future." University of Florida Natural Resources Leadership Institute, Homestead, Florida, February, 11, 2011.

"Accelerating Sea Level Rise and Earth's Tenuous Coastal Future." Graduate course in Global Warming and Environmental Health, Miller School of Medicine, University of Miami, Miami, Florida, February 21, 2011.

"Accelerating Sea Level Rise and Earth's Tenuous Coastal Future." Empowering Capable Climate Communicators Training Series, College of Arts and Sciences, University of Miami, March 5, 2011.

"Accelerating Sea Level Rise: Projections and Implications." Climate Change Professional Fellows Program, Florida International University, March 28, 2011.

"Accelerating Sea Level Rise: Projections and Implications." Climate Change Communication, Florida Atlantic University, Gumbo Limbo Nature Center, April 5, 2011

"Accelerating sea level rise – projections and implications (poster and talk). Sea Level Rise Adaptation in the Florida Keys: Conserving Terrestrial and Intertidal Natural Areas and Native Species. Hawks Cay Resort, Florida Keys. March 11, 2011.

"Rapidly Accelerating Sea Level Rise and Earth's Tenuous Coastal Future." Miami-Dade College, downtown campus, in conjunction with 24-hour presentation on Extreme Events. September 15, 2011.

"Accelerating Sea Level Rise: Projections and Implications." CLEO Institute, Vizcaya. Miami. September 22, 2011.

"Rapidly Accelerating Sea Level Rise and Earth's Tenuous Coastal Future." Florida International University. Miami. October 12,2011.

"Rapid Steps of Sea Level Rise: An Ominous View into the Future." Presentation during Field Trip in conjunction with the Society of Environmental Journalists Annual National Meeting, Emergency Management Center, Miami-Dade County. October 20, 2011.

"Rapid Steps of Sea Level Rise: An Ominous View into the Future." Plenary Presentation and Panelist at Plenary Luncheon of the Society of Environmental Journalists Annual National Meeting, Intercontinental Hotel, Miami. October 22, 2011.

"Rapid Steps of Sea Level Rise: An Ominous View into the Future." CLEO Institute, Pinecrest Gardens, Miami-Dade. November 4, 2011.

"Rapid Pulses of Sea Level Rise." Earth Ethics Institute, Miami Dade College, Kendall Campus. November 29, 2011.

2012 "Accelerating, Pulsed Sea Level Rise: Dire Implications for South Florida. Sustainable Living ECS 310. University of Miami. January 31, 2012.

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future." Ecology Club, Palm Beach State College, Boca Raton. February 10, 2012.

"Accelerating Sea Level Rise and Florida's Tenuous Coastal Future," University of South Florida at St Petersburg, Geography Department, April, 2012.

"Sea Level Rise and Climate Change: Your Property Value in the Balance." Friends of the Everglades 43rd annual meeting, Miami. April 15, 2012.

Keynote Speaker: "Carbonate Depositional Systems in the Context of Previous, Current, and Anticipated Global Change," in Gerace Symposium on Rapid Pulses of Sea Level Rise and Their

Effect on Past, Present, and Future Coastal Environments and Sequences, Gerace Research Center, San Salvador, Bahamas, June 14, 2012.

Gulf Coast Science Consortium Invited Workshop and presentation on Evidence for Rapid Steps of Sea level Rise: Past, Present and Future." Shell Center for Sustainability, Rice University, Houston, Texas. June 27-29, 2012.

"Evolution of the Loxahatchee River Estuary: Past–Present–Future." Friends of the Loxahatchee River, Jupiter, Florida. October 5, 2012.

"The Frightening Acceleration in Ice Melt and Sea Level Rise." For Is Miami the Next Atlantis? Community Conversations in the Good Government Initiative, University of Miami, Coral Gables, Florida. October 9, 2012.

"Pulses of Rapid Sea Level Rise: Their Effect on Past, Present and Future Coastal Environments and Sequences." Invited presentation in session on 'Rapid Sea Level Rise and Its Impacts: Past, Present and Future.' Geological Society of America Annual National Meeting, Charlotte, NC. November 4, 2012.

"Role of Storms, Oceanic Swells, Prevailing Energy and Sea Level in Defining Sediment Body Geometry, Composition and Texture on Caicos Platform, Turks and Caicos Islands." Keynote Speaker in session on 'New Insights on the Geology, Karst, and Paleontology of Carbonate Systems of the Bahamian Archipelago.' Geological Society of America Annual National Meeting, Charlotte, NC, November 4, 2012.

"The Frightening Acceleration in Ice Melt and Sea Level Rise." Howard Hughes Medical Institute Holiday Lectures Festival: Changing Planet: Past – Present – Future. University of Miami, Coral Gables, Florida. November 14, 2012

"The Frightening Acceleration in Ice Melt and Sea Level Rise." Howard Hughes Medical Institute Holiday Lectures Festival: Changing Planet: Past – Present – Future. Miami Dade College, Miami, Florida. December 3, 2012.

"The Frightening Acceleration in Ice Melt and Sea Level Rise." Broward County, Climate Change Task Force, Plantation, Florida. December 12, 2012.

2013 "Statement on Anticipated Sea Level Rise." Board of County Commissioners, Miami-Dade County, Miami, Florida. January 10, 2013

"The Frightening Acceleration in Ice Melt and Sea Level Rise." City of Miami Beach Chamber of Commerce, Miami Beach, Florida. January 23, 2013.

"The Frightening Acceleration in Ice Melt and Sea Level Rise." For Environmental History, University of Miami, Coral Gables, Florida. January 24, 2013.

"The Frightening Acceleration in Ice Melt and Sea Level Rise." For ECS 310, Sustainable Living, University of Miami, Coral Gables, Florida. January 24, 2013.

"Dynamics of a Warming Ocean: Changing Ocean Circulation, Changing Currents." For Empowering Capable Climate Communicators 2013 I, University of Miami, Coral Gables, Florida, February 2, 2013.

"The Frightening Acceleration in Ice Melt and Sea Level Rise." For Empowering Capable Climate Communicators 2013 I, University of Miami, Coral Gables, Florida, February 2, 2013.

"Straining the Fiber of Civilization: What We Lose If We Do Nothing." For Empowering Capable Climate Communicators 2013 I, University of Miami, Coral Gables, Florida, February 9, 2013.

"The Cyclic Drivers of Climate change and Sea Level Through Geologic Time." For Empowering Capable Climate Communicators 2013 I, University of Miami, Coral Gables, Florida, February 16, 2013.

"Dynamics of a Warming Ocean: Changing Ocean Circulation, Changing Currents." For Empowering Capable Climate Communicators 2013 I, University of Miami, Coral Gables, Florida, February 16, 2013.

"The Frightening Acceleration in Ice Melt and Sea Level Rise." For Empowering Capable Climate Communicators 2013 I, University of Miami, Coral Gables, Florida, February 16, 2013.

"The Frightening Acceleration of Ice Melt and Sea Level Rise." for Democrats of South Dade County, Miami, Florida. February 19, 2013.

"Straining the Fiber of Civilization: What We Lose If We Do Nothing." For Empowering Capable Climate Communicators 2013 I, University of Miami, Coral Gables, Florida, February 23, 2013.

"Hurricanes and Sea Level Rise – A Deadly Combination." For GSC 107, Natural Disasters: Hollywood Versus Reality. University of Miami, Coral Gables, FL. March 5, 2013

"The Frightening Acceleration in Ice Melt and Sea Level Rise." Oceans and Human Health. Rosenstiel School of Marine and Atmospheric Science, University of Miami. Virginia Key, FL. March 25, 2013.

"The Frightening Acceleration in Ice Melt and Sea Level Rise." Miami Beach 2100 Design Challenge: A Workshop on Sea Level Rise and Planning for resilience, Miami Urban Studies Studios, College of Architecture and the Arts, Florida International University. Miami Beach, FL. March 28, 2013.

"The Frightening Acceleration in Ice Melt and Sea Level Rise." Graduate Climate Education Program, Florida Atlantic University, Boca Raton, FL. April 4, 2013.

"Sea Level Rise and Climate Change: An Update of Dramatic Acceleration." Friends of the Everglades 44th Annual Meeting, Miami. April 14, 2013.

"Pulses of Rapid Sea Level Rise: Past, Present and Future", for Penrose/Chapman Conference: 'Record of Sea-Level Rise', Galveston TX. April 15, 2013.

"Frightening Acceleration in Ice Melt and Sea Level Rise", Rising Seas Summit ACCO, Ft. Lauderdale, FL. June 18, 2013.

"Greenland's Melt will Inundate South Florida", for ECS 310, Sustainable Living, University of Miami. September 3, 2013.

"Greenland's Melt will Inundate South Florida", for CLEO Institute Board Meeting Pinecrest, FL. September 16, 2013.

"Make the Difficult Decisions on Water Resources and Infrastructure with Sea Level Rise", for National League of Cities, Energy, Environment and Natural Resources Steering Committee, Pinecrest, FL. September 20, 2013.

"Frightening Acceleration in Ice Melt and Sea Level Rise", for Graduate Seminar, Department of biology, University of Miami, September 24, 2013.

"The Need for Orderly Planning for Inundation of Barrier Island Inundation", Geological Society of America, Denver, CO. October 28, 2013.

"The Need for Orderly Planning for Inundation of Barrier Islands and Low Coasts", for MSC 220, Climate Changes at UM, University of Miami. November 5, 2013.

"The Need for Orderly Planning for inundation of Barrier Islands and Low Coasts", for High Water Line Miami at University of Miami, November 12, 2013.

"Why is Miami Ranked as the Most Vulnerable City to Climate Change?" for Miami Dade College Climate Change Symposium, Kendall, FL. November 19, 2013.

2014 "Reinforcing Feedbacks Make Future Accelerating Ice Melt and Sea Level Rise Inevitable and Unstoppable", CLEO Institute Climate Training, Coral Gables, FL. January 23, 2014.

"The Need for Orderly Planning for inundation of Barrier Islands and Low Coasts", for ECS 310, Sustainability at UM, University of Miami, Coral Gables, FL. January 28, 2014.

"The Need for Orderly Planning for inundation of Barrier Islands and Low Coasts", 23rd Annual Southwest Florida Water Conference, Florida Gulf Coast University, Ft. Meyers, FL. January 31, 2014.

"What Sea Level Rise Should We Be Planning For?", for Energy, Climate Disruption and Sea Level Rise: New Directions in Law and Policy, Nova Southeastern University, Ft. Lauderdale, FL. February 6, 2014.

"The Need for Orderly Planning for Inundation of Barrier Islands and Low Coasts", for Climate Disruption and Sea Level Rise: New Directions in Law and Policy, Nova Southeastern University, Ft. Lauderdale, FL. February 6, 2014.

"Global Warming is a Warming Ocean", for Empowering Capable Climate Communicators, College of Arts and Sciences, University of Miami. February 8, 2014

"What Sea Level Rise Should We Be Planning For?" for Empowering Capable Climate Communicators, College of Arts and Sciences, University of Miami. February 8, 2014.

"The Beach on Key Biscayne: Problems and Solutions", for Condominium Association of Key Biscayne, Beach Club at Ocean Club, Key Biscayne, FL. February 11, 2014.

"Sea Level Rise Might Be Much Faster Than Models Are Predicting", for Empowering Capable Climate Communicators, College of Arts and Sciences, University of Miami. February 15, 2014.

"The Need for Orderly Planning for Inundation of Barrier Islands and Low Coasts", for Empowering Capable Climate Communicators, College of Arts and Sciences, University of Miami. February 15, 2014.

"Human-induced Global Warming is Causing An Acceleration in Global Sea Level Rise – This Will Have Serious Consequences for South Florida As The Century Progresses" Miami Beach Chamber of Commerce, Miami Beach, FL, March 16, 2014.

"Climate Briefing – Sea Level Rise Predictions and Possible More Severe Scenarios" Public event sponsored by CLEO Institute, Pinecrest, FL. March 24, 2014.

"This Can't Be Happening with David Lindorff", a one hour one-on-one interview with call in on the reality and rates of global warming, sea-level rise and desertification; nationally broadcast live on PRN, April 9, 2014.

"Oceans: The Future of Water – Coming To A Home Near You Sooner Than You Think." Featured Speaker - 17th Annual Earth Day Symposium, EarthWeb Foundation and Rollins College, Winter Park, FL. April 12, 2014.

"Climate Science Briefing Panel with U.S. Senator Sheldon Whitehouse." Pinecrest FL. April 25, 2014.

"Sea Level Response to Climate Change." Art Marshall Foundation Summer Intern Program, given at University of Miami, FL. June 16, 2014.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Florida League of Cities, Pinecrest, FL. August 15, 2014

"The reality of Human-Induced Climate Change." An invited presentation with four other scientists to Florida Governor Rick Scott. The Governor's Office, Tallahassee, FL. August 18, 2014.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Pinecrest Rotary Club, FL. August 19, 2014.

"Comes the Sea." Panelist and speaker following climate change movie presentation, Miami Beach Botanical Gardens, Miami Beach, FL. August 20, 2014.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Coral Gables Rotary Club, FL. September 4, 2014.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." 'BAD' (Boating, Angling and Diving) Group - Coconut Grove Yacht Club, Miami, FL. September 18, 2014.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." 'Protecting SE Florida's Oceans and Coastal Heritage', Sierra Club, Hallandale Beach, FL. September 20, 2014.

"Environmental Risks of Sea Level Rise on Miami Beach." EECOMB, Panelist and Speaker following three climate change movies. Miami Beach Botanical Gardens, Miami Beach, FL. September 20, 2014.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Coral Gables Women's Club, Coral Gables, FL. October 1, 2014.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Stag Night – Biscayne Bay Yacht Club, Miami, FL. October 14, 2014.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Best Practices Conference, Miami-Dade county League of Cities, Miami, FL. October 24, 2014.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." COSEE Florida: Water as Habtat Science Café, Wynwood (Gramps Bar), FL. October 28, 2014.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Presentation to Oxford Brooke's University, School of Architecture students and faculty. Miami, FL. November 3, 2014.

"Comes the Sea: Accelerating sea level rise will dramatically change plant life on Earth as the century progresses." University of Miami Arboretum Society, Coral Gables, FL. November 5, 2014.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Carl Sagan Day at Broward College, North Campus, Coconut Creek, FL. November 8, 2014.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." MSC 220 – Climate and Global Change, RSMAS, UM. November 20, 2014.

"The Risk We Face from Accelerating Sea Level Rise", CLEO Climate Change Symposium at Vizcaya, Miami, FL Dec. 10, 2014.

2015 "Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Biscayne Bay Regional Restoration Coordination Team, National Park service and NOAA, NOAA Marine Fisheries, Miami, FL January 14, 2015.

"The Risks of Fracking in south Florida." Miami-Dade County Commissioners meeting, Miami. FL. January 20, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Committee for Conservation at Deering Bay, Deering Bay Country Club, FL. January 20, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." ECS 310 – Sustainability, University of Miami. I on January 27 and II on January 29, 2015.

Panel discussing future of Andean Glaciers, following film presentation, ECCOMB, Miami Beach Gardens, Miami Beach, FL. February 6, 2015.

"Global Warming is a Warming Ocean", for Empowering Capable Climate Communicators, College of Arts and Sciences, University of Miami. February 21, 2015.

"What Sea Level Rise Should We Be Planning For?" for Empowering Capable Climate Communicators, College of Arts and Sciences, University of Miami. February 21, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Coral Gables Garden Club, Coral Gables, FL. February 23, 2015.

"Sea Level Rise Might Be Much Faster Than Models Are Predicting", for Empowering Capable Climate Communicators, College of Arts and Sciences, University of Miami. February 28, 2015.

"The Need for Orderly Planning for Inundation," for Empowering Capable Climate Communicators, College of Arts and Sciences, University of Miami. February 28, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." League of Women Voters of Collier County, Naples, FL. March 19, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Oceans and Human Health, RSMAS, University of Miami. March 24, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Sea Keepers and British Counsel General, RSMAS, University of Miami. April 14, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Keynote Speaker, Earth Web Foundation Annual Meeting, Orlando, FL. April 18, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." College of Arts and Sciences review Committee, University of Miami. April 23, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Southwest Florida Sea level Rise Summit. Florida Gulf Coast University, Ft. Myers, FL. May 7, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Florida Trust Annual conference, Miami, FL. May, 8, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." South Miami Rotary Club, South Miami, FL. May 12, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Western Newfoundland Environmental Program, Woody Point Newfoundland, Canada. June 30, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." ECS 310 – Sustainability. University of Miami. September 8, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Coral Gables Volsky Assembly, Coral Gables, FL. September 22, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." FSS 190 – Miami: Transformations in a Global City, University of Miami. September 22, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." CLEO Teachers Training Event, University of Miami. September 15, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." City of Coral Gables, Commission Chambers, Coral Gables, FL. September 29, 2015. (hour plus presentation posted on Community Television Network).

"The Coming Reality of Sea Level Rise: Too Fast Too Soon." Institute on Science for Global Policy, St. Petersburg College, St. Petersburg, FL. October 2-3, 2015.

"The Coming Reality of Sea Level Rise: Too Fast Too Soon." Speaker, Climate Change Workshop, Village of Pinecrest Council Chambers, FL. October 6, 2015.

"Historical Wetland Community Evolution in the Lower Everglades and Cape Sable." South Florida Water Management District, West Palm Beach, FL. October 29, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." University of Miami Citizen's Board – Lunch and Learn. Miami, FL. November 18, 2015.

"The Coming Reality of Sea Level Rise in New Jersey: Too Fast Too Soon." Institute on Science for Global Policy, Toms River, New Jersey. November 20-21, 2015.

"Changing Influences on South Florida's Beaches." ECS 310 – Sustainability. University of Miami. December 1, 2015.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Brandeis Study Group, Pinecrest, FL. December 1, 2015.

"Historical Wetland Community Evolution in the Lower Everglades and Cape Sable." ECS 310 – Sustainability. University of Miami. December 3, 2015.

"Assessment of Paris COP21.CMP11 Agreements on Sea Level Rise." French Consulate Evening on Global Ties. Center for Social Change, Miami, FL. December 11, 2015.

"Future Sea Level Rise in South Florida." Young Democrats Club. Miami, FL. December 16, 2015.

2016 "Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." South Florida Mensa. Coral Gables, FL. January 5, 2016.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Road Scholar, Miami Beach, January 11, February 1, and February 22, 2016.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." City of Miami Sea Level Rise Committee, Miami City Hall, Miami, FL. January 11, 2016.

"The Risk of Turkey Point with Sea Level Rise." CLEO Panel, Pinecrest Gardens, FL. January 19, 2016.

"Community Responsibility in the Face of Sea Level Rise." CLEO Institute Community Panel, Pinecrest, FL., January 18, 2016.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." ECS 310, Sustainability, University of Miami. January 21 and 26, 2016.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Opening Address, Northeast Florida Environmental Summit, Jacksonville, FL., January 25, 2016. See: https://www.youtube.com/watch?v=SooK37SuY_8&feature=youtu.be (7:27-36:06) and https://www.youtube.com/watch?v=aBVhJ4tQyC0&feature=youtu.be (38:38-59:42).

"How Climate Trends Will Impact Storms of the Future: Preparing Today for Later in the Century – King Tides, Storm Surges, Salt Spray and Sea Level Rise – Imminent Threats Now and Growing." Data Driven Outage Restoration for Electric Distribution 2016 Conference, Coconut Grove, FL., January 27, 2016.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Talk and Panel. Florida Interfaith Climate Action Network National Assembly, Longwood, FL., January 28-29, 2016.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." University of Miami Woman's Guild, University of Miami. February 1, 2016.

"Geologic Evolution of the Everglades from Start to Finish – The Past 5,000 years and the Next 100." Southeastern Geological Society Field Conference on the Everglades. Talk on 12th and Field Guide on 13th. Miami and the Everglades, February 12-13, 2016.

"Global Warming is a Warming Ocean", for Empowering Capable Climate Communicators, College of Arts and Sciences, University of Miami. February 20, 2016.

"What Sea Level Rise Should We Be Planning For?" for Empowering Capable Climate Communicators, College of Arts and Sciences, University of Miami. February 20, 2016.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Miami Beach as the century progresses." Harvard University Graduate School of Design Conference: 'South Florida and Sea Level – The Case of Miami Beach,' Miami Beach, FL., February 23.

"Sea Level Rise in South Florida," On-air panel with Elizabeth Kolbert of the *New Yorker* on NPR's WLRN *Topical Currents*, 1-2 PM, February 24.

"Sea Level Rise Might Be Much Faster Than Models Are Predicting", for Empowering Capable Climate Communicators, College of Arts and Sciences, University of Miami. February 27, 2016.

"The Need for Orderly Planning for Inundation," for Empowering Capable Climate Communicators, College of Arts and Sciences, University of Miami. February 27, 2016.

"Comes the Sea. Miami's Vulnerabilities: an Overview. UNESCO World Field Laboratory Symposium on Sea Level Rise and the Future of Coastal Settlements. Miami, FL. March 3, 2016.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." URB 301 – Cities in Time and Space. University of Miami. March, 15, 2016.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." The Conservancy of Southwest Florida, Naples, Earth Day, April 22, 2016.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." Earth Day with Congressional Candidate Ed Emery, Gainesville, FL, April 22, 2016.

"Changing Influences on South Florida's Beaches." University of Miami / Florida International University Architectural symposium on Beach Vulnerability, Miami Beach, May 2, 2016.

Role of Anticipated Sea Level Rise in Urban Planning." Urban Land Trust Focus on Arch Creek. Florida International University Symposium, FIU North Campus, Miami, Florida. May 24, 2016.

"Comes the Sea: Accelerating sea level rise will dramatically change life on Earth as the century progresses." NCGE (National Conference on Geographic Education), Human Geography Teacher Workshop, Keynote Speaker. Tampa, Florida, July 27, 2016.

"Comes the Sea – Miami's Vulnerabilities: an Overview." U.S. State Department International Visitor Leadership Program and Global Ties Miami. Miami, Florida, September 19, 2016.

"Historical Wetland Community Evolution, Collapse, and Migration in the Lower Everglades and Cape Sable. Florida International University Symposium on Wetland Dynamics and Saline Intrusion. Miami, Florida September 29, 2016.

"Comes the Sea - Miami's and the World's Vulnerabilities: an Overview." Villa Regina on Brickell Symposium, Miami, Florida. October 1, 2016.

"Comes the Sea." Symposium on the Current state of our Sea" in conjunction with the Smithsonian "Waterways Exhibit." The Curtiss Mansion, Miami Springs, Florida. October 6, 2016.

"Comes the Sea - Miami's and the World's Vulnerabilities: an Overview." ECS-310 Sustainability. University of Miami, Florida. October 13, 2016.

"Comes the Sea – A: The Reality of Human-Induced Climate Change; B: Causes for and Projections of Sea Level Rise; C: What This Means for Coastal Environments and Cities; and D:

What We Must Do and Opportunities for Our Students." (a 6-hour training presentation) Gulliver Schools Teacher Training Program. October 29, 2016.

"Comes the Sea – Planning for Accelerating Sea Level Rise Through This Century and Beyond." Board of Directors, The Conservancy of Southwest Florida, Naples, Florida. November 1, 2016.

"Planning for significant Sea Level Rise in Pinecrest." Village of Pinecrest Council chambers, Florida. Presentation to Mayor and citizens. November 2, 2016.

"Comes the Sea – Planning for Accelerating Sea Level Rise Through This Century and Beyond." Climate Across the Curriculum CLEO Workshop, University of Miami, Florida. November 12, 2016.

"Comes the Sea." Presentation and panel discussion as part of UM's Citizen U with Joshua Myers. Student Center, University of Miami, Florida. November 16, 2016.

"Comes the Sea – Planning for Accelerating Sea Level Rise Through This Century and Beyond." Keynote Speaker: NAIC (National Association of Insurance Companies) National Meeting: Sea Level Rise Workshop, Fontainebleau Hotel, Miami Beach, Florida. December 10, 2016.

2017 "Comes the Sea – Planning for Accelerating Sea Level Rise Through This Century and Beyond." Keynote Speaker. Now in My Back Yard. Rising Sea Level on the Florida Gulf Coast and What Can Be Done About It. South Seas Resort, Captiva Island, Florida. January 13, 2017.

"The Coming Reality of Sea Level Rise: Too Fast Too Soon – Planning for Accelerating Sea Level Rise Through This Century and Beyond." Florida Oceanographic Foundation Coastal Lecture Series, Blake Library, Stuart, Florida. January 23, 2017.

"Comes the Sea – Planning for Accelerating Sea Level Rise Through This Century and Beyond." Key Biscayne Rotary Club, Key Biscayne Yacht Club, Florida. January 27, 2017.

"Comes the Sea – The Future of south Florida Fishing with Accelerating Sea Level Rise Through This Century and Beyond." Tropical Anglers Club, Miami, Florida. January 31, 2017.

"Comes the Sea – Planning for Accelerating Sea Level Rise Through This Century and Beyond." Green Sanctuary Program: Progressive Voices Speak Out. Unitarian Congregation of Greater Naples, Florida. February 1, 2017.

"Anaerobic Bottom Waters Need Not Be Deep." Geo-Topics at Rosenstiel School of Marine and Atmospheric Science, University of Miami, Virginia Key, FL. February 6, 2017.

"Introduction," "Natural Climate Changes," "Global Warming is a Warming Ocean," "What Sea Level Rise Should We Be Planning For?" "Mapping Coastal Inundation and Infrastructure Vulnerability; Some Examples from Florida," "Sea Level Rise Will Likely Be Much Faster Than Models Are Predicting," and "The Need for Orderly Planning For Inundation." *Empowering Capable Climate Communicators Training Session.* University of Miami, Coral Gables, Florida. February 11, 2017.

"An introduction to South Florida – Planning for Accelerating Sea Level Rise Through This Century and Beyond. Opening Lecture for Community Resilience Panel. Neumann Alumni Center, University of Miami, March 9, 2017.

"Climate Change and Sea Level Rise in South Florida – Realities, Rates and Needed Responses." Lecture, Discussions, and Field Trip. Young Presidents Group. Ritz Carleton Hotel South Beach, Miami Beach, FL March 29, 2017.

"The Coming Reality of Sea Level Rise: Too Fast, Too Soon." American Institute of CPAs, Government Performance and Accountability Committee (GPAC) Meeting, Florida International University, Miami, FL. April 3, 2017.

"The Coming Reality of Sea Level Rise: Too Fast, Too Soon." Oceans and Human Health Course, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Virginia Key, FL. April 4, 2017.

"The Coming Reality of Sea Level Rise: Planning for Accelerating Sea Level Rise Through This Century and Beyond." Keynote Speaker. Gulf Coast Climate Change Symposium. University of South Florida, Sarasota, Florida. April 18, 2017.

"Comes the Sea: Planning for Accelerating Sea Level Rise Through This Century and Beyond." Sierra Club Earth Day Celebration at Anne Kolb Nature Center, Hollywood, Florida, April 23, 2017.

"Comes the Sea: Planning for Accelerating Sea Level Rise Through This Century and Beyond." Code for Miami, Cambridge Innovation Center, Wynwood, Florida. April 24, 2017.

"Comes the Sea: Planning for Accelerating Sea Level Rise through This Century and Beyond: impact on Design and growth." 2017 SEGD Conference – Experience Miami, Loews Miami Beach, Florida. June 9, 2017.

"Comes the Sea: Planning for Accelerating Sea Level Rise Through This Century and Beyond." Newfoundland Climate Group, Merchant's Warehouse, Woody Point, Newfoundland, July 3, 2017.

"Comes the Sea: Planning for Accelerating Sea Level Rise Through This Century and Beyond." A morning at Burger Bob's, Coral Gables, Florida. August 15, 2017.

"Comes the Sea: Planning for Accelerating Sea Level Rise through This Century and Beyond: impact on Design and growth." Miami-Dade County Urban Development Boundary Expansion Task Force, west Miami-Dade County, Florida. November 17, 2017.

"Water Sources and 'Re' Sources and Potential Losses: South Florida's Challenging Freshwater Future" and "The Coming Reality of Sea Level Rise: Too Fast, Too Soon." The Rivers Coalition, Stuart, Florida. November 29, 2017.

25a. **Other Professional Activities – Symposia Organization** (see #18 for papers presented at scientific meetings and symposiums):

"Empowering Capable Climate Communicators" a Cooper Fellow climate training series involving 14 climate scientists and communicator lecturers and panelists for four full Saturdays in the spring of 2011, College of Arts and Sciences, University of Miami. There were 65 participants.

"Empowering Capable Climate Communicators 2012" a Cooper Fellow climate training series involving 14 climate scientists and communicator lecturers and panelists for four full Saturdays in the spring of 2012, College of Arts and Sciences, University of Miami. There were 70 participants.

"Empowering Capable Climate Communicators I 2013" a Cooper Fellow climate training series involving 14 climate scientists and communicator lecturers and panelists for two full Saturdays in the spring of 2013, College of Arts and Sciences, University of Miami. There were 85 participants.

"Empowering Capable Climate Communicators II 2013" a Cooper Fellow climate training series involving 14 climate scientists and communicator lecturers and panelists for two full Saturdays in the spring of 2013, College of Arts and Sciences, University of Miami. There were 120 participants.

"Empowering Capable Climate Communicators 2014" a Cooper Fellow climate training series involving 13 climate scientists and communicator lecturers and panelists for two full Saturdays in the spring of 2014, College of Arts and Sciences, University of Miami. There were 110 participants; February 8 and 15, 2014.

"Empowering Capable Climate Communicators 2015" a Cooper Fellow climate training series involving 13 climate scientists and communicator lecturers and panelists for two full Saturdays in the spring of 2015, College of Arts and Sciences, University of Miami. There were 95 participants; February 21 and 28, 2015.

"Empowering Capable Climate Communicators 2016" a Cooper Fellow climate training series involving 13 climate scientists and communicator lecturers and panelists for two full Saturdays on February 20 and 27, 2016, College of Arts and Sciences, University of Miami. There were 120 participants and 15 lecturers.

"Empowering Capable Climate Communicators 2017" a Cooper Fellow climate training series involving 7 climate scientist lecturers and panelists for one full Saturday on February 11, 2017, College of Arts and Sciences, University of Miami.

25a. **Other Professional Activities** – Provided requested professional interviews to **Newspaper, Magazine, Book, Radio, TV, video, and online organizations (list only kept since 2014)**

2014 Newspapers: Miami Herald (numerous), Washington Post, Sun Centennial, New York Times, Key Biscayne Times, other Community Newspapers.

Magazines: Time, Rolling Stone, National Geographic, Die Stern (German), a Dutch magazine, Boca Raton Magazine (link below), and others.

Radio and TV: NPR (3), Marketplace (link below), WLRN 91.3 (link below), Fox News, NBC, CBS, Huffington Post, CBC Canada One (link below), and others. Several web-based news and talks shows.

http://www.cbc.ca/radio/thesundayedition/a-christmas-concert-michael-s-essay-harold-wanless-mail-about-dying-at-age-75-cat-christmas-documentary-mail-about-refugee-policy-bob-bossin-menorah-s-hidden-history-1.2905337/coastal-florida-and-miami-are-doomed-says-scientist-harold-wanless-1.2905344

http://www.marketplace.org/topics/sustainability/water-high-price-cheap/rising-seas-threaten-south-floridas-drinking-water

http://bocamag.com/blog/2015/03/02/is-south-florida-in-hot-water/

http://wlrn.org/post/florida-officials-ban-term-climate-change

2015 Boca Raton Magazine, Center for Investigative Reporting (Tristan Korten), Verge (Josh Dzieza), Fairchild Garden, Morad – pbu TV (Clemence de la Robertie), MSNBC (Ed Schultz), Puerto Rican Sistema TV Geo, Sun sentinel (David Flescher), Stewart News on ASRs (Scripps Howard), Perkins and Will, Agencie France Television (Frederica Nanancio), WWL First News radio New Orleans (Tommy Tucker), Progressive News Network (Karina Veaudry Internet Radio Podcast), Korean Broadcasting Service, The Nation (re Jeb Bush record), Tampa Bay Tribune, The Daly Show, ZDF German TV, Years of Living Dangerously (Jon Meyershon), Vanity Fair (David Kamp), American Prospect (Nathalie), Fabiano D'Yomato, CBC (Michael Enright – replaying previous interview), ABC (Evan Simon), CNBC (Robert Ferris), City University of NY (Ashley Dawson – book interview), Miami Herald, France 2 TV (Sabrina Buckwalter), conserve turtles.org (Gary), Dutch Freelance (Eline van Nes), Center for Urban and Community Design (Sonia Chao), New Yorker (Elizabeth Kolbert), the Weather Channel (Michael Lowery and Mark Elliott).

2016 NJTV News (Brenda Flanagan), KYW Radio (Madden), Radio Free Europe (Igor Yefimov), Orlando Sentinel (Kevin Spear), University of Amsterdam Graduate Program in Human Geography (Lars Ankum, Wessel Brocken, and Tiemen Koch), Ed Emery for Congress (training about Climate Change and effects), Weather Channel (Sam Champion), University of Buenos Aires Law Program (Claude Lutzky, Exec. Director), MIT Masters in City Planning, Urban Studies (Devon Neary), Politico Magazine (Sarah Solovitch), WLRN Topical Currents (Joseph Cooper) hour show with Elizabeth Kolbert, MSNBC (Chris Hayes), Malibu Magazine (full page coverage), FORWARD Florida Magazine (Dave Cocchiarella), Olonne sur Mer, Vendée, France (Germain Piveteau, and Emmanuel Ayet); *Ahead of the Tide* (Ariel Gudwin); CBS News (Chris Libel); Organized *Ahead of the Tide* video presentation at UM (4/11/17); MSNBC interview (Joelle Martinez); NPR Interview (Gina Jordan and Laura Coburn); Gizmo Science Tech (Maddie Stone); Muse Magazine (Corbie); Josh Dzieza; The Hokkaido Shimbun Press (Katsuhori Hashimoto); The Tokyo Shimbun (Tomonori Ishikawa); The Chunnhi Shimbun (Conrad Chaffee); Louisville Courier-Journal (James Bruggers); National Geographic (Laura Parker); CavU (recorded sea level Webinar on SLR); THEOECO.org (Steve Richards); Years of Living Dangerously (interview in advance of premier of Climate/Sea Level episode with Jack Black), Tower Theater, Miami; Distraction Magazine (Marissa Vonesh); Dutch Journalist video interview on Sea level rise on Miami Beach (Max van der Heijden); Film on sea level rise by David Able(visiting Knight Chair in Journalism Department); Sea level rise interview with Prof. Alejandre Portes, UM School of Law; Sea level rise interview with Molly Cominick, Sophie Barrows, and Danni Dikes, UM Communication Program; Sea level rise interview with Ben Travers (on 1,000 mile awareness tour of Florida);Climate Change interview (Prof Rick Van Noy, English Dept, Radford University, Virginia).

2017 Throughline Productions interview for movie on water and sea level rise in Florida (Chuck Davis and Dr. Timothy Beatley, a University of Virginia Sustainable Communities Professor); Santiva Chronicle (reporter David Rohn interview re sea level rise presentation on Captiva Island, Florida); captivasanibel.com Community News (reporter Ashley Goodman interview re sea level presentation on sea level rise on Captiva Island, Florida); KelvinFilm (2-day film interview by Joanna Engel on Major film on worldwide adaptation to climate change including interactions with Angaangaq Angakkorsuaq an Elder representative from the Greenland Eskimos); clearpath.org (Jay Faison, clean energy advocates for republicans in Washington D.C.; Mary Ann Rozance, Toulan School of Urban Studies and Planning, Portland State University; Chris De Angelo, Huffington Post, Washington D.C.; Angilique Millan and Maria Cubas, FIU Journalism; Thomas Salme (re Italian movie producer murder conviction); BBC Inisgen Anderson at Matheson Hammock; Biscayne Times; Mary Ann Rozance, Portland State University on sea level rise adaptation; Stephanie Wakefield, New School in NYC, Anthropocene Working Group; WLRN Topical Currents on air interview on WSLR; Tom walker USF Sarasota - WSL– FM interview on sea level rise; Matt Mornick, Seattle photo-journalist on king tides and sea level rise; Lisa Aunon, PhD student on communication of environmental risk; Mario Alejandro Ariza, Journalist on socio-economic inequality of climate change in Miami; Ari Odzer, NBC 6, Trumps 1st 100 days and sea level rise and climate change; Christophe Washer, ISURU, Brussels, Lack of proper strategic thinking; Jamie Hopkins, Center for Public Integrity on electricity generation and climate change issues affecting South Florida; Rosilind Margie Donald, Columbia PhD on climate science censorship; Anne Greggis, SunSentinel; Maggie Stone, sea level rise; Mike Vogel, editor Florida Trend; Ann-Dorit Bay, with Neve Zurcher Zeitung (Swiss Daily Newspaper) political journalist; Manuela Tobias of Politifact on hurricane Harvey and climate change; Arinn campo or Wall Street Journal on Harvey and climate change; Nelson Aroque and Fai Agliarde of Newsweek; Brady of Washington Post; Geta of In These Times (Chicago); John Flesher of Associated Press on Miami-Dade Water and Sewer response to climate change; Ari Nalter, Bloomberg News on Irma, Everglades, climate change and sea level rise; Chelsea Harvey of Washington Post on Irma and Everglades; Kelly Sweet of RedRock Films on Irma and Everglades; Christa Marshall of E&E News on why not more inundation; Jeanette Francis of Australian TV video interview; Alissa Groeninger, a USF journalism graduate student on Everglades; Rosilind Margaret Donald of Columbia, video interview; Deepa Fernandez of NPR-PRI interview in Satellite Beach on Climate Change and sea level rise; Jeff Goodell; Kate Fleming; Coral Gables Planning Department on Vulnerability Assessment; Elizabeth Rush, book writer on climate change; Jamie Rush at Public Integrity .org on climate change and public officials; Oliver Milman of The Guardian on Archaeological sites and sea level rise; J. Van Leer at UM on Positive feedback for ocean cooling.

TEACHING

26a. **Courses Taught:**

ENS 103-104 - Environmental Issues of South Florida
Taught 1996, Spring 1998, Spring 1999.

ENS 492 - Field Study in Environmental Science
Taught: Spring 2000, Fall 2001, 2002

FNS 180 - Evidence for and Societal Implication of Global Change (Freshman Seminar)
Taught: 1991, 1992.

GSC 100 – Marine Geology of South Florida, part of Summer Scholar Program for High School Students.
Taught: Summer of 1998, 1999, 2000.

GSC 105 – The Global Environment
Taught: Fall 2004

GSC 110 - Physical Marine Geology (A dual enrollment course taught at MAST Academy, Dade County Public Schools)
Taught: 1993, 1996.

GSC 111 – Historical Geology
Taught: 2003, 2006

GSC 120 - Environmental Geology
Taught Spring 1993, Fall 1993, Fall, 1994, Fall 1995, Spring 1996, Fall, 1996, Spring 1997, Fall 1997, Fall 1998, Fall 1999, Fall 2000.

GSC 160 - Historical Geology: Taught Spring 1993.

GSC 230 - Reef Systems through Time:
Taught Spring 1998, 1999, 2000, 2001, 2002, 2004, 2005, 2006, 2009, 2010, 2011, 2012, 2013, 2014.

GSC 231 - Field Study of Reef Systems Through Time
Taught: Spring Break 2000, 2001. 2004, 2009, 2011, 2012, 2014, 2016.

GSC 260 – Earth Materials: Co-taught fall 2011, 2012, 2013, 2014, 2015, 2016.

GSC 350 - Stratigraphy: Taught: 1992, 1994, 1995, 1996, 1997, 1998, 2004.

GSC 360 - Depositional and Diagenetic Systems:
Taught: Spring 1999, 2000, Fall 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009 2010, 2011, 2012, 2013, 2014, 2015, 2016.

GSC 440 – Petrology
Taught with D. McNeill: Spring 2015, 2016, 2017.

GSC 450 - Sedimentology
Taught: 1988, 1989, 1990, 1992, 1993, 1994, 1995, 1996, 1997, 1998.

GSC 462 – Paleoclimatology Taught: Spring 2014, 2015, 2016, 2017.

GSC 480 – Structural Geology: Taught with D. Olson: Spring 2013.

GSC 482 (was 596) - Field Methods and Mapping:
Taught: spring 1994, 1995, 1996, 1997, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2017.

GSC 561 – Colloquium, fall (capstone course for seniors) 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016.

GSC 574; now 580-581 - Geology Summer Field Course
Taught: 1994, 1995, 1996, 1997, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2017.

GSC 574 - Geologic Studies in the Grand Canyon
Taught: 2007

GSC 575 – Coastal Processes
Taught: 2008

GSC 582(01) - Field Study of Reef Systems Through Time
Taught: Spring Break 2012, 2014, 2016

MGG 511 - Sedimentation
Taught: 1972-1991.

MGG 541 - Field Evaluation of Fossil Platforms, Margins and Basins
Taught: 1978, 1980, 1981, 1984, 1985, 1986, 1987, 1988, 1991.

MGG 558 - Geology of Florida
Taught: Fall 1979, 1982, 1983, 1985, 1986.

MGG 584, 585 - Geology of Tropical Marine Environments
Taught: Summer 1979.

MGG 672 - Basin Analysis (with others)
Taught: 1979.

MGG 683 - Sediment Diagenesis
Taught: 1977, 1982, 1984, 1987, 1989.

MGG 684 - Environments of South Florida
Taught: 1981, 1984.

MGG 685 - Sediment Dynamics
Taught: 1981, 1983, 1984, 1985.

MGG 687 - Substrate Influence on Benthic Communities
Taught: 1977, 1987.

MSC 111 – Introduction to Marine Science. Taught: Fall 2002

MAST Academy – Dual Enrollment Marine Geology 1996, 1997.

27. **Thesis and Dissertation Advising:**

Major Advisor for the Following Undergraduate Senior Thesis:

1997 Rodebaugh, Amy. Diatom Assemblages in a 100-Year Sediment Record from Whitewater Bay, South Florida.

1999 Kathrine A. Banner. Internal Architecture of Archaeocyathid Bioherms, Labrador, Canada, 64p.

1999 Andrew Zachary Krug. Environmental Zonations Within a Platform Margin Reef, Lower Head, Newfoundland.

2000 Stacy Anderson. A Paleoenvironmental Analysis of the Key Largo Limestone.

2002 Matthew Brewer. Mangroves, Storms and Sea-Level: an air photo analysis of the past 70 years of coastal evolution in the Gopher Key Region, SW Florida.

2002 Katie Inderbitzen. A Sedimentary-Exhalatory Barite Deposit and Associated Chemosynthetic Bioherm, Aguathuna Quarry, Port au Port Peninsula, Newfoundland, Canada.

2002 Lauren Moyer. Diagenesis and Tectonic history of Cambro-Ordovician Sediments in a Fore-Arc Basin, Northwestern Newfoundland.

2002 Amy Sofge. Origin of Cavities in Lower Cambrian Archaeocyathid Reefs, Southeast Labrador.

2004 Kelly Jackson. Late Holocene Evolution of the Lower Shark River Discharge in response to a high-frequency sea level oscillation, Everglades National Park, Florida

2006 Katie Murray (Magna Cum Laude), Potential Effects of Increased Scour Depth on Chum Salmon Redds in the Gray's River, Washington. November, 2006

2007 Noelle Van Ee, Analysis of abrasion susceptibility of Bahamian sands proposed for placement on south Florida's beaches, 2008

2012 Max Tenaglia, Re-evaluation of the Late Permian carbonate reef margin facies patterns, Dark Canyon, New Mexico, December 2012.

2015 William Farrell, Diagenetic and porosity evolution in Early Pennsylvanian carbonate mud mounds, New Mexico.

Zoe Smith, Fauna and diagenesis in Lower Cambrian carbonate nodules in black shale sequences.

Major Advisor of the Following Masters of Science Theses:

1976 Barron, Eric J. Suspended Sedimentation Processes, Marco Island, Florida. M.S. Thesis, University of Miami, 182p.

1976 Warzeski, E. Robert. Growth History and Sedimentary Dynamics of Caesar's Creek Bank. M.S. Thesis, University of Miami, 195p.

1977 Dravis, Jeffrey J. Holocene Sedimentary Depositional Environments on Eleuthera Bank, Bahamas. M.S. Thesis, University of Miami, 386p.

1978 Bohlke, Brenda. Clay Fabric and Geotechnical Properties Associated with Crust Zones in the Mississippi Prodelta Deposits. M.S. Thesis, University of Miami, 95p.

1979 Harlem, Peter. Aerial Photographic Interpretation of the Historical Changes in North Biscayne Bay, Florida: 1925-1976. M.S. Thesis, University of Miami, 152p.

1983 Craig, Genevieve. Holocene Carbonate Sedimentation in a Pleistocene Depression Adjacent to Key Largo. M.S. Thesis, University of Miami, 120p.

1984 Burton, Elizabeth Ann. X-ray Diffraction of Natural High and Low Mg Calcites. M.S. Thesis, University of Miami, 148p.

Rossinsky, Victor, Jr. Sedimentation and Holocene History in the Loxahatchee River Estuary, Jupiter, Florida. M.S. Thesis, University of Miami, 247p.

1988 Waltz, Michael D. The Evolution of Shallowing-Upwards Reef to Oolite Sequences at the Leeward Margin of Caicos Platform, B.W.I. M.S. Thesis, University of Miami, 98p.

1989 Tagett, Mathew G. Stratigraphy, Nucleation and Dynamic Growth History of a Holocene Mudbank Complex, Dildo Key Mudbank, Western Florida Bay. M.S. Thesis, University of Miami, 210p.

1990 Huang, Holan. Holocene Environmental History in a Marginal Marine Area of the Everglades of South Florida. M.S. Thesis, University of Miami, 131p.

1991 Emerson, James D. Surficial Carbonate Facies of the Caicos Platform, British West Indies. M.S. Thesis, University of Miami, 183p.

1993 Frederick, Bruce. The Development of the Holocene Stratigraphic Sequence Within the Broad-Lostman's River Region, Southwest Florida Coast, M.S. Thesis, University of Miami, 173p.

1995 Bischof, Barberel. Aerial Photographic Analysis of Coastal and Estuarine Mangrove System Dynamics of the Everglades National Park, Florida, in Response to Hurricanes: Implications for the Continuing Sea-level Rise. M.S. Thesis, University of Miami, 135p. Plus Figures.

1996 Gelsanliter, Sarah. Holocene Stratigraphy of the Chatham River Region, Southwest Florida; with a Reevaluation of the Late Holocene Sea-level Curve, M.S. Thesis, University of Miami, 182p.

2001 Michaels, Brian A. Holocene Stratigraphy and Geomorphic Evolution of the Cape Sable Region, Southwest Florida: Evidence for Late Holocene Sea-level Dynamics, M.S. Thesis, University of Miami, 183p.

2003 Manne, Tiina. Archaeocyath Growth Morphology as a Reflection of Bioherm Form, Cavity Development and Life Habit, Newfoundland nad Labrador, Northeastern Canada, M.S. Thesis, University of Miami, 100 p. (awarded Rosenstiel School’s Dean Prize for outstanding M.S. Thesis for 2002-2003)

2006 Christina Smith (Defended and completed, April, 2006).

<u>Major Advisor for the following Ph.D. Dissertations:</u>

1981 Nelson, Terry. The Nature of the General and Mass Sedimentary Processes on the Outer Shelf, Slope and Upper Rise, Northeast of Wilmington Canyon. Ph.D. Dissertation, University of Miami, 303p.

1982 Perlmutter, Martin. The Role and Recognition of Storm Deposits in the Subtidal Sediments of the Ten Thousand Islands, southwest Florida. Ph.D. Dissertation, University of Miami, 230p.

1984 Figueiredo, Alberto G., Jr. Submarine Sand Ridges: Geology and Development, New Jersey, U.S.A. Ph.D. Dissertation, University of Miami, 408p.

1987 Dominguez, Jose M.L. Quaternary Sealevel Changes and the Depositional Architecture of Beach-Ridge Strandplains Along the East Coast of Brazil. Ph.D. Dissertation, University of Miami, 288p.

1987 Meeder, John F. A Depositional Model of the Tamiami Formation of Southwestern Florida. Ph.D. Dissertation, University of Miami, v. 1, 433p.; v. 2, -748p.

1987 Parkinson, Randall. Holocene Sedimentation and Coastal Response to Rising Sea Level Along Subtropical Low Energy Coast, Ten Thousand Islands, Southwest Florida. Ph.D. Dissertation, University of Miami, 224p.

1989 Cottrell, Daniel J. Holocene Evolution of the Coast and Nearshore Islands, Northeast Florida Bay, Florida. Ph.D. Dissertation, University of Miami, 194p.

1990 Rossinsky, Victor Jr. Topographic, Vegetative and Climatic Controls on the Petrography and Geochemistry of Calcretes in the Bahamas and South Florida. Ph.D. Dissertation, University of Miami, 228p.

1991 Tedesco, Lenore P. Generation of Carbonate Fabrics and Facies by Repetitive Excavation and Infilling of Burrow Networks in Recent and Ancient Sequences. Ph.D. Dissertation, University of Miami, 434p.

1993 Briggs, Kevin B. High-frequency Acoustic Scattering from Sediment Interface Roughness and Volume Inhomogeneities. Ph.D. Dissertation, University of Miami, 143 p.

1998 Risi, J. Andrew. Event Sedimentation from Hurricane Andrew Along the Southwest Florida Coast. Ph.D. Dissertation, University of Miami, 198 p.

2007 Brigitte M. Vlaswinkel. Field Results and Physical Modeling of the Sediment Dynamics of a Channeled, Peritidal Coastal System in Southwest Florida, Ph.D. Dissertation, University of Miami, 303 p.

Member of Advisory Committee for the following graduate students:

Completed: Shirley Pomponi, Mark Palmer, James Rine, Mohammed Almasi, David Beach, Bernard Pierson, Zelinda Leao, Bill Corso, Charles Evans, Sue Markley, Stuart Williams, Sach Prasad, Pamela Ried, Charles Evans, Michael Westphall, Jorge Jiminez, Kathy Browne, Joshua Feingold, Michael Grammar, David Obdura, Carrie Kievman, Ken Lindeman, Symma Finn, Tony Poiriez, Xavier Jansen, Matt Bonicotti, Emily Bowlin.

SERVICE

28. **University Committee and Administrative Responsibilities:**

RSMAS School Council 1984-1987

MGG Academic Committee 1990-1992

Chairman Search Committee for Paleoecologist, GSC 1993

Tenure Review Committee, College of Arts and Sciences, 1993-1996

Search Committee for Dean, School of Arts and Sciences, 1996-1997

Senate Committee on Rank, Salary and Terms of Employment 1997-1999

Chair, Department of Geological Sciences, September 1998-.

Interim Director, Institute for Interdisciplinary Tropical Science 2003-2004

Search Committee, Weeks Endowed Professorship 2005-2006

29. **Community Activities:**

Scoutmaster of Troop 322, Key Biscayne, Boy Scouts of America 1979-1987 and 1995-2001; asst. leader 2002-2006.

Member of Technical Advisory Committee to EPA and Munisport Dump Coalition on Munisport Toxic Waste Dump: 1989-2000.

Advisor to Key Biscayne Council and Village of Key Biscayne on shore management: 1989-1992. Member Technical Advisory Task Force on Beach Management: 1995- termination of Task Force in 1998. (including preparation of guidelines for future beach renourishment activities in 1998).

Scientific advisor to the City of Naples, Florida: on beach, lagoons and wetland management, 1978 and 1989-1990.

Judge at elementary, middle and high school science fair competitions: 1965-1995.

Advisor on Post-Hurricane Resource Inventory and Recovery Strategy to Everglades National Park, Biscayne National Park, Cape Florida Park, Dade County Parks, and coastal citizen groups and individuals.

Technical Advisor to South Florida Water Management District: 1997-present.

Mentor to Miami-Dade County High School Interns (two of which have achieved semifinalist in Westinghouse Science Talent Search), 1993-present.

Advisor on forensic geology to Miami Homicide, Miami-Dade States Attorney Office and Federal Justice Department, 1998-2000.

Co-Chair Biscayne Bay Initiative Science Survey Team, 1999-2001. Coordination and preparation of science synthesis, issues, and recommendations to State of Florida Legislature.

Invited contributor to scientific design of South Florida Management District's RECOVER (research and monitoring) design for the Comprehensive Everglades Restoration Plan, 2001-2005.

Invited Advisor to Everglades National Park, Coastal Instability on southwest coast of Everglades National Park, 2002.

Invited Advisor to Big Cypress National Preserve on Recreational Off-road Management Plan and construction of defined vehicle trails, 2002.

Invited member and leader of science evaluation group, Miami-Dade County's 'Climate Change Adaptation 'Task Force' and now Committee, a committee of the Miami-Dade County Commissioners, 2003 – 2007.

Chair of Science and Technology Committee, Miami-Dade County Climate Change Advisory Task Force of the Miami Dade County Commissioners (2007-2011).

Member of Miami-Dade County Climate Change Advisory Task Force of the Miami Dade County Commissioners (2007-2011).

Invited speaker/advisor to Florida legislative committees on the Everglades (2007).

Invited speaker to White House Council on Environmental Quality concerning relocation of Mississippi River outlet (2009).

Member, Ad Hoc Committee on Sea Level Rise, South Florida regional Planning Council, tasked with defining a projected sea level rise for 2030, 2060, 2100, and 2110 to be used by southeast Florida Counties for planning purposes – final report is published and has been adopted by the four southeast Florida Counties. Presented at a Four County Compact meeting in December, 2011. (2010-2011).

Member Science Advisory Committee Florida Beaches for Habitat Conservation Plan, Florida Fish and Wildlife Conservation Commission. 20defining habitat risks for construction and other activities in the portion of the coastal beach/dune zone that can be regulated, including changes in response to rising sea level, 2010 - present.

Coordinator and Host of "Empowering Capable Climate Communicators" and full four Saturday series of training lectures and discussions to produce qualified speakers on climate change. Done as a Cooper Fellow Series and Sponsored by the Department of Geological Sciences and the College of Arts and Sciences, University of Miami. Spring of 2011, Spring of 2012, Spring of 2013 (two sessions), Spring of 2014, and Spring of 2015.

Board of Directors, the CLEO Institute. A program for involving and training secondary school, college students and adults in climate change, locally, nationally, and globally. (2011- present).

Invited Speaker to Miami Beach Chamber of Commerce, January 2013.

Informal (non-paid) advisor to numerous coastal governments, chambers of commerce, businesses, and/or organizations in Florida on optimal response to sea level rise, including Miami Beach Chamber of Commerce, Bay Harbor Islands, Fairchild Gardens, (2014).

Member, Committee on Sea Level Rise, South Florida Regional Planning Council, tasked with revisiting and revising (upwards) projected sea level rise rates for 2045, 2060, 2100, and 2130 being used by southeast Florida Counties for planning purposes – Adopted by the four-county Compact (October 2014 - March 2015).

Stormwater Master Plan – Pinecrest (2015).

Invited presenter and advisor to cities of Coral Gables, Miami, and Pinecrest; Fairchild Gardens, community groups, service organizations, and individuals on projected rates of sea level rise and recommended solutions (2016).

EXHIBIT B: REFERENCES

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Exhibit B B8

EXHIBIT C: PREVIOUS TESTIMONY IN PRECEDING FOUR YEARS

In re: Florida Power & Light Company; Dania Beach Clean Energy Center Power Plant Siting Application, No. PA89-26A2 (State of Florida, Div. of Administrative Hearings), Case No. 17-4388EPP, OGC No. 17-0922.

Southern Alliance for Clean Energy, Tropical Audubon Society, Inc. and Friends of the Everglades, Inc. v. Florida Power & Light Co., No. 16-CV-23017 (S.D. Florida).