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UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA
SAN FRANCISCO DIVISION

FRIENDS OF THE EARTH, INC., et al., Plaintiffs, v. PETER WATSON, et al., Defendants.	Civ. No. C 02 4106 JSW Date: February 11, 2005 Time: 9 A.M. Courtroom 2, 17th Floor

DECLARATION OF DR. MICHAEL C. MacCRACKEN

I, MICHAEL C. MacCRACKEN, declare as follows:

1. I received my Bachelor's of Science in Engineering degree with high honors in Aerospace and Mechanical Sciences from Princeton University in 1964. I was also recognized by election to the Phi Beta Kappa honor society. I then received my Master of Science and Ph.D. degrees in Applied Science from the University of

Plaintiffs' Exhibit #2

California Davis in 1966 and 1968, respectively. My graduate studies were also recognized by election to the Phi Kappa Phi honorary society. From 1968 to 2002, I was employed as a physicist at the University of California's Lawrence Livermore National Laboratory (LLNL), where I led a number of scientific projects using numerical models to simulate the effects of transport and industrial emissions on air quality and the response of the climate to a range of natural and human-induced perturbations, including the likely impacts of an increase in the concentrations of greenhouse gases such as carbon dioxide. As a result of these and related projects, I am the co-author/co-editor of eight books, 22 journal articles, and hundreds of other reports and notes. In addition, I served as Deputy Division Leader of the Atmospheric and Geophysical Sciences Division from its formation in 1974 to 1987 and as Division Leader from 1987 to 1993.

2. From 1993 to 2002, I was on assignment from my permanent position with LLNL to serve as the senior scientist on global change at the interagency Office of the U. S. Global Change Research Program in Washington, DC. In this capacity, I served as the first Executive Director of the Office of the U.S. Global Change Research Program ("USGCRP") from 1993-1997. I was responsible for assisting in the coordination of the global change[1] research programs of ten federal agencies, including the Environmental Protection Agency, the Department of Energy, the National Science Foundation, the National Oceanographic and

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[1] The term "global change" encompasses research relating to climate variability and change, depletion of stratospheric ozone and atmospheric chemistry, changes in land cover such as deforestation and desertification, and associated impacts such as changes in water, resources ecosystems and land cover, etc.

Atmospheric Administration, NASA, and others. In addition, in my role as senior scientist, I was responsible for keeping up with scientific advances in the field for the USGCRP and assisting the Office of Science and Technology Policy (OSTP) of the Executive Office of the President in summarizing the scientific advances for government leaders.

3. Following my tenure as Executive Director of the Office of the USGCRP, I was appointed Executive Director of the National Assessment Coordination Office, and served from 1997 through 2001 in this role. I led a small staff that had responsibility for coordinating the U.S. National Assessment of the Potential Consequences of Climate Variability and Change (U.S. National Assessment), which was carried out under the auspices of the USGCRP. This responsibility included helping to design and support the overall assessment activity, ensuring the high quality of the scientific aspects of the assessment effort, and otherwise facilitating the effective conduct of the assessment effort. The U. S. National Assessment was carried out at the direction of the Director of OSTP in his role as Executive Secretary to the National Science and Technology Council, which is chaired by the President and the members of which are the cabinet secretaries. The National Assessment brought together the efforts of 20 university-based regional teams, 5 joint university-government scientific teams focused on particular sectors of the economy and natural resources, and a federal advisory committee composed of 12 leading scientists and experts known as the National Assessment Synthesis Team (NAST). In addition to participating in and reviewing many of the

regional and sectoral activities and reports, I served as an additional lead author and generally contributed to the preparation of the national level reports entitled *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change*, which were published in 2000 and 2001.[2] I was an additional lead author of the National Assessment's Overview Report, and for the National Assessment's Foundation Report I was one of the lead authors of "Chapter 1: Scenarios for Climate Variability and Change" and "Chapter 12: Potential Consequences of Climate Variability and Change for Native Peoples and Homelands." In my role as Executive Director of the National Assessment Coordination Office, I also prepared Chapter 6 of the U.S. Government's *Climate Action Report 2002*.[3] This report was the U.S. Government's quadrennial national communication under the United Nations Framework Convention on Climate Change (UNFCCC); Chapter 6, on impacts and adaptation, incorporated the findings of the National Assessment. In 2002-2003, I also assisted the Department of Transportation in the conduct of a workshop on the potential impacts of climate change on transportation, and gave the opening invited talk on the science of climate change.

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[2] U.S. Global Change Research Program, *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change: Overview Report* (2000) and *Foundation Report* (2001). Available from Cambridge University Press.

[3] U.S. Dept. of State, *U.S. Climate Action Report 2002* (U.S. Government Printing Office 2002).

4. I have served in various capacities in the preparation of the First, Second and Third Assessments of the Intergovernmental Panel on Climate Change (IPCC). The IPCC is the international organization responsible for preparing authoritative assessments of the science of climate change, impacts, adaptation, and mitigation in support of the UNFCCC. For the IPCC's First Assessment Report, which was completed in 1990, I was a contributor to two chapters in the Working Group I report: Chapter 5 on "Equilibrium Climate Change—and its Implications for the Future" and Chapter 8 on "Detection of the Greenhouse Effect in the Observations." For the Second Assessment, which was completed in 1995, I was a contributor to Chapter 8 of Working Group I, "Detection of Climate Change and Attribution of Causes," and a lead author of Chapter 25 of Working Group II, "Mitigation: Cross-Sectoral and Other Issues." For the Third Assessment that was completed in 2001, I was a contributing author to Chapter 12 of Working Group I, "Detection of Climate Change and Attribution of Causes." I was also a reviewer of various chapters for each of these assessment reports. As part of my responsibility with the Office of the U.S. Global Change Research Program, I served as scientific coordinator for the official reviews of the U.S. Government for both the Working Group I and II contributions for the Second and Third IPCC Assessment Reports. I also served as scientific advisor to the U.S. delegation at the plenary meetings of Working Group I for the Second and Third Assessments,[4] contributing to the

[4] Held, respectively, in Madrid, Spain in November 1995 and in Shanghai, China in January 2001. Prior to joining the Office of the USGCRP, I also served as a

preparation of the Summary for Policymakers of each assessment. For the IPCC's Fourth Assessment Report to be completed in 2007, I was recently appointed by the leadership of Working Group II to serve as Review Editor for Chapter 14, which will focus on past, ongoing, and future impacts of climate change on North America.

5. Since retiring from the Lawrence Livermore National Laboratory in September 2002 upon the completion of my assignment with the Office of the USGCRP, I have continued to be active in assessment of the science of climate change and its consequent impacts. I am currently serving as Chief Scientist for Climate Change Programs with the Climate Institute in Washington D.C., which is the oldest non-governmental organization focused on understanding and helping to address the climate change issue. I was also appointed to the 13-member Assessment Integration Team of the 8-nation Arctic Climate Impacts Assessment (ACIA), which has just completed two reports[5] on how climate change and enhanced ultraviolet radiation are now affecting and are likely in the future to affect the Arctic region, and how these changes then impact the world. In addition, in 2003 I was elected to a four-year term as President of the International Association of Meteorology and Atmospheric Sciences, which is an international scientific organization whose sponsoring members are the national academies of science of

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scientific adviser to the US delegation for consideration of the IPCC Working Group I special report in January 1992 held in Guangzhou, China.

[5] Arctic Climate Impact Assessment (ACIA), *Impacts of a Warming Arctic: Arctic Climate Impact Assessment (Synthesis Report)*, Cambridge University Press, 2004; and *Impacts of a Warming Arctic: Arctic Climate Impact Assessment (Technical Report)*, Cambridge University Press, 2005 (in press).

the leading nations of the world; as a result of my position, I also serve on executive committees of several additional international organizations/activities. Among other international panels on which I serve, the most recent is the Scientific Expert Group (SEG) on Climate Change and Sustainable Development organized on behalf of the United Nations Commission on Sustainable Development in cooperation with Sigma Xi, The Scientific Research Society, of which I am also a member.

<u>Summary of Opinions</u>

6. The following findings and supporting information are offered as my expert scientific opinion, based on my education, qualifications, experience, and knowledge of the relevant scientific literature. These findings, in my expert opinion, also reflect the strong consensus of opinion among qualified scientific experts involved in climate change research in the U.S. and around the world:

a. The atmospheric concentrations of three important greenhouse gases, namely carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), have been increasing since about 1750 as a result of human activities, principally the combustion of fossil fuel (i.e., coal, oil, and natural gas). The higher concentrations of these greenhouse gases enhance the Earth's natural greenhouse effect and exert a warming influence on the Earth's climate. The human-induced increases in the concentrations of CO_2, CH_4, and N_2O are widely considered to be the major factor responsible for the global warming of about 0.6°C (about 1°F) that occurred during the 20^{th} century.

b. The most probable scenarios of future greenhouse gas emissions indicate that, in the absence of limits on the emissions of these gases by all sectors of the economy and international community, atmospheric concentrations of greenhouse gases will continue to rise relatively rapidly throughout the 21st century, very likely exceeding concentrations seen over at least the last 10 million years. As a result, global average surface air temperature, which has already increased by about 0.6°C (about 1°F) over the past 100 years, will also continue to rise at rates unprecedented in human history. In its Third Assessment Report, considering the range of possible emissions and averaging across the results of climate models, the IPCC concluded that global surface air temperature is likely to increase by about 0.2 to 0.5°C (about 0.3 to 0.9°F) per decade. Using the no-policy emission scenarios developed by the IPCC and encompassing the ramifications of the uncertainties in understanding of climate science, global average surface air temperature is projected to increase by about 2 to 4.5°C (about 3.5 to 8°F) over 1990 levels by the end of the 21st century. Recognizing that the current warming of 0.6°C (about 1°F) is already having significant environmental and societal consequences for some areas, a further rise by even the minimum increase identified by IPCC would have widespread consequences around the world, and some suggest would exceed the "dangerous anthropogenic interference" level incorporated in the UN Framework Convention on Climate Change (UNFCCC) to which the US is a signatory. Independent of the uncertainties in the climate projections, the amount and consequences of climate change will become much more significant in the future, at whatever level of reduced emissions that can be achieved. The question is thus how great the consequences will be, not whether there will be any significant consequences or not.

c. Important environmental impacts of the global warming of about 0.6ºC (about 1ºF) that has occurred to date include: (i) the warming of the oceans and the increased melting of many mountain glaciers around the world that provided the major contributions to the rise in global sea level of 10 to 20 cm (4 to 8 inches) observed during the 20th century; (ii) the lengthening of the growing season in mid- and high-latitudes that has contributed to poleward and altitudinal shifts of plant and animal ranges and the declines of some plant and animal populations; and (iii) coastal erosion in regions where the sea ice that suppresses storm waves has been melted back, where the permafrost is thawing, and where there is later freezing and earlier break-up of ice on rivers and lakes is already leading to plans for moving endangered communities to safer ground.[6]

d. The environmental impacts of projected global warming over the 21st century will include: (i) an increase in the rate of sea level rise as compared to the rate during the 20th century, amounting to an average rate of rise of about 1

[6] Some text is drawn from the IPCC's Third Assessment Report *Climate Change 2001: Impacts, Adaptation and Vulnerability*; Cambridge University Press, page 3.

to 9 cm (about 0.5 to 3.5 inches) per decade and totaling 9 to 88 cm (about 4-35 inches) by the end of the century (with the most likely value being, in my expert opinion, near or above the middle of this range as a result of the faster than expected melting of mountain glaciers and parts of the Greenland Ice Sheet that have been identified since the most recent IPCC assessment report); (ii) intensification of the shifts and disturbances of ecosystems, leading to severe and irreversible changes to important natural ecosystems such as coral reef, arctic, and, alpine environments and geographic features such as forest boundaries, barrier islands and low-lying coastal regions, and glaciers and ice sheets; and (iii) continued and accelerating reduction of water storage in winter snowpack in mountainous regions with direct and important economic consequences;

e. Significant reductions in emissions of CO_2 and other greenhouse gases are needed to slow and then halt the build-up in atmospheric concentrations of these gases in order to delay and moderate many of the adverse impacts of global warming. With the existing rate of emissions already inducing significant impacts of some types and in some regions, and projected to cause significant further damage, allowing additional emissions from fossil fuel combustion will further accelerate climate change in an already changing world, bringing on consequences that are more severe and that would occur sooner, thereby making adaptation more difficult, if possible at all, and requiring cutbacks in emissions that would be more drastic and very likely more costly than if actions were taken today.

The scientific basis for each of these findings is explained in more detail below.

Current State of Scientific Authority on Climate Change

7. Collective scientific understanding of climate change is best represented in major assessment reports that assemble, evaluate and critically summarize the results of thousands of scientific papers and studies that have been written about the many aspects of the climate change issue. These carefully peer reviewed assessment reports present the most authoritative international consensus available of the scientific understanding of the effects of human activities on climate, as well as of the potential impacts of climate change on the world and the U.S. While there are those critical of these major assessments, in no case have their contentions been found to have any significant influence on the consensus findings of the assessments when carefully considered by the scientific community at large as part of the review process for these assessments.

8. In the late 1980s, the international community formed the Intergovernmental Panel on Climate Change (IPCC), which produced a series of major assessments of climate change in 1990, 1995 and 2001.[7] The national

[7] The IPCC's First Assessment Report series in 1990 consisted of the following reports: *Scientific Assessment of Climate Change – Report of Working Group I* (Cambridge University Press, UK); *Impacts Assessment of Climate Change – Report of Working Group II* (Australian Government Publishing Service Marketing Section); and *The IPCC Response Strategies – Report of Working Group III* (Island Press, USA). The IPCC's Second Assessment Report Series in 1995 consisted of the following: *Climate Change 1995: The Science of Climate Change; Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change:*

academies of science of approximately twenty nations, including the U.S.,[8] recognize the IPCC's 2001 findings as the most authoritative available concerning human-induced changes in climate and associated consequences.[9] As a result of my involvement in the development of these assessments, as summarized in paragraph 4, I have an extensive understanding of the findings of the IPCC reports relating to climate change science and consequent impacts, especially as they relate to the United States.

9. The National Assessment of the Potential Consequences of Climate Variability and Change, undertaken by the US Global Change Research Program (USGCRP) pursuant to Section 106 of the Global Change Research Act of 1990

Scientific-Technical Analyses; and *Climate Change 1995: Economic and Social Dimensions of Climate Change* (all available from Cambridge University Press). The IPCC's Third Assessment Report series in 2001 consisted of the following: *Climate Change 2001: Synthesis Report; Climate Change 2001: The Scientific Basis* (Houghton et al. eds., Cambridge Univ. Press 2001) (available at http://www.grida.no/climate/ipcc_tar/wg1/index.htm) ("Working Group I report"); *Climate Change 2001: Impacts, Adaptation and Vulnerability* (McCarthy et al. eds., Cambridge Univ. Press 2001) (available at http://www.grida.no/climate/ipcc_tar/wg2/) ("Working Group II report");and *Climate Change 2001: Mitigation* (Pachauri et al. eds., Cambridge Univ. Press 2001) (available at http://www.grida.no/climate/ipcc_tar/wg3/index.htm) ("Working Group III report"). In addition, the IPCC has published many other special reports and documents. See http://www.ipcc.ch/pub/reports.htm.

[8] National Research Council, *Climate Change Science: An Analysis of Some Key Questions*, (National Academies Press 2001).

[9] The IPCC assessment reports are prepared by internationally nominated and appointed expert teams, undergo multiple stages of review, and are considered in plenary session by representatives of over 150 countries. All of the IPCC reports have been accepted and agreed to unanimously by all of the participating nations of the world, including the US, as the best and definitive summarization of scientific understanding.

[Public Law 101-606], is the major assessment most directly focused on the potential impacts of climate change for the United States.[10] As a result of my role as an author and as Executive Director of the office responsible for coordinating preparation of the National Assessment (see paragraph 3), I have a detailed knowledge of the findings of the National Assessment.

10. The US Government also included the findings of the National Assessment in its *Climate Action Report 2002*,[11] the U.S. Government's quadrennial national communication under the United Nations Framework Convention on Climate Change (UNFCCC). In my capacity as Executive Director of the National Assessment Coordination Office of the USGCRP, I prepared Chapter 6 of this report, which dealt with the issues of the present and potential impacts of climate change on the United States, and the potential for adaptation. This chapter, which was formally approved by agencies across the US Government, including the Executive Office of the President, and was then forwarded by the U.S. Department of State to the Secretariat of the UNFCCC as the official position of the US Government, is in full agreement with the presentation of the science and impacts contained in the IPCC and National Assessment reports.

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[10] U.S. Global Change Research Program, *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change: Overview Report* (2000) and *Foundation Report* (2001). Both reports are available from Cambridge University Press.

[11] U.S. Dept. of State, *U.S. Climate Action Report 2002* (U.S. Government Printing Office 2002).

11. The IPCC and NAST assessments carefully indicate the level of confidence and uncertainty that can be associated with the various dimensions of the issue. For example, to more clearly indicate the significance of the inevitable presence of uncertainties, the IPCC's Third Assessment Report adopted a specific set of terms to address the level of confidence associated with various findings, with a numerical range of likelihood associated with each term: "In this Summary for Policymakers and in the Technical Summary, the following words have been used where appropriate to indicate judgmental estimates of confidence: *virtually certain* (greater than 99% chance that a result is true); *very likely* (90-99% chance); *likely* (66-90%); *medium likelihood* (33-66% chance); *unlikely* (10-33% chance); *very unlikely* (1-10% chance); *exceptionally unlikely* (less than 1% chance)."[12] For the U.S. National Assessment, NAST developed a similar lexicon: very likely or very probable, likely or probable, possible, unlikely or some chance, and very unlikely or little chance. My use of these terms in the following paragraphs is consistent with this IPCC and NAST usage.

<u>The Role of Greenhouse Gases in Global Warming</u>

12. Greenhouse gases in the atmosphere let most of the solar energy reach and warm the surface, but then absorb about 90% of the heat energy that is radiated upward from the Earth's surface. These greenhouse gases then re-radiate much of the absorbed energy back down to the surface, contributing to further

[12] IPCC Working Group I report, 2004, page 2, footnote 7 [italics in original].

warming. In this way, the greenhouse gases act in a manner roughly equivalent to adding a blanket over the Earth. The higher the concentrations of greenhouse gases, especially CO_2, CH_4, and N_2O, the greater will be the trapping of heat and the increase in surface temperature. That this is the case is well established, and this tendency is confirmed in laboratory experiments, in reconstructions of the Earth's climatic history, and in observations of the climates of other planets.

<u>Human-Induced Increases in Greenhouse Gas Concentrations Have Already Caused Global Warming</u>

13. The concentration of CO_2 in the air has increased from about 278 ppmv (about 0.028%) to over 375 ppmv[13] (about 0.0375%) since the start of the Industrial Revolution.[14] The global average methane (CH_4) concentration has increased from about 0.7 ppmv in 1750 to close to 1.8 ppmv at present, and the global average nitrous oxide (N_2O) concentration has increased from about 0.27 ppmv in 1750 to over 0.314 ppmv today. The concentrations of several hydrofluorocarbons, human-

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[13] The abbreviation "ppmv" stands for parts per million by volume, which is equivalent to saying the number of molecules in the atmosphere of a given substance for every million molecules of dry air.

[14] Annual average concentration for the globally representative Mauna Loa station for 2003 (see http://cdiac.esd.ornl.gov/trends/co2/sio-mlo.htm). For 2004, NOAA recently reported that the peak monthly value of the CO_2 concentration had reached over 380 ppmv.

created compounds invented in the 20th century that have a similar radiative influence as natural greenhouse gases, are also increasing.[15]

14. Over the past two centuries of intensifying industrial activity, the temperature record, which has been reconstructed using various types of proxy evidence to augment the instrumental record, shows relatively stable, even possibly decreasing, temperatures prior to industrial activities, and then a marked increase in temperatures since that time.[16] This record indicates that the natural variability of the global average surface temperature from year to year is only a few to several tenths of a degree (even including uncertainties due to limited amounts of data) after account is taken of the influences of natural forcings due to changes in solar radiation and intermittent volcanic eruptions. The warming that has taken place over the past few centuries is unlike any earlier warming since the end of the last glacial epoch and is larger than can be explained by natural influences on the climate, making clear that the long-term trend in human-induced climate change is larger than can be explained by natural factors.

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[15] *See* IPCC, Working Group I report, 2001, at page 358, and updates from the Carbon Dioxide Information Analysis Center (http://cdiac.esd.ornl.gov/by_new/bysubjec.html#atmospheric)

[16] The instrumental record of temperature goes back to about 1850, and proxy indicators such as tree rings, pollen fractions, and coral rings have been used to extend the annual record back about 1000 years [see "On Past Temperatures and Anomalous Late-20th Century Warmth" by M. Mann, C. Amman, R. Bradley, K. Briffa, P. Jones, T. Osborn, T. Crowley, M. Hughes, M. Oppenheimer, J. Overpeck, S. Rutherford, K. Trenberth, T. Wigley, in *Transactions of the American Geophysical Union (EOS),* 2003]. The changes in average surface air temperature for the Northern Hemisphere, which, when averaged over a few years, are very likely quite similar to the changes in global average temperature.

15. The IPCC has looked particularly closely at climate change during the 20th century, and found that the increase in greenhouse gas concentrations is very likely the dominant cause of the increase in average global surface temperatures of approximately 0.6ºC during this period. This conclusion has recently been strengthened as more careful analyses have indicated that the troposphere is warming at a rate similar to the warming at the surface, thereby removing the most important lingering uncertainty about the attribution. Although, as the NRC report indicates, the exact contributions of the various natural and human-induced factors contributing to the century's global warming have not been unequivocally established, there can be no doubt that the human-induced changes in atmospheric composition are intensifying the natural greenhouse effect and causing global warming that is larger and much longer lasting than could be induced by natural oscillations such as an El Niño event.

16. Evidence of global-scale warming over this period is also found in the unusually strong and unprecedented retreat of mountain glaciers in many areas of the world, the faster rate of rise of sea level as compared to the period before the 20th century[17] (as a result of both additional glacial meltwater flowing into the oceans and heating-induced thermal expansion of the ocean waters), increases in the amount of moisture in the atmosphere and in the share of total precipitation

[17] Evidence indicates that, prior to shifting to a relatively rapid rate of rise during the 19th century, global average sea level had fluctuated very little (i.e., less than a few centimeters) since the melting of the continental glaciers at the end of the last glacial epoch roughly 6000 years ago. Thus, the relatively large increase of the 20th century is highly unusual and, based on an analysis of the factors contributing to it, is very likely largely a consequence of human activities.

occurring during intense rainfall events, and geographic shifts in the ranges of various plants and animals that are largely consistent with human-induced shifts in the climate. Each of these changes is indicative of global-scale warming and associated changes in climate since the mid-19th century, and all are occurring simultaneously.

17. Natural influences alone cannot explain the very sharp warming of the late 20th century[18]. If solar irradiance has been changing significantly at all, it appears to have been decreasing during the second half of the 20th century, and the intermittent sequence of volcanic eruptions over this period also indicates that they have also likely induced a cooling influence over the past 50 years. Thus, it appears likely that the two most important natural influences on global average temperature would have tended to cool the Earth just when it was in fact warming rapidly. The warming has also been larger than could be explained by the record of past natural oscillations in the climate since the end of the last glacial epoch about 10,000 years ago. Therefore, with natural causes unable to explain the 20th century warming and human activities being the only factor that could create a strong warming influence, the IPCC concluded that human activities must clearly be the dominant factor leading to the warming.

<u>Approaches for Estimating Changes in Climate Over the 21st Century</u>

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[18] IPCC, *Climate Change 2001: Synthesis Report; Climate Change 2001: The Scientific Basis* (Houghton et al. eds., Cambridge Univ. Press 2001) (available at http://www.grida.no/climate/ipcc_tar/wg1/index.htm) ("Working Group I report"), chapter 12.

18. Insights about the functioning of the climate are gained by direct study of the atmosphere, oceans, land, and snow/ice systems. However, because of its complexity, the system cannot be manipulated in the wide variety of ways (e.g., by doubling the CO_2 concentration) that would be needed to understand exactly how it might react to the range of possible changes in greenhouse gas concentrations in the atmosphere. Because of its four billion year history, study of the climatic history of the Earth as evidenced in geological and biological records of past conditions, especially of the much warmer times when the carbon now sequestered in fossil fuels was present as CO_2 in the atmosphere, can provide important insights about how the climate will be affected by changing greenhouse gas concentrations. Because the Earth system is too complex to recreate in a laboratory, climate models have been constructed that incorporate physical, chemical, and biological relationships derived from observations and theoretical studies. Tests of the performance of these models in comparison to the observed climatic behavior indicate that the models reproduce and emulate many of the most important features determining the large-scale and long-term climate. These climate models, which are extensions of the widely used and widely tested models used to generate weather forecasts, represent the most tested and comprehensive approach to estimating how the global climate would respond to natural and/or human-induced influences.

19. With present understanding and capabilities, generating reliable projections of future changes in the climate is most effectively carried out by: (a)

generating scenarios (or storylines) about the plausible future evolution of society that are based upon the best available projections of how population, economic development, and energy technologies are expected to evolve, and how these changes will lead to emissions of greenhouse gases and aerosols; and (b) introducing the calculated emissions into carbon cycle and climate models that then calculate the expected influences of the projected emissions on atmospheric composition and the climate in a way that ensures objective and quantitative consideration is given to all relevant processes and factors governing the behavior of the climate system.

Projections of Changes in Greenhouse Gas Emissions and Concentrations Over the 21st Century

20. Absent changes in policy to reduce the combustion of fossil fuels (i.e., coal, oil, and natural gas) to generate energy, internationally accepted quantitative scenarios generated by the IPCC[19] project that the warming influences of the increasing atmospheric emissions of CO_2 and other greenhouse gases are likely to continue to increase for at least the next several decades by at least as much and at least as fast as in recent decades. These scenarios cover a wide range of possible outcomes that I believe convincingly span the range of likely possibilities from now until the end of the 21st century in terms of global population growth, economic development, and energy technologies and rates of use if no policy actions are taken to constrain emissions because of concerns regarding climate change.

[19] IPCC, *Emissions Scenarios*, 2000 (Cambridge Univ. Press 2000) (avail. at http://www.ipcc.ch/pub/sres-e.pdf).

21. If annual global emissions of greenhouse gases continue to increase in the next several decades in accordance with these scenarios, there will be significant increases in the atmospheric concentrations of these gases. This conclusion is clear because of the scientific understanding of the cycles of CO_2 and other related substances through the environment. For CO_2, we know that there is a natural cycle that involves: (a) uptake of CO_2 by plants and soil biota, which store the carbon until it is consumed by humans, animals, fire, or plant respiration and decay and thereby generally released back into the atmosphere, having no net effect on the atmospheric concentration unless there is net growth or destruction of the vegetation and soil carbon reservoir; and (b) release and solution of CO_2 in upper ocean waters, depending on temperature and ocean chemistry, with a relatively small transfer of carbon to the deep ocean as a result of sinking ocean waters and detritus from upper ocean marine organisms that, in the absence of human induced emissions of carbon would balance additions to the atmosphere and upper ocean by volcanoes and solution into runoff of carbon from rocks. While these natural fluxes of carbon into and out of the biota and oceans total nearly 200 billion tonnes of carbon per year (GtC/yr), the nearly steady concentration of CO_2 in the atmosphere over the nearly 10,000 years prior to industrial activity make clear that these fluxes were close to being in balance. The human-induced emission into the atmosphere of over 6 GtC/yr from fossil fuel combustion would be small in comparison if the natural removal processes could adjust to accommodate this additional carbon; however, only about half of the increment due to the emitted CO_2 is presently being

taken up by adjustments in these natural processes, with the rest accumulating in the atmosphere. Study of these natural processes and the limits to their ability to adjust indicate that the fractional uptake is likely to decrease as the CO_2 emissions rise to several times current emission levels and so the atmospheric CO_2 concentration is very likely to rise even more rapidly than in the past, even if the growth in emissions is slowed. Because of how the carbon cycle works, it is the ratio of a given contribution to the total human-induced emissions of carbon that is of importance, not the ratio to the gross emissions from the oceans and the biosphere that are naturally balanced by uptake by these two carbon reservoirs.[20]

22. Because the increments to the atmospheric CO_2 caused by human emissions persist in the atmosphere for a few centuries, the six month to a year time for CO_2 to become well-mixed globally means that the location of emission is not important in considering the potential climatic impacts; that is, the global mixing time is much shorter than the removal time. It is for this reason that emissions of CO_2 anywhere on Earth affect the climate everywhere on Earth, causing consequences for everyone, especially because of how intercoupled our environmental and economic systems are and have become. In that respect,

[20] To give a more familiar example of this point, what is of importance is not how much cash goes in and out of a store's cash register during the day, but how much is recorded for the actual sale of various items. That is, a customer using a hundred dollar bill to pay for a $1 item does not generate $100 dollars in sales, but only $1, and finding a way to increase the profit on the $1 sale by 10 cents is really a 10% increment and not a 0.1% (that is, 10 cents divided by $100) increment in sales.

emissions of CO_2 outside the U.S. will contribute to global warming impacts in the U.S.

23. There are no plausible scenarios for which the CO_2 concentration will not increase very significantly in the future unless stringent policy steps are taken by all emitting groups to stop growth in and eventually substantially reduce emissions. Even continuing at present emission levels will lead to larger and larger impacts than have already occurred. Assuming that no or only very limited actions to limit emissions are taken, the most plausible energy scenarios project that the CO_2 concentration will continue to increase over the coming decades, reaching between two to three times its preindustrial level by the end of the 21st century (for reference, the current concentration is approximately 1.35 times the preindustrial concentration).

Future Global Warming as a Result of Continuing and Increasing Emissions

24. The projected increases in greenhouse gas concentrations will accelerate the warming influence of human activities, and very likely accelerate the rate of warming. In its Third Assessment Report, averaging across the results of climate models, the IPCC concluded that global surface air temperature is likely to increase by about 0.2 to 0.5°C (about 0.3 to 0.9°F) per decade through the 21st century [about 0.15 to 0.6°C (about 0.25 to 1.1°F) for the full range of model estimates of climate sensitivity]. By the end of the century, global average surface

air temperature is projected to increase by about 2 to 4.5°C over 1990 levels [1.4 to 5.8°C (about 2.5 to 11°F) for the full range of model estimates of climate sensitivity]; in all of the cases studies, further warming would continue in the 22nd century. This range in estimates of the amount of global warming is about equally created by uncertainties in how society-driven emissions will change and by uncertainties about how the climate will respond. While narrowing this range by reducing uncertainties is a worthy goal, even the lowest of the projected changes[21] [i.e., about 2°C (about 3.5°F)] above preindustrial climatic conditions would result in very significant temperature, precipitation, and sea level-induced impacts on the environment and society. It is the recognition that, even after accounting for the uncertainties, the lowest plausible no-policy emissions scenario for the future would lead to significant climatic change that inspired the nations of the world (including the United States) to adopt the UN Framework Convention on Climate Change in 1992. The UNFCCC sets as its goal limiting emissions of greenhouse gases to avoid "dangerous anthropogenic interference" with the climate system. Research on and consideration of how much climate change would be "dangerous" for the *world* is still underway; however, well before that level is reached (if it has not already been exceeded), adverse consequences in many regions would be expected to be very

[21] Note that this scenario would require unprecedented technological advances, economic viability, and rapid and extensive deployment of non-fossil energy technologies on an international basis as well as the smallest viable response of the climate system (given the Earth's climatic history)—and so would be of relatively low probability. T. M. L. Wigley and S. C. B. Raper (see "Interpretation of High Projections for Global-Mean Warming" Science 293, 451-454, 2001) argue in a probabilistic analysis that the most likely value is roughly twice the minimum value indicated by the IPCC.

significant (and some locations, such as the Arctic, are already experiencing such changes).

25. The projections for changes cited in paragraph 24 are for changes in the global average surface temperature. Because of its reduced heat capacity and relative dryness, temperature changes over land areas such as the United States are expected to be greater than over the ocean, and, because of various feedback processes associated with evaporation rates and snow and ice cover, temperature changes in mid to high latitude regions such as the United States are expected to exceed changes in low latitudes. Because of this, the IPCC's projections of regional temperature change over North America are significantly greater than projections of change in the global average temperature,[22] leading to use of projected warming of roughly 3 to 5ºC (5 to 9ºF) over the contiguous 48 states of the U.S. in the analysis carried on as part of the U.S. National Assessment.[23] Warming in the Arctic region, particularly in Alaska, is projected to be even greater.[24] While the details of regional changes remain somewhat uncertain, model simulations agree on the broad outline

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[22] IPCC Working Group I report, 2001, at chapter 10.

[23] U.S. Global Change Research Program, *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change: Overview Report* (2000) and *Foundation Report* (2001). Both reports are available from Cambridge University Press.

[24] See Arctic Climate Impact Assessment (ACIA), *Impacts of a Warming Arctic: Arctic Climate Impact Assessment (Synthesis Report)*, Cambridge University Press, 2004; and *Impacts of a Warming Arctic: Arctic Climate Impact Assessment (Technical Report)*, Cambridge University Press, 2005 (in press).

of expected changes for many regions across North America and the U.S.,[25] with warming very likely to cause the climates of the northern tier of states to become like the central tier of states, the climate of the central tier of states to become like that of the southern tier of states, and with conditions in the southern tier to become more tropical and subtropical.[26] Not knowing the exact details of the projected regional changes does not mean that there will be no changes, only that the departure of changes in a region from the large-scale sub-continental estimates of the global warming pattern are not yet well-established. And of course, global sea level rise will affect everywhere in the globe (see ¶30-31 below).

26. Overall, this projected temperature increase would be likely to make average conditions by the end of this century warmer than they have been for at least 420,000 years (the period for which ice core data is available), and likely warmer than average global temperatures have been over many millions of years. It is not only the amount of warming, but also its very rapid rate that pose unprecedented challenges to the extant environment and the society and communities that have developed in the world. The need to limit emissions is thus to both reduce the amount of change and to slow the onset of the change, creating a greater likelihood that adaptation is possible and will cost less, and that some potential adverse impacts will not occur at all.

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[25] IPCC Working Group I report, 2001, at chapter 10.

[26] U.S. Global Change Research Program, *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change: Overview Report* (2000) and *Foundation Report* (2001). Both reports are available from Cambridge University Press.

The Consequences of Future Global Warming

27. The projected temperature increases would have widespread adverse consequences.[27] For the United States, the National Assessment summarizes key findings for different regions of the country and for different national sectors[28] and a new assessment has just been completed of the observed impacts of global warming on the ecosystems and wildlife of the United States.[29] The following enumeration of conditions focuses mainly on consequences related to human health and the services provided by ecosystems and landscapes within the United States.

28. ***Increased incidence of high temperatures and extremely high heat index:*** The climate scenarios considered in the U.S. National Assessment were based primarily on model simulations done by two IPCC-accepted models,

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[27] Projected international impacts are summarized in IPCC's Third Assessment Report *Climate Change 2001: Impacts, Adaptation and Vulnerability* (McCarthy et al. eds., Cambridge Univ. Press 2001) (available at http://www.grida.no/climate/ipcc_tar/wg2/) ("Working Group II report"). For the Arctic region, a new a impacts assessment has recently been completed (see Arctic Climate Impact Assessment (ACIA), *Impacts of a Warming Arctic: Arctic Climate Impact Assessment (Synthesis Report)*, Cambridge University Press, 2004; and *Impacts of a Warming Arctic: Arctic Climate Impact Assessment (Technical Report)*, Cambridge University Press, 2005 (in press). In addition, a database of articles on the expected impacts of climate change for the U.S. and other countries is available at <http://www.climate.org/CI/index.shtml>.

[28] National Assessment Synthesis Team, U.S. Global Change Research Program, *Climate Change Impacts on the United States*, *Overview* (Cambridge Univ. Press 2000) and *Foundation* (Cambridge Univ. Press 2001) (these reports and supporting regional and sectoral reports are also available at <http://www.usgcrp.gov/usgcrp/nacc/default.htm>).

[29] C. Parmesan and H. Galbraith, *Observed Impacts of Global Climate Change in the U.S.*, 2004, Pew Center of Global Climate Change, Washington DC.

each running a mid-range scenario for future emissions. These models projected an annual average warming of about 3 to 5ºC (about 5 to 9ºF) across the U.S. during this century, which would be several times greater than the increase across the U.S. during the 20th century.[30] The change in summertime temperatures, combined with the associated increase in absolute humidity, is projected to cause the 24-hour average heat index (a combined measure of temperature and humidity) for July (as a representative summer month) to increase by at least 6ºC (about 10ºF) over most of the country by 2100. Changes are projected to be about double this amount in some regions, particularly across the southeastern and south-central U.S. where the summertime heat index is already high. In addition to such changes in the monthly average temperature, the models also project that the length of the very warm season will increase and the occurrence of very high heat index conditions will be expected to be more frequent in more northerly parts of the country where people are not well adapted to such conditions. A further study using the new climate model developed at the National Center for Atmospheric Research in Boulder, Colorado, provides additional support for the finding that global warming will lead to more frequent, more intense and longer-lasting heat waves over the U.S.[31] As is well recognized in analysis of the distribution of weather events, with variability

[30] MacCracken et al., Climate change scenarios for the U.S. National Assessment, *Bulletin of the American Meteorological Society,* **84**, 1711 (2003) (<avail. at http://ams.allenpress.com/pdfserv/i1520-0477-084-12-1711.pdf>).

[31] G. Meehl and C. Tebaldi, More Intense, More Frequent, and Longer Lasting Heat Waves in the 21st Century, *Science* **305**, 994-997, 2004.

remaining as it has been, an increase in the mean temperature will very significantly increase the number of extreme hot episodes.

29. ***Air quality is likely to be further impaired:*** Without additional control measures, ongoing and projected changes in climate due to global warming are very likely to increase emissions of various pollutants.[32] This is likely because of increased evaporation of volatile compounds from various types of storage devices, and increased release of organics from vegetation. Higher temperatures caused by global warming, especially because of the increased frequency, intensity and length of heat waves (see footnote 30), will also increase the rates of the photochemical reactions that convert smog-forming emissions (volatile organic compounds and oxides of nitrogen) into ozone smog.[33] In addition, unless there is a substantial and compensating tightening of emissions standards on all types of sources, longer warm seasons are very likely to increase the frequency of high ozone concentration episodes and violations of air quality standards.

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[32] For example, warmer temperature will increase demand for energy (in buildings, cars, etc.) while decreasing the efficiency of combustion processes (in generating plants and in internal combustion engines), leading to the emission of more pollutants; warmer temperatures will increase the release of smog-forming hydrocarbons from oil storage tanks and other storage containers and from forests and vegetation; the increased CO_2 concentration is expected to enhance growth of biomass, which could in some regions provide a larger source of hydrocarbon emissions; warmer temperatures will tend to increase the summertime drying of biomass, making the increased biomass into a larger fuel base for fires and the pollutants that they emit.

[33] As an example, results from the New York Climate and Health project indicate that warmer temperatures significantly increase the likelihood of ozone exceedances in that region. National Assessment Synthesis Team, U.S. Global Change Research Program, *Climate Change Impacts on the United States*, *Overview* (Cambridge Univ. Press 2000), page 104.

30. ***Projected warming will also cause significant sea level rise:*** Since the melting of the continental ice sheets created during the last glacial epoch ended over 6000 years ago, global sea level has remained essentially unchanged, with, for example, Roman coastal baths still near their original levels. Coinciding with the start of the industrial period, however, global sea level began to rise. Global warming contributed significantly to the 10 to 20 cm (about 4 to 8 inches) rise in sea level during the 20th century.[34] The meltback of mountain glaciers and warming of the oceans will contribute even more significantly to future sea level rise. The IPCC assessment projects that these factors, and other factors affecting the amount of water stored in reservoirs and in underground aquifers, will cause sea level to rise by about 9 to 88 cm (about 4 to 35 inches) by 2100, with a central range estimate of 20 to 70 cm (8 to 28 inches). Based on subsequent findings of more rapid than anticipated melting of tropical glaciers and certain parts of the Greenland Ice Sheet, I believe that sea level rise during the 21st century is more likely to be in the upper half of the range estimated by IPCC in the Third Assessment Report. To convert from estimates of global sea level rise and determine the projected sea level rise at a particular location, the local rate of subsidence or uplift of the coastal region must also be accounted for. For example, in regions such as the Mid-Atlantic, the land is subsiding naturally and so local sea level rise has been greater than the global average, contributing over the past few hundred years to the disappearance of some low-lying, but formerly inhabited, islands in the

[34] IPCC Working Group I report, 2001, at chapter 11.

Chesapeake Bay. The US Geological Survey provided information for the US National Assessment indicating that virtually all of the US coastline is undergoing moderate or severe erosion, with the most severe erosion concentrated along the Gulf and East Coasts, especially where there are barrier island and coastal wetlands. [35] For most coastal regions, the impacts of global warming are real and occurring now—these changes are not in any sense just theoretical.

31. ***Increase of ocean temperatures and loss of Arctic sea ice:*** Over the oceans, much of the additional energy trapped by the increasing concentrations of greenhouse gases goes into warming the oceans. This warming causes the expansion of ocean waters (i.e., their density is decreased and the same mass of sea water takes up more space) and contributes to global sea level rise. In addition, changing the temperature of ocean waters causes the preferred locations of fisheries to shift, and marine records of fish catches indicate that even small changes in temperature can cause relatively significant relocations of fish. In addition, adding energy to polar ocean waters causes sea ice to thin and melt (causing an increase in winter temperatures). The melting of the sea ice also tends to darken the surface, enhance absorption of solar radiation, and further melt the ice and then warm the ocean waters and further warm the atmosphere above. The melting back of sea ice over the past few decades has been significant around Alaska and elsewhere in the Arctic, and the waves and storm surges that are no longer being suppressed are

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[35] National Assessment Synthesis Team, U.S. Global Change Research Program, *Climate Change Impacts on the United States*, *Overview* (Cambridge Univ. Press 2000), page 113.

eroding barrier islands and leading to the need to relocate Indigenous communities, which is expected to require substantial resources[36] that will be paid either by the government or through taxes or fees levied on resources such as oil being extracted from the region; both mechanisms would spread the cost of warming across the U.S.

32. ***More frequent and intense extreme weather events:*** The additional energy available from increased average temperature will drive an increase in evaporation, ensuring that more moisture will be available to precipitate out as rain and snow. The increased rate of condensation will release additional energy to the atmosphere and intensify convective (e.g., thunderstorm-like) events in the atmosphere. Observations from many countries, including the U.S., indicate that such changes are already evident as a result of the warming during the 20th century, and these observed trends are very likely to continue, contributing to more frequent flooding and inundation in vulnerable regions. Of particular concern is the potential for an increase in the wind speed and peak rate of precipitation of major tropical cyclones (i.e., hurricanes and typhoons). Simulations using the progenitor to the US national hurricane model clearly indicate that an oceanic warming of about 2°C (about 3.5°F) would lead to an intensification of peak winds by up to about 6% (which would lead to an increase in the energy of damaging winds by about 18%) and a significant increase (up to 18%) in the amount of peak rainfall within 100 km

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[36] Alaska Native Villages Affected by Flooding and Erosion Have Difficulty Qualifying for Federal Assistance, Statement to Congress on June 29, 2004 of Robert A. Robinson, Managing Director, Natural Resources and Environment, Government Accounting Office, Report GAO-04-895T.

(about 60 miles) of the center (eye) of the hurricane.[37] Thus, those living in low-lying areas and on barrier islands along the Gulf and Southeast coasts of the US (e.g., North and South Carolina) where hurricanes often strike can expect more intense storms and it is, in my expert opinion, likely that the intense phases of these tropical cyclones would reach further north along the US coastline (e.g., up to the northeastern US) and further inland (e.g., over the Appalachian Mountains) due to the overall warmer conditions and greater average intensity of these systems. While the changes in hurricane characteristics that would be expected to have occurred due to past warming are not yet large enough to definitively detect in a statistical sense given the year-to-year and storm-to-storm variability that occurs, the presence of greater moisture in the atmosphere seems very likely to lead to more intense systems as further warming occurs.

33. ***An increase in local flooding and coastal inundation:*** The increase in the frequency and intensity of intense convective rainfall events is likely to increase incidents of localized flooding. The increased wind speed and peak rate of precipitation from hurricanes, along with higher storm surges due to the increase in sea level and in hurricane winds, are very likely to cause greater damage and put those in the paths of hurricanes (or along streams and rivers whose levels are raised by hurricanes) at greater risk of physical injury, property damage, and subsequent anguish. Soil compaction, sea level rise and recurrent severe storms have been

[37] T. Knutson and R. Tuleya, Impact of CO_2-Induced Warming on Simulated Hurricane Intensity and Precipitation: Sensitivity to the Choice of Climate Model and Convective Parameterization, *Journal of Climate* **17**, 3477-3495, 2004.

leading to the loss of approximately 20-30 square miles of Louisiana wetlands each year. These wetlands serve as the “shock absorber” for storm surges that could inundate New Orleans, significantly increasing the risk to this major urban population. The projected increase in the rate of sea level rise will worsen this situation, although costly preventative measures in that region involving partially breaching the levees along the Mississippi River (which would cause impacts, for example, to shipping) could at least partially ameliorate this threat for at least a few decades. More frequent flooding and inundation induced by global warming will also increase the risk for other low-lying regions around the country, including along low-lying coastal areas on the Gulf of Maine, Cape Cod, Long Island, metropolitan New York, New Jersey, and further south along the East and Gulf coasts. Along the West Coast of the US, especially along the coast of California, a further important contributor to higher sea level is the occurrence of El Niño events. The climate model of the Max Planck Institute in Hamburg, Germany, which has been especially configured to simulate tropical ocean conditions, projects that there will be larger oscillations between El Niño and La Niña conditions, [38]causing larger year-to-year variations in sea level, which, along with the global increase in sea level, is very likely to cause new high extremes of sea level at just the times when El Niño events are sending intensified storms into the coast of California. With the projections of more intense rains, higher sea level, and storm-

[38] National Assessment Synthesis Team, U.S. Global Change Research Program, *Climate Change Impacts on the United States*, *Overview* (Cambridge Univ. Press 2000), pages 18 and 83.

induced waves, increased erosion and inundation seem very likely for California coastal communities.

34. ***Climate change will lead to more droughts and wild fires, and also will impact water resources:*** More precipitation falling in more intense weather events will increase both flood- and drought-related damage. As soils become saturated, more frequent instances of very heavy rainfall events will increase run off into streams and rivers, more often leading to conditions that exceed the ability of land cover to slow the amounts that rapidly flow off and contribute to flooding. At the same time, the increased temperatures will cause more rapid evaporation of what moisture does exist in the soil, leading to more rapid drying. In vulnerable regions, this drying will cause more dust to be lofted. The increased occurrence of very dry conditions in regions such as along the front range of the Rocky Mountains (e.g., in Colorado) and along the West Coast (e.g., California) not only increases the risk of forest fires that can wipe out homes and communities, but also sets the stage for the subsequent compounding effects of mudslides. In mountainous areas of the western U.S., including the Rocky Mountains (e.g., Colorado) and the Sierra Nevada (i.e., California), where winter snowpack is an important source of springtime runoff into rivers and reservoirs, the warming projected in the climate scenarios used in the National Assessment will

lead to sharp reductions in springtime snowpack[39] and very significant shifts in the timing of snowmelt and thus reductions in warm season water resources.

35. ***Water quality is likely to be adversely affected:*** A wide range of potential influences are likely to affect water quality and increase the risk of disease from aquatic organisms harvested from rivers, estuaries, and coastal environments.[40] Increasing air temperatures and a longer warm season, for example, will increase stream and estuarine temperatures, allowing more rapid development of various microbial vectors. Additionally, changes in flow conditions are likely to allow increased salinity in estuarine areas in some regions. Pulses of higher precipitation, runoff, and flooding are also likely to augment the transport of non-point pollution and soil into rivers and estuaries. Moreover, higher storm surges[41] are very likely to increase destruction of coastal development, including agricultural and industrial areas and sewage treatment facilities, carrying polluting materials into freshwater and marine systems; such conditions have created particular problems in the southeastern US (e.g., North Carolina) following torrential rains from hurricanes. Higher temperatures tend to enhance the rate of

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[39] National Assessment Synthesis Team, U.S. Global Change Research Program, *Climate Change Impacts on the United States*, *Overview* (Cambridge Univ. Press 2000), page 97.

[40] National Assessment Synthesis Team, U.S. Global Change Research Program, *Climate Change Impacts on the United States*, *Overview* (Cambridge Univ. Press 2000), page 108.

[41] Because of how wind creates waves in shallow water, the increase in storm surge height is estimated to be 50% greater than the increase in the depth (i.e., the rise in sea level).

spread of invasive species into water environments, and high precipitation conditions can exceed the capacity of combined sewage-storm water systems, necessitating release of untreated or undertreated sewage into waterways.

36. ***Conditions are likely to be more conducive to the spread and persistence of various disease vectors:*** At present, many insect, tick, and rodent borne disease vectors in the U.S. are kept under control by carefully regulated and maintained development, by essential but costly building and community design standards, and by the seasonal cycle of temperatures that tends to limit reproduction or even kill off or slow the reproduction of existing disease vectors (for instance, persistent temperatures below freezing can kill off some types of mosquitoes). Warmer conditions and alteration of traditional precipitation amounts are likely to improve conditions for both existing and new vectors, causing an expansion of ranges in the U.S. for endemic vectors and making it easier for pests that are unintentionally introduced by travelers, ships, or freight to become established. Limiting disease outbreaks will require enhanced and more expensive public health programs, greater use of pesticides, upgraded building and community design standards, and increased education and awareness of the public, all of which will necessitate increased resources.[42]

37. ***Severe threats to coral habitats:*** The warming of ocean waters and the changes in ocean chemistry caused by the increase in the CO_2 concentration

[42] National Assessment Synthesis Team, U.S. Global Change Research Program, *Climate Change Impacts on the United States*, *Overview* (Cambridge Univ. Press 2000), pages 102-107.

itself will lead to a drastic reduction in the areas of the ocean suitable for growth of new coral and even of the sustenance of existing coral colonies. For the United States, this means that areas of Florida, Hawaii, and various US Trust Territories that were once optimal for coral growth will be only marginal for coral growth by 2050 and marginal to unlikely to be able to support corals by 2100.[43] In that coral growth is essential to sustaining these areas, that these areas are among the most biodiverse in the world, and that sea level rise will lead to deepening of coastal waters, global warming poses a very severe threat to coral habitats. In that tourism to view such coral reefs is a key advantage of many of these areas, the economic damage from loss of coral habitats could be as significant as the threat to such unique ecosystems.

38. ***Changes in the composition of forests:*** Global warming will shift the regions that are most conducive to trees and other flora, causing dramatic changes in the character of ecosystems. Studies conducted as part of the US National Assessment project dramatic shifts in the nature of the forest cover of the eastern US. In particular, both the hot-dry scenario of the Canadian Climate Centre model and the warm-moist scenario of the UK's Hadley Centre model were projected to lead to the complete loss by the last third of the 21st century of the Maple-Beech-Birch forest type that now is present over most of New England, New

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[43] National Assessment Synthesis Team, U.S. Global Change Research Program, *Climate Change Impacts on the United States*, *Overview* (Cambridge Univ. Press 2000), page 111.

York state, Pennsylvania, and around the northern Great Lakes.[44] That such changes can occur is evident from records of the slow shift in forest boundaries due to past changes in climate; the acceleration of global warming over the past few decades will increase the rate of these changes. In addition, because trees in a region tend to die off before replacement species can grow up, especially dry years can increase the fire hazard, and ecosystem simulations do project an increased likelihood in forested areas where transition of ecosystem type is occurring. Such changes are already evident in Alaska, where over 6 million acres of forest burned in 2004 and where the spruce bark beetle killed off 2.3 million acres of forest on the Kenai Peninsula.[45]

39. I have reviewed the declarations submitted on behalf of the cities of Oakland, Santa Monica, Arcata, and Boulder, as well as the personal declarations of Dr. Phillip Dustan, Melanie Duchin, Pam & Jesse Williford and Arthur Berndt, and I find the nature and scope of the injuries alleged therein to be consistent with the nature and scope of impacts that, in my expert opinion, can be expected to result from climate change in each particular location.

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[44] National Assessment Synthesis Team, U.S. Global Change Research Program, *Climate Change Impacts on the United States*, *Overview* (Cambridge Univ. Press 2000), page 116-117.

[45] National Assessment Synthesis Team, U.S. Global Change Research Program, *Climate Change Impacts on the United States*, *Overview* (Cambridge Univ. Press 2000), pages 74-79.

OPIC/Ex-Im CO_2 Emissions are Substantial, Contribute to the Acceleration of Global Warming, and Threaten to Increase the Severity of its Impacts.

40. Cumulative emissions of CO_2 as a result of project approvals by the Overseas Investment Corporation (OPIC) and the Export Import Bank of the United States (Ex-Im) of fossil fuel resources and combustion related projects have been separately estimated to total roughly 51,600 million metric tons of CO_2 equivalent (MMT of CO2E) over the life of these projects (i.e., the next several decades). [46] For purposes of comparison, this estimate can be converted to carbon equivalent, and is roughly 14,000 MMCTE, and for comparison with the estimates of carbon fluxes described in earlier paragraphs of this affidavit, this emission of CO_2 is roughly equivalent to 14 GtC.[47]

41. Emission of 14,000 MMCTE is a large amount and will lead to larger changes in the climate and a greater risk that various climatic thresholds will be exceeded. This amount of emissions is roughly equivalent to total global emissions for a period of about 2 years and the equivalent of total US greenhouse gas emissions of over 8 years.[48] That the projected amount of emissions is large is also evident when compared to the Administration's program to limit emissions, which was reported on as follows: "The President's goal is to lower the U.S. rate of

[46] *See* Declaration of Richard Heede. Pls.' Exh. 1 .

[47] To convert to emission in GtC, divide the total mass of emissions of CO_2 in MMT CO2 by 1000 and then by the relative molecular weights (i.e., 44/12 or 3.67).

[48] Energy Information Administration report for 2003 emissions. See http://www.eia.doe.gov/oiaf/1605/ggrpt/index.html.

greenhouse gas emissions from an estimated 183 metric tons per million dollars of gross domestic product (GDP) in 2002 to 151 metric tons per million dollars of GDP in 2012. Meeting this commitment will prevent greenhouse gas emissions of over 500 million metric tons of carbon equivalent (MMCTE) from entering the atmosphere over the next ten years, and is equivalent to taking 70 million (or one out of three) cars off the road."[49] The OPIC/Ex-Im responsibility for about 14,000 MMCTE is thus roughly 28 times larger than the President's stated goal, assuming, conservatively, that the goal is met.[50]

42. While no international decision has been made about the level at which atmospheric concentration needs to be limited to avoid "dangerous anthropogenic interference," very substantial cutbacks in the projections of CO_2 emissions will be required in the next few decades to significantly limit the warming projected for later in the 21st century. The earlier the cutbacks begin, the more effective they will be and the greater the likelihood that climatic and environmental thresholds that would commit society to "dangerous anthropogenic interference" with the climate system would not be exceeded. With these thresholds in mind, international negotiators are considering levels for stabilization ranging

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[49] 68 Fed. Reg. 52932.

[50] It should be noted that the EIA base case actually assumed that business as usual activities would achieve about 75% of this reduction, meaning that the President's initiatives are really only responsible for about one quarter of the indicated amount. If the comparison were thus to the impact of the special initiatives of the President, the OPIC/Ex-Im emissions would be roughly 100 times as large.

from about 450 to 750 ppmv.[51] Integrated over the century, not exceeding these concentration limits will require that total emissions during the 21st century not exceed about 600 to 1400 GtC and that significant reductions follow in later centuries.[52] By contrast, the IPCC's scenarios without control measures would lead to a CO_2 concentration between about 500 and 1100 ppmv based on total CO_2 emissions over the 21st century ranging from about 1000 to 2100 GtC.

43. In that current global fossil fuel-induced emissions of CO_2 alone are over 6 GtC/yr (and would be higher if the contribution from deforestation were added in), continuation of the present level of emissions would use up the *total* allotment for the lowest stabilization level (i.e., 450 ppmv) and use up about 50% for the highest plausible acceptable stabilization level (i.e., 750 ppmv). Note that it is only with considerable effort that any current emitters are making efforts to reduce their present emissions commitment, while most, including the US, are emitting increasing amounts of greenhouse gases.

44. As indicated earlier, the compilation of CO_2 emissions for Ex-Im and OPIC totals approximately 51 billion tonnes of CO_2 over the course of the 21st

[51] The IPCC projects that stabilization at these concentration levels would lead to an increase in global average temperature from 2000 to 2100 of about1.7 to 2.6ºC (about 2.9 to 4.7ºF), with further warming continuing after 2100 (stabilization at higher levels would lead to even larger changes in climate). Adding in the 0.6ºC (about 1ºF) warming that has already taken place, this would mean that human activities would have raised the global average temperature by roughly 2.3 to 3.2ºC (about 3.1 to 5.8ºF). An increase in the global average temperature by such amounts would trigger the various consequences enumerated in this affidavit.

[52] IPCC, *Climate Change 2001: Mitigation* (Pachauri et al. eds., Cambridge Univ. Press 2001) (available at http://www.grida.no/climate/ipcc_tar/wg3/index.htm) ("Working Group III report"), figure SPM.2 on page 6.

century (roughly 14 GtC). If the decision is made to stabilize the atmospheric composition at 450 ppmv in order to limit the damaging environmental and societal consequences of climate change, the OPIC/Ex-Im emissions of 14 GtC over the next several decades is about 2.3% of the total global allotment of emissions for the 21st century and would need to be 100% offset by reductions in the emissions of other current emitters if the 600 GtC limit on total emissions during the 21st century is not to be exceeded. Even if the 750-ppmv level is selected, and such a choice would lead to very damaging climatic and environmental consequences, this choice would allow for only an additional 800 GtC over the 21st century, and the OPIC/Ex-Im claim from recent approvals of projects is already at about 1% of this total. In that there will be many demands for a share of this total, it would seem that very careful consideration should be given to all projects that would draw upon any commitment of future emissions.

45. With emissions at current rates already causing significant environmental impacts in some regions of the US and around the world, eliminating or greatly reducing the substantial amount of carbon emissions associated with OPIC/Ex-Im projects would help ensure that critical climatic thresholds are not exceeded and would be an important component of efforts to significantly reduce and delay the projected adverse consequences of global warming resulting from present and future emissions. Significant limitations in emissions would also significantly increase the likelihood that there would be time for additional development and deployment of more efficient and non-carbon releasing

technologies before key environmental thresholds are exceeded. With such efforts, accompanied by progress in limiting emissions of other greenhouse gases and of CO_2 from other sectors, it would be much more likely that the extent of climate change could ultimately be limited to levels that would avoid the most serious impacts of global warming.

I declare under the penalty of perjury that the foregoing is true and correct to the best of my knowledge.

Executed on Dec 22, 2004, in Bethesda, Maryland.

Michael C. MacCracken, PhD