Juliana, et al. v. United States of America, et al.

Expert Report of Professor John P. Weyant

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PRIVLEGED AND CONFIDENTIAL

I. Qualifications

1. I am a Professor of Management Science and Engineering, Director of the Energy Modeling Forum (EMF), and Deputy Director of the Precourt Energy Efficiency Center at Stanford University. I am also a Senior Fellow of the Precourt Institute for Energy and an affiliated faculty member of the Stanford School of Earth, Energy, and Environmental Sciences, the Stanford Woods Institute for the Environment, and the Freeman Spogli Institute for International Studies at Stanford. My current research focuses on global climate change policy and systems analysis, energy systems analysis, energy technology assessment, and models for strategic planning. I currently serve as honorary co-editor of the journal *Energy Economics* and on the editorial board of the journal *Energy*.

2. I have been a convening lead author or lead author for the Intergovernmental Panel on Climate Change ("IPCC") for chapters on integrated assessment, greenhouse gas mitigation, integrated impacts of climate change, and sustainable development. More recently, I served as a review editor for the climate change mitigation working group of the IPCC's fourth (2003–2006) and fifth assessment (2010–2013) reports. I am a founder and have served as chairman of the Scientific Steering Committee of the Integrated Assessment Modeling Consortium (IAMC)—a collaboration of over 50 global modeling centers from around the world—since its inception in 2007. Over the years I have been active in the United States ("U.S.") debate on climate change policy through the Department of State, the Department of Energy, and the Environmental Protection Agency ("EPA"). In California, I was a member of the California Air Resources Board's Economic and Technology Advancement Advisory Committee (ETAAC), which was charged with making recommendations for technology policies to help implement AB 32, The Global Warming Solutions Act of 2006.

3. I have been awarded the U.S. Association for Energy Economics' 2008 Adelman-Frankel award for unique and innovative contributions to the field of energy economics and the International Association for Energy Economics Outstanding Contributions to the Profession Award for 2017. I was honored in 2007 as a major contributor to the Nobel Peace Prize awarded to the IPCC and in 2008 by Chair Mary Nichols for contributions to the ETAAC on AB 32.

4. I was asked to provide Congressional testimony on oil security during the 1980s and climate policy during the 1990s and have testified before several California state agencies on climate policy during the 2000s.

5. I earned a B.S. in Aeronautical Engineering and Astronautics, M.S. degrees in Engineering Management and in Operations Research and Statistics all from Rensselaer Polytechnic Institute, and a Ph.D. in Management Science with minors in Economics, Operations Research, and Organization Theory from University of California at Berkeley. After receiving my doctorate, I was a National Science Foundation post-doctoral fellow at Harvard's Kennedy School of Government.

6. My CV, which is attached as Appendix A, summarizes my professional experiences and accomplishments. It also includes a list of my publications, including those in the last 10 years. I have not previously testified in federal or state court. I am being compensated for my time on this matter at an hourly rate of \$650. My compensation is not contingent on the outcome of the litigation. I have been assisted in this matter by the staff of Cornerstone Research, who worked under my direction. A list of documents I have relied on for my report is attached as Appendix B.

II. Summary of Allegations and Assignment

7. Plaintiffs, a collection of young adults and youth, allege that the U.S. government, broadly, and specific federal governmental agencies have been aware for decades about the harm of carbon dioxide (CO₂) emissions and the negative effects that unabated CO₂ emissions have on the global climate.¹ Plaintiffs point to a White House report on the environment in 1965 and to

¹ First Amended Complaint for Declaratory and Injunctive Relief, *Kelsey Cascadia Rose Juliana et al., Plaintiffs, v. The United States of America et al., Defendants,* 9/10/2015 ("Complaint"), ¶1 ("For over fifty years, the United States of America has known that carbon dioxide ('CO2') pollution from burning fossil fuels was causing global warming and dangerous climate change, and that continuing to burn fossil fuels would destabilize the climate system on which present and future generations of our nation depend for their wellbeing and survival.").

the EPA and Congressional Office of Technology Assessment (OTA) reports in 1990 and 1991, respectively, as evidence of the government's historical knowledge of the harms of greenhouse gases ("GHG").² This "knowledge," combined with an alleged failure to act to phase out CO₂ emissions (part of the Defendants' conduct at issue) has allegedly resulted in exposing Plaintiffs to hazardous conditions through the mechanism of climate change.³ The Complaint specifies a list of injuries that each Plaintiff has allegedly incurred because of his or her exposure to human-induced climate change.⁴

8. The Complaint alleges that there is consensus within the scientific community that "[p]resent climate change is a consequence of anthropogenic GHGs, primarily CO₂, derived from the combustion of fossil fuels,"⁵ a position to which the federal Defendants agreed in their response to the Complaint.⁶ Plaintiffs state that atmospheric CO₂ levels in excess of 350 ppm have created energy imbalances in the global climate and, as part of their claimed remedies, ask the Court to direct the Defendants to take action "to ensure that atmospheric CO₂ is no more concentrated than 350 ppm by 2100."⁷

9. Plaintiffs have submitted multiple expert reports in support of their positions. I was directed to examine aspects of the reports of Dr. Kevin Trenberth and Prof. Steven Running. Counsel for Defendants in this matter asked me to:

a. Evaluate whether the current climate models can tie increases in GHG (primarily CO₂) emissions attributable to Defendants' conduct at issue to the injuries alleged by Plaintiffs. Alternatively posed, can climate models demonstrate that Plaintiffs, living in the various states where they reside (Oregon, Colorado, Louisiana, etc.), suffered the types of climate-related injuries they have claimed because of increased CO₂ emissions attributable to the actions of the Defendants?

² Complaint, $\P2-3$.

³ Complaint, ¶7 ("Yet, rather than implement a rational course of effective action to phase out carbon pollution, Defendants have continued to permit, authorize, and subsidize fossil fuel extraction, development, consumption and exportation – activities producing enormous quantities of CO_2 emissions that have substantially caused or substantially contributed to the increase in the atmospheric concentration of CO_2 . Through its policies and practices, the Federal Government bears a higher degree of responsibility than any other individual, entity, or country for exposing Plaintiffs to the present dangerous atmospheric CO_2 concentration.").

⁴ Complaint, ¶¶16–92.

⁵ Complaint, ¶202.

⁶ Federal Defendants' Answer to First Amended Complaint for Declaratory and Injunctive Relief (Defendants' Answer), ¶202.

⁷ Complaint, ¶¶12, 203, 257.

b. Estimate what would have happened to atmospheric CO₂ concentrations had the U.S. government curbed U.S. CO₂ emissions in 1990.

III. Overview of Report and Summary of Opinions

10. As is not disputed in this lawsuit, the current scientific consensus is that global temperatures have increased, in part due to anthropogenic reasons (i.e., human-induced causes, where human-induced causes include some unrelated to GHG and some related to GHG, of which some part is related to Defendants' conduct at issue). As is also not disputed in this lawsuit, this increase in global temperatures has resulted in climate change across the planet.⁸ I agree with the consensus view, and my report does not dispute this general understanding. Rather, I am addressing the current state of the science of climate change models and their ability to support the localized effects implicit in Plaintiffs' claims of harm (i.e., what injury did they suffer as a result of the Defendants' conduct at issue).

11. My summary opinions in this matter are:

- The reports of Plaintiffs' experts Dr. Trenberth and Prof. Running do not and cannot reliably tie global climate change due to the Defendants' conduct at issue to the claimed injuries they allege affected Plaintiffs where they live, work, or recreate. Their reports do not and cannot distinguish any injuries suffered by Plaintiffs to the specific Defendant conduct at issue (versus other entities, governments, or countries that have substantially contributed to human-induced climate change) because the current state of our scientific understanding is not sufficiently developed. This is because:
 - These climate and climate impact models generally cannot determine the regional effects of global climate change to the degree of specificity necessary to causally link to specific weather events, let alone to individuals and any claimed injuries.
 - A critical challenge is that it is difficult to disentangle the effect of regional climate changes from the effect of other region-specific confounding factors. While the local climate affects the circumstances of outcomes such as crop productivity, coastal damage from storms, frequency of wildfires, injury from heat stress, etc., so do other factors such as local economic growth, migration, urbanization, air and water

⁸ Defendants' Answer, ¶202.

pollution, forest and farm management processes, etc. The current set of climate and climate impact models cannot separate these factors with sufficient certainty to disentangle the effect of regional climate changes from the effect of other region-specific confounding factors.

- Thus, the current state of the climate change and climate impact analysis and modeling do not allow one to determine if the specific types and magnitude of injuries to individuals, as asserted by Plaintiffs' experts, are related to something as specific as CO₂ emissions attributable to Defendants' conduct at issue.
- Dr. Trenberth's use of the "conditional" approach that he describes does not remedy the inability of current climate models to determine if Plaintiffs have been injured due to the Defendants' conduct at issue.
- Had the U.S. government been able to stop all U.S. emissions of CO₂ from fossil fuels immediately beginning in 1990—whether from government entities directly or from the U.S. private sector—I predict using a climate model that atmospheric CO₂ concentration in 2015 (when the Complaint was filed) would have been 389 ppm instead of 401 ppm, a 12 ppm difference.

IV. Injury Asserted by Plaintiffs' Expert Dr. Trenberth

12. Dr. Trenberth discusses specific injuries that he claims Plaintiffs experienced as a consequence of human-induced climate change.⁹ Exhibit 1 is a summary of the types of climate change impacts Dr. Trenberth has made on behalf of Plaintiffs and the nature of Plaintiffs' alleged injuries. In arriving at his conclusions, Dr. Trenberth discusses two approaches to the climatological science research associated with climate events—one he calls the "conventional" approach, and the other he calls the "conditional" approach.¹⁰ The conventional approach has been the fundamental approach used by scientists and is the basis for IPCC assessments used to inform policymakers on the state of scientific understanding of climate change and its impacts.

13. Dr. Trenberth acknowledges the difficulties of determining if specific weather events are the result of naturally occurring cycles versus the result of human-induced climate change under the conventional approach. After acknowledging these limitations of the conventional approach

⁹ Report of Kevin Trenberth ("Trenberth Report"), April 11, 2018, pp. 20–22.

¹⁰ Trenberth Report, pp. 14–16.

to impact assessment, Dr. Trenberth dismisses the conventional approach in favor of a new "conditional" approach:

- "The second kind of attribution study, the conditional approach, relates to the objective of assessing the role of human activities, and especially of human-induced climate change, in the event. Results depend, however, upon how the questions are framed." ¹¹
- "Because of the infinite variety of weather systems and how rapidly they develop and respond to small perturbations, the atmospheric circulation (dynamics) aspects of climate change are much less predictable than those associated with heat and temperature (thermodynamics). Hence separating out the thermodynamic from dynamic effects in extreme events, i.e., the conditional approach, is a new fruitful way forward in evaluating attribution and results in a different set of questions to be addressed than in the past (prior to 2015)."¹²

14. After introducing the conditional approach, Dr. Trenberth then discusses several examples of extreme climate events before summarizing how various Plaintiffs were affected. What Dr. Trenberth critically does not address is how the weather events Plaintiffs experienced resulted in the injury that he asserts they incurred due to human-induced climate change. To understand why his assertions are unsupported, it is necessary to understand why the conventional approach cannot translate into localized impacts at the scale necessary to know that an individual has been injured by a human-induced changing climate, let alone injured due to the Defendants' conduct at issue. Dr. Trenberth's use of the conditional approach does not remedy these limitations.

A. Dr. Trenberth's Criticisms of the Intergovernmental Panel on Climate Change are Misguided

- 15. Dr. Trenberth offered several criticisms of the IPCC process:
 - "it is a consensus assessment among very disparate scientists from many countries with varying expertise";
 - "it is extremely conservative and lags behind the state-of-the-art scientific understanding";

¹¹ Trenberth Report, p. 15.

¹² Trenberth Report, p. 16.

• "because it is thoroughly reviewed, it is not current at time of publication."¹³

16. Scientists contributing to the IPCC reports arrive at a consensus opinion. Authors who are responsible for various chapters in the report (coordinating lead authors) work with the IPCC leadership to recruit additional lead authors for their chapters, but can also solicit help from other contributing authors who are scientists in specific key areas. Coordinating lead authors have great discretion in deciding who to invite to be contributing authors and in deciding how many of them would be useful in improving the quality of their chapters. These authors work with IPCC leadership and governments to get the best scientific and government reviewers of the work. A large amount of input is obtained from the experts that participate in the IPCC's comprehensive, open, scientific and government review cycles.

17. The process is designed to avoid bias and to avoid drawing strong conclusions from new literature that has not been replicated or thoroughly vetted by the relevant scientific communities. In my opinion, the IPCC process is a detailed but necessary one that serves the purpose that Dr. Trenberth notes: "to provide policy makers with an objective assessment of the scientific and technical information available about climate change, its environmental and socio-economic impacts, and possible response options."¹⁴

18. In criticizing the timeliness of the information provided by IPCC reports, Dr. Trenberth ignores the flexibility in the IPCC process, afforded by its current rules, to consider the most recent scientific work that is published closer to the time of the issuance of the IPCC's report. Additionally, the IPCC's assessment reports are complemented by (a) IPCC special reports that operate on a faster time table; (b) National Climate Assessment ("NCA") reports done in the U.S. every four years; and (c) analyses from the National Academy of Sciences ("NAS") and other scientific bodies here and abroad to develop science consensus reports to fill in and update the state of the science between IPCC reports.

¹³ Trenberth Report, p. 15, footnote 5.

¹⁴ Trenberth Report, p. 15, footnote 5.

B. Dr. Trenberth's Conditional Approach Lacks the Elements to Determine Regional and Sectorial Impacts

19. As noted above, Dr. Trenberth endorses a "conditional" approach for evaluating whether extreme weather events were affected by human-induced climate change. To understand the flaws in Dr. Trenberth's conclusion that Plaintiffs have been injured, it is useful to understand the models for studying climate change's impacts.

20. Scientists have developed a wide range of models of varying degrees of sophistication and resolution used to study climate changes and their impacts on natural and human systems. Three main types of models have been developed and applied in parallel. First, there are comprehensive large-scale earth systems models of the global climate system that have been developed over the last three or four decades. Second, a number of physical and social systems models have been developed to study the impacts of changes in climate and other physical and socioeconomic drivers on physical and economic activity in key sectors and regions of the United States and elsewhere. Finally, in parallel with the other two model types, so-called integrated assessment models have been developed and refined to combine representations of human behavior with simplified representations of the physical earth system to study interactions between the two in more detail. Taken together, these models are focused on measuring and predicting the effects of climate change on natural systems and human systems in specific locations. These models are used to try to draw conclusions about the global climate system changing beyond the annual to decadal cycles in average weather around the world and the role that human activities have played in driving these trends (i.e., the human-induced element of climate change). Results from all three types of models have been used to inform global understanding and decision making regarding global climate change and possible responses to it.

21. The conditional approach is a partial substitute for the first type of model in the conventional approach (i.e., the comprehensive large-scale earth system models). The conditional attribution framework examines the influence of some meteorological measures of extreme climate events, but does not consider the factors included in the second and third types of models. Understanding impacts on physical and social systems—the goal of understanding how human-induced climate change may be affecting people—is not addressed by the conditional approach described by Dr. Trenberth.

22. The physical and social system models (second model type) and integrated assessment models (third model type) examine how we are impacted by the climate event, not simply whether the intensity of the extreme weather event may have been increased by additional GHG emissions. For example, changes in agricultural crop growth, coastal zone damage from hurricanes, heat stress-related illness, and wildfire activity can be affected by global climate change, but they are also impacted by other socioeconomic factors.¹⁵ In the conventional approach, attributing these specific changes to human-induced global climate change is a difficult research task because (1) relating changes in local climate to change in global climatology, including sorting out the global and regional effects of annual and inter-annual variability on the climate system, is complicated science; and (2) the local changes that have been observed may be due to a number of non-meteorological factors (e.g., population growth, urban development, air and water pollution, etc.), as well as changes in local climatology. The conventional approach attempts to understand the attribution "pathways" and has been an important aspect of climate change research. Dr. Trenberth's use of the conditional approach does not eliminate the need to understand these pathways, even if it changes the initial manner in which the climatological influence on local meteorological conditions question is posed.

23. Since the 2001 IPCC report, some of the pathways from increased GHG concentrations to regional changes in climate to changes on physical (e.g., crop growth, ecosystems, and sea levels) and socioeconomic systems (e.g., food prices and farm incomes, coastal zone storm damages) in those regions have been partially identified and measured at least qualitatively, but others remain largely unmeasured and/or unresolved. There are confounding factors that provide alternative explanations for regional and sectoral climate changes, and especially events that may cause negative impacts on people and property. These confounding factors can be other physical and human changes (e.g., population growth, urban development, costal development, forest and agricultural management practices, air and water pollution, etc.) that affect the ability to attribute local impacts to human-induced climate change. Also, any fine-scale projections of climate change impacts have to model the degree of adaptation assumed in past and projected future human behavior. Adaption refers to the process by which people change their behaviors to limit

¹⁵ "Climate Change 2001: Impacts, Adaptation, and Vulnerability," IPCC Third Assessment Report Working Group II Summary for Policy Makers, p. 5, https://www.ipcc.ch/ipccreports/tar/wg2/pdf/WGII_TAR_full_report.pdf.

harmful effects from changing climates. Adaptation has been part of IPCC commentary to policymakers. Policymakers need to consider adaptation when they evaluate policy options relating to climate change.

24. In attributing specific impacts in specific locations on specific individuals, it is necessary to analyze historical data on climate changes and other physical and socioeconomic trends in those specific locations. In the conventional approach, this creates the challenge of running a very high resolution climate model and/or "downscaling" the climatic conditions to the scale where the impacts are most effectively analyzed (e.g., growing regions, water and/or river basins, urban or rural neighborhoods, etc.). However, climate projections at finer scale are less reliable than global averages, and the techniques for downscaling to more specific geographic locations adds additional uncertainty to the calculations. This further adds to the lack of reliability in projections of regional impacts resulting from incremental changes in global GHG emissions.

25. To understand fully how global GHG concentrations contribute to regional impacts, global climate models also need to be integrated with regional/sectoral models and then further integrated with physical and economic impacts that until recently have not generally accounted for other confounding influences that may affect local climate change impacts. These local conditions can include changes in demographics (e.g., population growth, migration, urbanization, forestry management practices) and other environmental stresses (e.g., water, air, and solid waste pollution). I am unaware of efforts to integrate the results of any conditional approaches with local conditions to attribute local impacts to human-induced climate change. By failing to analyze the potential confounding effect of local conditions, Dr. Trenberth reaches conclusions about the impacts on Plaintiffs that are unsupported and therefore unreliable.

C. Unsupported Logical Leap of Dr. Trenberth's Analysis

26. Dr. Trenberth concludes that numerous Plaintiffs have experienced extreme weather events exacerbated by human-induced climate change and that based on where they live they likely will experience more.¹⁶ The analytical support that Dr. Trenberth provides for each

¹⁶ Trenberth Report, p. 23 ("Plaintiffs including Jayden, Levi, Xiuhtezcatl, Victoria, Jaime, Journey, Zealand, and Nathan are already experiencing extreme weather events that have been exacerbated due to anthropogenic climate change. Furthermore, based on the regions where they live, it is my expert opinion that they are likely to experience even greater impacts from extreme weather events in the coming decades.").

Plaintiff varies, but all his conclusions of the injuries to Plaintiffs suffer from the same failure to connect his conditional approach conclusions to Plaintiffs' local circumstances.

- 27. To illustrate the incompleteness in Dr. Trenberth's analysis, a few examples follow:
 - a. Dr. Trenberth states: "Plaintiff Jaime from Cameron, AZ, has experienced water shortages related to increasing significant drought, wildfires and heat waves. Wildfires, drought and heatwaves have increased in the area of Jaime's home and reservation because of human-induced climate change."17 As a case in point, with regard to heat waves, Dr. Trenberth does not address her individual circumstance nor the conditions in Arizona where she lived when experiencing heat waves.¹⁸ Increases in local temperature extremes have been observed in some locations as global mean temperature rises, but how this has caused the incidence of heat stress on local populations may also depend on whether the area has become urbanized, creating what is called an "urban heat island effect" that raises inner city temperatures more than in the surrounding suburban and rural areas. Complicating efforts to measure incidences of heat stress are changing demographics within communities, if, for example, the population becomes more vulnerable (e.g., becomes more weighted to the very young or very old). Further complication results if the population adapts its behavior in response to higher temperatures, including undertaking less rigorous activities during heat waves or times during the day when temperatures peak. Overall, Dr. Trenberth's conclusions are not supported by analysis that allows one to determine how and to what degree Jaime's experiences with water shortages, wildfires, droughts, or heat waves are exacerbated by human-induced climate change. In other words, how were these events different (e.g., more extreme) than in a normal year in arid Arizona? Dr. Trenberth's conclusion about the causes of Plaintiff Jaime's injuries are not based on any analysis of her situation.

¹⁷ Trenberth Report, p. 21.

¹⁸ Dr. Trenberth states that Plaintiff Jaime is from Cameron, Arizona, but the Complaint (¶66) states that she moved to Flagstaff in 2011.

b. Dr. Trenberth states that Plaintiffs Levi from Florida, Journey from Kauai, HI, and Victoria from White Plains, NY, all experienced hurricanes to one degree or another that were magnified in some manner by human-induced climate change.¹⁹ Dr. Trenberth does not address the individual circumstances of the hurricanes that threatened Kauai in 2015, nor in any detail Hurricanes Matthew in 2016 or Irma in 2017 that reached landfall in Florida. He does discuss meteorological aspects of Super Storm Sandy which affected Plaintiff Victoria.²⁰ Extreme weather events that are localized by their very nature, such as hurricanes, offer another example of the challenges of determining if, or to what extent, coastal zone damage from a hurricane can be attributed to human-induced climate change. Increases in property losses due to hurricanes may result from more intense storms involving higher winds, which may or may not be accompanied with more intense rainfall. Whether flooding and any related property losses occur depends on the topography of where the hurricane makes landfall combined with rainfall amounts and intensity. Property losses from high winds, rain, or flooding may increase simply because there are more people, infrastructure, and economic activity in coastal areas now than there has been historically. Such coastal migration would increase the expected damage from storms even without any climate changeinduced changes in the intensity of the storms.²¹ Dr. Trenberth concludes "Sandy was undoubtedly larger and stronger as a result of climate change, and the storm surge was much greater owing to high sea levels and strong winds" and that subways in New York would not have flooded without these warming-induced

¹⁹ Trenberth Report, pp. 20–21.

²⁰ Trenberth Report, p. 18. Dr. Trenberth's discussion includes cost estimates of the storm.

²¹ See National Academies of Sciences, Engineering, and Medicine, *Attribution of Extreme Weather Events in the Context of Climate Change* (The National Academies Press, 2016) ("NAS Report 2016"), p. 41. ("The 'extreme' nature of coastal flooding is therefore a product of a combination of different anthropogenic impacts, some of which have little to do with climate-mediated effects like sea level rise."). Adaptive strategies that can affect storm damage and complicate attribution efforts include items such as (a) improved predictions on storm direction providing more advanced warning times to threatened communities; (b) emergency preparedness efforts by individuals, firms, and government agencies; and (c) stricter building code rules and enforcement.

storm effects.²² Dr. Trenberth fails to analyze (or even discuss) the confounding factors I mention, which renders his attributions conclusory.

- c. Dr. Trenberth states: "Plaintiff Journey in Kauai is threatened by extreme storm events. In 2015 an unprecedented number of hurricanes threatened the Hawaiian Islands, again enhanced by human-induced climate change."²³ Dr. Trenberth offered this opinion without explanation for how and the degree to which these storms were "enhanced" by human-induced climate change compared to a year when Kauai would have experienced a typical number of hurricanes.²⁴
- d. Dr. Trenberth states: "Plaintiff Jacob, Roseburg, Oregon, lives on a farm and enjoys the outdoors. He has become very concerned and influenced by the expanding wildfire season, especially in 2015, when smoke degraded the air quality on many days. The wildfire season has become longer and more intense due to human-induced climate change."²⁵ Dr. Trenberth's analysis does not address the degree to which the 2015 wildfire season in Oregon was affected by human-induced climate change compared to a normal wildfire season in the area where Plaintiff Jacob lives. Human activity in and near forests is a confounding factor in any analysis of the incidence of wildfire, and Dr. Trenberth is silent on such confounding factors. Importantly, in conjunction with the IPCC's most recent report, the group summarizing the state of scientific understanding for policymakers noted that there was only medium confidence that climate change was a *minor* contributor to increased wildfire activity in western U.S. forests.²⁶ Specific to Oregon, Exhibit 2 is a chart prepared by the Oregon Department of Forestry ("ODF") for forests in Oregon for which ODF is responsible. The chart

²² Trenberth Report, p. 18. A *Time* article indicates that age or design likely contributed to the flooding problems that the New York subway experienced in the storm. The Lessons from New York's Flooded Subways, Jeffrey Kluger, *Time*, October 30, 2012.

²³ Trenberth Report, p. 21.

²⁴ See general discussion of hurricanes at pages 10–14 of the Trenberth Report.

²⁵ See general discussion of droughts and wildfires at pages 8–9 of the Trenberth Report.

²⁶ "Climate Change 2014: Impacts Adaptations, and Vulnerability," IPCC, Summary for Policymakers, p. 31 ("Increase in wildfire activity, fire frequency and duration, and burnt area in forests of the western U.S. and boreal forests in Canada, beyond changes due to land use and fire management (medium confidence, minor contribution from climate change)".).

overlays several types of historical data related to wildfire activity. Among the contributing or potentially contributing causes of fire activity, the chart depicts drought years, warm versus cool local climate phases, human-started versus lightning-caused fires, and regulatory and legislative changes involving forest management. Each of these factors is likely relevant in examining the extent of wildfire activity in Oregon. The ODF chart undermines Dr. Trenberth's assertions that 2015 was extraordinary and that the wildfire season has become longer and more intense due to human-induced climate change. At a minimum, Exhibit 2 shows that Dr. Trenberth's claims would require further analysis to be scientifically reliable.

e. Dr. Trenberth states: "Plaintiff Nathan has experienced thawing permafrost and wildfires around his home in Fairbanks, Alaska, especially in 2015. Thawing permafrost is uneven and more likely on sunlight slopes, and has led to tilted and broken buildings and frost heaves in roads. Wildfires were widespread in Alaska in the summer of 2015. These harms are made worse by human-induced climate change."²⁷ As with his other examples, Dr. Trenberth does not address any confounding factors that might have contributed to the specific weather outcomes in Alaska in 2015, the analysis of which is essential to reach a scientifically valid conclusion about any causal role played by human-induced climate change on Plaintiff Nathan.

V. Limitations of Prof. Running's Analysis

28. Prof. Running concludes that climate change has affected Plaintiffs and impaired their quality of life.²⁸ See Exhibit 1. He concludes that the inaction of the U.S. government "will serve to penalize future generations of Americans, including the Plaintiffs, for as far into the future as I can imagine."²⁹ Prof. Running's report, however, does not measure the contribution of the U.S. government, either directly or via policy to change the behavior of the U.S. public, to

²⁷ Trenberth Report, p. 22.

²⁸ Report of Steven W. Running (Running Report), April 3, 2018, pp. 3, 9, 13, 14, 17.

²⁹ Running Report, p. 29.

the climate change trends that his report discusses. Specifically, his report fails to describe, because the science cannot support it, the interaction between these two factors: (a) how to disentangle natural cycles from human-induced climate change at the regional and sectoral level he examined, and (b) what the Defendants' contribution (whether via its direct GHG emissions or a broader definition) is to the ecological impacts he addresses and the alleged injuries to Plaintiffs.

29. When Prof. Running makes claims about injuries to Plaintiffs, he simply presumes that human-induced climate change is the major cause of the multiple hydrological and ecological changes that he discusses, despite the fact that population growth and migration, forest and water management practices, and wildfire and flood prevention measures are also important determinants of the climate events he analyzed. For example, while global warming and less precipitation lead to dryer forests on average, other human activities confound attempts to isolate the impact of climate variables on the area of forest land burned by fires in a given region, unless they are explicitly in the specifications of the model.³⁰

A. Extreme Events

30. Identifying the root causes of extreme events, including storms, droughts, and wildfires, can be particularly difficult. A recent compilation report from the NAS of the known science related to these events examined the degree to which they can be attributed to human-induced climate change, noting:

• "Some types of observation-based approaches to event attribution use the historical context in order to determine changes in the rarity of an observed event based on long-term data. For example, this might involve comparing the statistical probability of an event in today's climate to its probability in some previous time several decades earlier when the concentration of anthropogenic greenhouse gases (GHGs) was much lower. In practice, historical observations are often not available for a long enough period to enable a reliable statistical

³⁰ Studies that consider the role of climate change in increasing fire extent may not be very definitive if, for example, changes in the number of trees resulting from forest management practices, number of people living near forests, number of people visiting forests, and number of forest rangers are all changing simultaneously and those changes are not taken into account.

evaluation of whether there has been a significant change in event frequency or intensity."³¹

- "Droughts, floods, and wildfires, for instance, all have human, as well as natural, components. Land management, controlled burning, and dams and levees impact the magnitude and frequency of these extreme events."³²
- "Non-meteorological factors can limit the accuracy of model simulations of extreme events and confound observational records. Drought and wildfire are examples of events for which non-meteorological factors can be especially challenging in attribution studies."³³
- "Event attribution can be further complicated by the existence of other factors that contribute to the severity of impacts. For example, while many studies have linked an increase in wildfires to climate change, the risk of any individual fire depends on past forest management, natural climate variability, human activities in the forest, and possibly other factors, in addition to any exacerbation by human-caused climate change."³⁴

B. Human Influence on Wildfires

31. Human activity is a distinct confounding factor in evaluating the causes of wildfires. Humans are frequently responsible for starting fires. The ODF chart (Exhibit 2) shows that human-started fires were more common than lightning-caused fires in each year between 1957 and 2017 in Oregon. It is estimated that across the coterminous U.S. 84 percent of wildfires between 1992 and 2012 were started by people, with distinct regional differences in the proportion of human-initiated fires.³⁵ This research also notes that, by starting fires *when* they would not start naturally, humans have prolonged the wildfire season outside of the normal summer months.³⁶ Finally, by starting fires *where* they would not start naturally, humans have

³¹ NAS Report 2016, p. 3.

³² NAS Report 2016, p. x.

³³ NAS Report 2016, p. 7.

³⁴ NAS Report 2016, pp. 7–10.

³⁵ Jennifer K. Balch et al., "Human-Started Wildfires Expand the Fire Niche across the United States," Proceedings of the National Academy of Sciences, *PNAS* 114, no. 11 (March 14, 2017) ("Balch et al. (2017)"), pp. 1–2 ("[O]ver 84% of the government-recorded wildfires were started by people from 1992 to 2012. Sixty percent of the total land area of the coterminous United States was dominated by human-started wildfires, whereas only 8% of the area was dominated by lightning fires.").

³⁶ Balch et al. (2017), p. 2 ("Of all lightning-ignited fires, 78% occurred in the summer (June–August), 9% in the spring (March–May), and 12% in the fall (September–November). In contrast, human-ignited wildfires were more evenly distributed throughout the year, with 24% in summer, 38% in spring, 19% in fall, and 19% in winter.").

expanded the area where wildfires likely occur.³⁷ Other papers suggest human presence "swamps" the effect of climate on wildfire activity.³⁸

32. More people living in and near forests is a confounding factor when evaluating the causes and impacts of wildfires. For example, the population in Oregon nearly doubled between 1969 and 2016, growing from 2.1 million to 4.1 million. Eugene, Oregon, were several Plaintiffs live, grew 77 percent over that same period.³⁹ Recent research indicates that people are encroaching on forested areas, which complicates firefighting policy and potentially diverts wildfire fighting resources.⁴⁰

33. The management of U.S. forests is another confounding factor when examining the incidence of wildfires. Forestry management practices of fire suppression, combined with other factors, have increased fuel loads in forests, increasing hazards compared to historical norms.⁴¹

34. In sum, humans are frequently responsible for starting fires, but our impact on the incidence and extent of wildfires is similarly pronounced. These types of complicated interactions are emblematic of the confounding factors that scientists need to consider when examining the influence of climate change. It is the part of the reason why Prof. Running's

³⁷ Balch et al. (2017), p. 3 ("Areas and months of moderate to high human-caused fire density had approximately 40% fewer lightning strikes, and nearly 50% higher fuel moisture levels (based on median values) than for moderate to high lightning-caused fire density.").

³⁸ Alexandra D. Syphard et al., "Humans Diminish Climatic Influence on Wildfire," Proceedings of the National Academy of Sciences, *PNAS Early Edition*, December 11, 2017, p. 1 ("Climatic variation played a significant role in explaining annual fire activity in some regions, but the relative importance of seasonal temperature or precipitation, in addition to the overall importance of climate, varied substantially depending on geographical context. Human presence was the primary reason that climate explained less fire activity in some regions than in others. That is, where human presence was more prominent, climate was less important. This means that humans may not only influence fire regimes but their presence can actually override, or swamp out, the effect of climate.") See also Michael L. Mann et al., "Incorporating Anthropogenic Influences into Fire Probability Models: Effects of Human Activity and Climate Change on Fire Activity in California," *PLOS One*, April 28, 2016.

³⁹ Eugene MSA's population rose from 208,936 in 1969 to 369,519 in 2016. "Eugene MSA vs. Oregon, Comparative Trends Analysis: Population Growth and Change, 1969–2016," Oregon Regional Economic Analysis Project, https://oregon.reaproject.org/analysis/comparative-trends-analysis/population/tools/78570000/410000/.
⁴⁰ Scott L. Stephens et al., "U.S. Federal Fire and Forest Policy: Emphasizing Resilience in Dry Forests," *Ecosphere*, November 11, 2016 ("Stephens et al. (2016)"), p. 1 ("Current U.S. forest fire policy emphasizes short-term outcomes versus long-term goals. This perspective drives managers to focus on the protection of high-valued resources, whether ecosystem-based or developed infrastructure, at the expense of forest resilience." "Expansion of the wildland–urban interface will continue to drive suppression costs higher; new federal partnerships with States and local governments are needed to address this problem.").

⁴¹ Stephens et al. (2016), p. 6 ("Accordingly, fire suppression response continues to prevail due to a set of decisions and disincentives that heavily favor short-term outcomes. First, it is often most cost-effective in the short-term to contain fire at the smallest reasonable extent but the collective impact of this response over the long-term is to ensure continued fuel accumulation and greater future fire hazard...").

statement that an increased wildfire season due to climate change has and will affect many of the Plaintiffs is an overbroad assertion.⁴² Until our scientific understanding is improved and without a more specific examination of Plaintiffs' circumstances, we cannot know.⁴³ Lastly, Prof. Running makes no effort to address the relative contribution of the Defendants versus other global actors to his opinions.

C. Other Considerations in Attributing Impacts

35. Climate change attributable to GHG emissions is a global phenomenon. Other sources of GHG emissions dwarf emissions from fossil fuels in the United States, let alone GHG emissions of the U.S. government. Prof. Running attributes none of Plaintiffs' injuries to non-U.S. sources of GHG. Not only do other countries generate the majority of GHG emissions, they also do other things that influence outcomes in the United States. For example, Prof. Running discusses the impacts of wildfire smoke on Plaintiffs and notes that Plaintiff Aji of Seattle experienced smoke and ash from a wildfire in 2017, but fails to mention the Canadian influence on that smoke and ash. The news article to which he cites notes that wildfires in Canada were combining with smoke from other U.S. fires to inundate the Pacific Northwest.⁴⁴ In this circumstance, events in Canada influenced by regional environmental factors, Canadian forest management practices, and Canadian wildfire fighting policies and resources contributed to the impact on Plaintiff Aji in Seattle.

⁴² Running Report, p. 13 ("...will impact the many Plaintiffs in the West who suffer increased risk and severity of impacts from wildfires near their homes, in places that they visit for recreation, and in the air they breathe during the extended fire season, including Xiuhtezcatl, Jaime Lynn, Jacob, Sahara, Kelsey, Alex, Zealand, Nick, Aji, Nathan, Hazel and Avery.").

⁴³ Additionally, the 2014 IPCC assessment report offers only medium scientific confidence that human-induced climate change had a minor contribution to wildfire activity in the western U.S., a conclusion at odds with Prof. Running. This IPCC report also notes low scientific confidence involving a minor contribution from climate change on impacts to North American terrestrial ecosystems involving regional increases in tree mortality and insect infestations in forests—another topic to which Prof. Running attributed a larger impact from human-induced climate change and one he indicated negatively affected several Plaintiffs. See "Climate Change 2014: Impacts Adaptations, and Vulnerability," IPCC, Summary for Policymakers, p. 31; Running Report, pp. 13, 17.
⁴⁴ Alan Blinder and Christina Caron, "Seattle Chokes as Wildfire Smoke from Canada Blankets the Northwest," *New York Times*, August 7, 2017, https://www.nytimes.com/2017/08/07/us/wildfires-canada-seattle.html ("Government officials have cautioned people about air quality in a region that is usually known, especially at this time of year, for pristine cobalt skies. But that has not been the case since last week, as the Pacific Northwest has been inundated by plumes of smoke from Canada, where more than 20 wildfires are blazing.... 'There are several fires in the Pacific Northwest that have contributed to the smoke as well,' said Mr. Apfel, who estimated that there were currently about 16 large fires in Washington and Oregon. 'Previous years have had quite a bit of rainfall, and you get a lot of vegetation — and when it dries up, that's what starts burning when the fire starts.'").

VI. Modeling the Effects of a Cessation of U.S. CO₂ Emissions

36. As an additional element of my assignment, I was asked to determine, if possible, what the effects would be on atmospheric CO₂ concentrations had the United States eliminated all fossil fuel CO₂ emissions starting in 1990. In this analysis, I have assumed that the U.S. government as well as all of the U.S. private sector ceased fossil fuel CO₂ emissions beginning in 1990.

37. I examined the change in atmospheric CO₂ concentration from 1990 to 2015 (the date of the Complaint), using the "Model for the Assessment of Greenhouse Gas Induced Climate Change" (MAGICC), a widely used representation of the climate system that links CO₂ emissions to the mean surface temperature on the earth.⁴⁵ The IPCC has used MAGICC extensively to predict global mean temperature increase and sea-level rise.⁴⁶

38. I used the most recent version of the model, MAGICC 6, to calculate CO₂ concentrations in the earth's atmosphere under two CO₂ emissions scenarios:⁴⁷ (1) a baseline business as usual emissions path, and (2) a 100% emissions reduction scenario where the U.S. completely stops emitting CO₂ from burning fossil fuels from 1990 forward. In the no-emissions case, I find that global CO₂ concentrations would decline by 12 ppm (from 401 to 389) in 2015 relative to the baseline business as usual scenario. Exhibit 3A illustrates the effect of the no-emissions case. Cases predicated on more modest emission reductions assumptions result in smaller effects on atmospheric CO₂ levels. For example, assuming an immediate and sustained 25 percent reduction in U.S. CO₂ fossil fuel emissions from 1990 forward, atmospheric CO₂ concentrations would decline from 401 ppm to 398 ppm in 2015, a 3 ppm reduction (see Exhibit 3B).⁴⁸

⁴⁵ MAGICC has a carbon cycle that describes how atmospheric CO₂ concentrations change as a function of emissions and a climate model that relates greenhouse gas concentrations to radiative forcing and mean surface temperature. Major carbon sources and syncs in the carbon cycle component of MAGICC include (1) CO₂ emissions from fossil fuel combustion, industrial activity, and other human-related activity such as agriculture; (2) carbon sequestration in the ocean; and (3) carbon sequestration in land-based biomass. For more details, see Malte Meinshausen et al., "Emulating Coupled Atmosphere-Ocean and Carbon Cycle Models with a Simpler Model, MAGICC6 – Part 1: Model Description and Calibration," *Atmospheric Chemistry and Physics* 11, no. 4 (2011), pp. 1417–1456 ("Meinshausen et al. (2011)").

⁴⁶ Meinshausen et al. (2011).

⁴⁷ MAGICC 6 makes several updates to previous versions, including a more detailed carbon cycle. Meinshausen et al. (2011) provide a summary.

⁴⁸ If asked, I could do this calculation for other assumptions about U.S. CO₂ emissions.

Executed this 13th day of August, 2018

John P. Wayout

John P. Weyant, Ph.D.

Appendix A

CURRICULUM VITAE

(as of August 11, 2018) John P. Weyant

BACKGROUND

ADDRESSES

Room 260 Huang Engineering Center Stanford University Stanford, CA 94305-4121 (650) 723-3506

861 Allardice Way Stanford, CA 94305 (650) 494-3570

PROFESSIONAL INTERESTS

Application of quantitative methods to policy development and strategic planning.

ACADEMIC APPOINTMENTS

STANFORD UNIVERSITY

Professor – Dept. of Management Science and Engineering (1/2000 – present) Professor- Engineering-Economic Systems and Operations Research (9/96-12/99) Professor - Department of Engineering-Economic Systems (9/89-8/96) Associate Professor - Department of Engineering-Economic Systems (9/84-8/89) Senior Research Associate - Department of Operations Research (9/80-8/84) Research Associate - Department of Operations Research (6/77-8/80)

EDUCATION

HARVARD UNIVERSITY:

Postdoctoral Fellow - John F. Kennedy School of Government Research Topic: Quantitative Models in Energy Policy

UNIVERSITY OF CALIFORNIA, BERKELEY:

Doctor of Philosophy - Management Science Minor Fields: Economics, Operations Research, Organization Theory

RENSSELAER POLYTECHNIC INSTITUTE:

Master of Science in Operations Research and Statistics Master of Science in Management B.S. in Aeronautical Engineering and Astronautics

RESEARCH EXPERIENCE

STANFORD UNIVERSITY

PROGRAM ON INTEGRATED ASSESSMENT MODELING DEVELOPMENT DIAGNOSTICS AND INTERCOMPARISONS: Cutting edge research on uncertainty, technology dynamics, and fine scale climate impacts, model diagnostics development, and scenario ensemble construction for IAM community- Lead PI (20 PIs at seven institutions) 8/10-ENERGY MODELING FORUM: The EMF conducts systematic comparative studies of energy-economic models applied to policy problems of current interest. Director (9/84-present) Executive Director (J.L. Sweeney, Director): 1/83 - 8/84 Deputy Director (J.L. Sweeney, Director): 12/79 – 12/82 Associate Director (J.L. Sweeney, Director): 8/78 – 11/79 Research Staff (W.W. Hogan, Director): 6/77 – 11/79 SNOWMASS SUMMER WORKSHOPS ON INTEGRATED ASSESSMENT OF CLIMATE CHANGE: Inter-disciplinary workshops on critical issues for integrated assessment - 6/95-PRECOURT INSTITUTE FOR ENERGY EFFICIENCY: Deputy Director (J.L. Sweeney, Director): 9/07-present GLOBAL CLIMATE AJND ENERGY PROJECT Staff (Lynn Orr, Director): 9/02-9/06 GENERAL MOTORS COLLABORATIVE LABORATORY ON WORK SYSTEMS Co-Director (With Arthur Veinott): 9/00-9/03 INTERNATIONAL ENERGY PROGRAM: The IEP conducted studies on international energy policy issues of current interest. Research Staff (A.S. Manne, Director). 7/81 – 8/85 Research Staff (H.S. Rowen, Director): 9/77 - 6/81 COMBINING ENERGY MODELS PROJECT: The CEM project attempted to develop a set of rules for the combination of energy models of different types. Research Staff (W.W. Hogan & L.J. Lau, Principal Investigators): 8/77 - 4/81

HARVARD UNIVERSITY

ENERGY AND ENVIRONMENTAL POLICY CENTER: 4/76 - 6/77

RAND CORPORATION (Summer Internships)

Air Force Energy Problems (for J.R. Gebman): 6/75 - 3/76 Air Force R&D Planning (for G.K. Smith): 6/74 - 9/74 Air Quality Modeling (for J.R. Gebman): 6/72 - 9/72 Aerodynamics Computer Module (for G.K. Smith): 6/70 - 9/70

U.C., BERKELEY

ENERGY & RESOURCES PROGRAM: Post Graduate Researcher (J.P. Holden, Director): 9/74-6/75

OPERATIONS RESEARCH CENTER:

Postgraduate Researcher (R.C. Grinold, Director): 10/72-12/73

TEACHING EXPERIENCE

STANFORD UNIVERSITY

COURSES TAUGHT: Energy Policy and Strategy Modeling (EES 283 & EES&OR 483 & MS&E 473) 1979 - 2001International Environmental Policy (MS&E 92Q): 2001-present Policy and Strategy Analysis (MS&E 190): 2006-2009 Public Policy Analysis (MS&E 290): 2000-2006 (with William Perry) Climate Policy Analysis (MS&E 294): 2004-present Energy Policy Analysis (MS&E 295): 2005-present Doctoral Research Seminar in Advanced Energy and Environmental Analysis (MS&E 391): 2011-present. Entrepreneurship through the Lens of Venture Capital (MS&E 476): 2014-present (with Ernestine Fu) The Energy Seminar (MS&E 494): 2014-present Entrepreneurship from Business to Government (MS&E 477): 2015-present (with Ernestine Fu)

Seminar on Business & Technology Department of Engineering-Economic Systems 1987 – 1993 Models and Applications of Operations Research in Society (O.R. 50/150) Department of Operations Research 1979-1980

Contingency Planning – The World Oil Market (O.R. 348 A, B, and C, with A. S. Manne) Department of Operations Research 1981 – 1982

Financial Decisions, IE 235 Department of Industrial Engineering Winter 1990, fall 1990, Winters 1993, 1994 & 1995

DISSERTATION COMMITTEES (Total – 191; Principal Adviser – 42): <u>Principal Advisees (Completed Only)</u> Gregory Hamm (Engineering-Economic Systems – 1986) Xia Shi (Engineering-Economic Systems – 1989) Douglas Robinson (Engineering-Economic Systems – 1990) Peter Lilienthal (Engineering-Economic Systems - 1991) Hean-Lee Poh (Engineering-Economic Systems - 1991) Sylvia Kwan (Engineering-Economic Systems – 1994) Eric Johnson (Engineering-Economic Systems – 1994)

Ming-Fai Sit (Engineering-Economic Systems – 1994) Elisabeth Browne (Engineering-Economic Systems – 1995) Thomas Hoff (Engineering-Economic Systems and Operations Research – 1996) Robert Earle (Engineering-Economic Systems and Operations Research – 1996) Chi-Peng Chu (Engineering-Economic Systems and Operations Research – 1996) Shu-Cheng Liu (Engineering-Economic Systems and Operations Research – 1997) Enrique Garza-Escalante (Eng.-Economic Systems and Operations Research- 1998) Quingxuan Meng (Engineering-Economic Systems and Operations Research – 1998) Michael Hsu (Engineering-Economic Systems and Operations Research – 1999) Akira Maeda (Engineering-Economic Systems and Operations Research – 1999) Karen (Cushing) Sepucha (Eng.-Economic Systems and Operations Research – 1999) Karl Knapp (Eng.-Economic Systems and Operations Research – 1999) Kevin Zhu (Eng.-Economic Systems and Operations Research – 1999) Antie Kann (Eng.-Economic Systems and Operations Research – 2000) Wenlong Weng (Eng.-Economic Systems and Operations Research – 2001) Michelle Freed (Eng.-Economic Systems and Operations Research – 2001) John McConnell (Eng.-Economic Systems and Operations Research - 2001) Erin Baker (Eng.-Economic Systems and Operations Research – 2002) Jochen Kleinknecht (Eng.-Economic Systems and Operations Research – 2002) Kazuhiro Ninomiya (Management Science and Engineering – 2003) Tao Yao (Management Science and Engineering – 2005) Albert Whangbo (Management Science and Engineering – 2005) Geoff Blanford (Management Science and Engineering – 2006) Oytun Eskiyenenturk ((Management Science and Engineering – 2006) Leslie Holmes Hummel (Interdisciplinary Program on Environment and Resources-2006) Katherine Calvin (Management Science and Engineering-2007) Dhruv Sharma (Management Science and Engineering -2010) Nikit Abhyankar (Interdisciplinary Program on Environment and Resources -2013) Danny Cullenward (E-IPER & JD Stanford Law School- 2013) John Bistline (Management Science and Engineering – 2013) Jordan Wilkerson (Management Science and Engineering – 2014) Delavane Diaz (Management Science and Engineering – 2015) Ben Leibowicz (Management Science and Engineering – 2016) Karim Farhat (Management Science and Engineering – 2016) Lauren Culver (Management Science and Engineering – 2017)

ENGINEER'S THESIS ADVISEES (3):

Teodoro Myslabodski (Operations Research) Anousheh Alamzad (Engineering-Economic Systems) Vincent Lui (Engineering-Economic Systems and Operations Research)

OTHER ACTIVITIES

MAJOR ADVISORY BOARDS AND COMMITTEE MEMBERSHIPS

- N.R.C. Committee on Nuclear and Alternative Energy Systems (1975-77)
- The Institute for the Future Advisory Board on NSF Interactive Modeling (1978-82)
- Scientists' Institute for Public Information Oil Emergency Task Force (1980)
- Energy Research Commission of Sweden-Research Program Evaluation Comm. (1982-84)
- Office of Technology Assessment Advisory Board on U.S. Gas Supply (1983-84)
- Chairman: E.P.A. Peer Review Panel on Acid Deposition Research (1983-87)
- Advisory Board Electric Power Research Institute Visibility Valuation Project (1983-87)
- National Academy of Sciences: Committee on the Gas Research Institute (1985-87)
- Advisory Board on Utility Model Reviews, California Public Utilities Commission (1986-89)
- Peer Reviewer Final Assessment Report-National Acid Precipitation Assessment Prog. (1990)
- Secretary of Energy Advisory Board (1992-1993)
- Nat. Renewable Energy Lab., Analytic Studies Division Advisory Board (1993-1996)
- Convening Lead Author: Intergovernmental Panel on Climate Change Second Assessment Report, Chapter on Integrated Assessment– Working Group III on Economic and Social Dimensions (1993-1995)
- Lead Author: The Contribution of the Social Sciences to Global Climate Change Policy: A State of the Art Report (1993-1996)
- Director: Snowmass Workshops on Climate Change Impacts and Integrated Assessment (1995-)
- Advisory Board, Consortium on International Earth Sciences Information Network (1995-2002)
- Lead Author, Intergovernmental Panel on Climate Change, Special Report on Emissions Scenarios (1996-1998).
- Advisory Board: Yale/National Bureau of Economic Research Program on Economics and Policy Issues in Global Warming National Science Foundation Center (1996-2005)
- Adviser: National Institute for Environmental Studies, Japan (1997-)
- Chairman: External Review Panel- Electric Power Research Institute: Environment Division
- Coordinating Lead Author, Intergovernmental Panel on Climate Change, Third Assessment Report, Working Group II on Climate Impacts and Working Group III on Climate Change Mitigation (1998-2001).
- Independent Expert Review Panel, Energy Information Administration Report on <u>Likely Costs</u> <u>and Energy Sector Impacts of the Kyoto Protocol on Climate Change Policy</u>, Report Prepared for the U.S. House of Representatives Committee on Science (1998).
- Chairman, Lawrence Berkeley Laboratory, Director's Review Panel, Environmental Energy Technologies Division (1998, 2003, 2008, 2011, 2015).
- Co-founder, The Boathouse Group of Climate Negotiators fro the twelve largest carbon emitting countries (2003-).
- Review Editor, Intergovernmental Panel on Climate Change, Assessment Report Number Four, (2004-2007).
- California Air Resources Board, (ARB) –Economic and Technology Advancement Advisory Committee (ETAAC) (2007-).
- World Bank Academic Advisory Board for World Development Report on Climate Change 2010.
- Chairman, Scientific Advisory Board, European Commission's AMPERE Project on Integrated Assessment Model Diagnostics.

- Steering Committee, Latin American Modeling Project
- Member: Economic and Technology Advancement Advisory Committee to the California Air Resources Board on Implementation of AB32 the Climate Solutions Act of 2006
- American Statistical Association Review Committee, the Energy Information Administration U.S. Department of Energy (2006-2012) (2015-).
- Co-Editor in Chief, <u>Energy Economics</u>
- Editorial Board, <u>The Energy Journal</u>
- Chairman: Scientific Steering Committee of the Integrated Assessment Modeling Consortium (IAMC) 50 International Member Institutions (2007-present).
- National Academy of Sciences Committee on <u>America's Climate Choices; Advancing the</u> <u>Science of Climate Change</u>, Board on Atmospheric Sciences and Climate, National Academy of Sciences (2008-2010).
- Review committee member and chair: International Institute for Applied Systems Analysis.
- Participant, Forums on Global Change, Joint Program on the Science and Economics of Global Change, Massachusetts Institute of Technology.
- Adviser: National Institute for Environmental Studies, Japan.
- Member, Steering Committee, The International Project on "Developing a Technology Strategy for Dealing With Climate Change," Lead by Pacific Northwest National Laboratory for An International Consortium of Government and Industry Sponsors.
- Review Editor, Inter-Governmental Panel on Climate Change Report Number Five, (2010-2013).
- Chairman, Scientific Advisory Board, European Commission's ADVANCE Project on Cutting Edge Research for Integrated Assessment Modeling.
- Chairman, Scientific Advisory Board, European Commission's Climate and Development Linkages (CD-LINKS) Project on Cutting Edge Research for Integrated Assessment Modeling.
- Biological and Environmental Research Advisory Board, Office of Science, U.S. Department of Energy (2014-).
- National Academy of Sciences Committee on <u>Valuing Climate Damages: Updating Estimation of</u> <u>the Social Cost of Carbon Dioxide</u>, Board on Atmospheric Sciences and Climate, National Academy of Sciences (2015-2017).

OTHER UNIVERSITY ACTIVITIES

Freeman Spogli Institute for International Studies SENIOR FELLOW (1998-2012)

Woods Institute for the Environment SENIOR FELLOW (2007-2016)

Precourt Institute for Energy SENIOR FELLOW (2010-)

Northeast Asia - United States Forum on International Policy FELLOW (1982 - 1985)

Engineering Library Committee MEMBER 1986-1995 CHAIRMAN 1988-1991

University Committee on Libraries MEMBER 1988-1991

OFFICES IN PROFESSIONAL SOCIETIES

President, Northern California Chapter-International Association of Energy Economists Vice President, U.S. Institute of Energy Economics Vice President, International Association for Energy Economics Chairman, IAEE Nominating Committee for 1989 Selection Committee – Best Paper in the Energy Journal for 1997 - 1998

CONSULTING

Rand Corporation Electric Power Research Institute U. S. Department of Energy Environmental Protection Agency Pan Heuristics Applied Decision Analysis Science Applications, Inc. Charles River Associates U.S. Arms Control and Disarmament Agency United States Synthetic Fuels Corporation National Acid Precipitation Assessment Program California Energy Commission Federal Trade Commission

MAJOR HONORS and AWARDS

STANFORD UNIVERSITY

Outstanding Contributions to the Profession Award for 2017, International Association for Energy Economics (Maximum One Award per Year)

Adelman Frankel Award for 2008, U.S. Association for Energy Economics, for Unique and Enduring Contributions to the Field (Maximum One Award per Year)

Nobel Peace Prize, 2007, Significant Contributions to the Intergovernmental Panel on Climate Change Award.

HARVARD UNIVERSITY:

POSTDOCTORAL FELLOW, National Science Foundation, Harvard University (1976-1977)

UNIVERSITY OF CALIFORNIA, BERKELEY:

REGENTS FELLOW (1972-1974) DISTINCTION Plus, Ph.D. Qualifying Examination in Economic Theory (June 1973) DISTINCTION Plus, Ph.D. Qualifying Examination in Operations Research (September 1973) DISTINCTION Plus, Ph.D. Qualifying Examination in Management Science (Dec. 1973)

PUBLICATIONS

JOURNAL ARTICLES

R.C. Grinold and J.P Weyant (1976). "The Transition Fractions in Organizational Manpower Planning Models," <u>Behavioral Science</u>, Vol. 21, No. 4, pp. 240-251.

J.P. Weyant (1978). "A Comparative Analysis of Three of ERDA's Major R & D Programs <u>Energy - The International Journal</u>, Vol. 3, No. 6, pp. 747-768.

J.L. Sweeney and J.P Weyant (1978/79). "The Energy Modeling Forum: Past, Present, and Future," Journal of Business Administration, Vol. 10, Nos. 1 and 2, pp. 295-320.

A.S. Manne, R.G. Richels and J.P Weyant (1979). "Energy Policy Modeling: A Survey," <u>Operations</u> Research, January/February (feature article), Vol. 27, No. 1, pp. 1-36.

J. P. Weyant, "Quantitative Models in Energy Policy (1980)," <u>Policy Analysis</u>, Published by the University of California, spring 1980, pp. 211-234.

H.S. Rowen and J.P Weyant (1981). "Oil and National Security: An Integrated Program for Surviving an Oil Crisis," <u>Annual Review of Energy</u>, Vol. 6, pp. 171-198.

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B. Ball, J. Houghton, J.L. Sweeney and J.P Weyant (1981). "U.S. Oil and Gas Supply," in J.B. Ramsey, ed., The Economics of Exploration for Natural Resources, <u>Contemporary Studies in</u> <u>Economic and Financial Analysis</u>, Vol. 26, pp. 119-149.

Theodore Myslabodski and J.P Weyant (1981). "Managing an Oil Bonanza: An Analysis of Alternative Mexican Export Policies," <u>Energy Policy</u>, September, Vol. 9, No. 3, pp. 186-196.

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W.W. Hogan and J.P Weyant (1982). "Combined Energy Models," in J. R. Moroney, editor, Formal Energy and Resource Models, <u>Advances in the Economics of Energy and Resources</u>, Vol. 4, pp. 117-150.

H.G. Huntington, J.L. Sweeney and J.P. Weyant (1982). "Modeling for Insights, Not Numbers; The Experiences of the Energy Modeling Forum," <u>OMEGA; The International Journal of the</u> <u>Management Sciences</u>, August, Vol. 10, No. 5, pp. 449-462.

J.P. Weyant and D.M. Kline (1982). "Policies to Reduce OECD Vulnerability to Oil Supply Disruptions," <u>Energy - The International Journal</u>, December, Vol. 7, No. 6, pp. 199-211.

J.P. Weyant (1982). "OPEC and the Oil Glut: Outlook for Oil Export Revenues during the 1980s and 1990s" OPEC <u>Review</u>, winter, Vol. VI, No. 4, pp. 333-364.

W.W. Hogan and J.P. Weyant (1983). "Methods and Algorithms for Combining Energy Models; Optimization in a Network of Process Models," in B. Lev, editor, "Energy Models and Studies," Studies in Management Science and Systems, Vol. 20, pp. 3-43.

J.P Weyant and D.M. Kline (1983). "Key Determinants of Optimal Oil Import Tariffs; An International Perspective," <u>Energy Policy</u>, June, Vol. 11, No. 2, pp.101-118.

J.P. Weyant (1983). "Reducing the Economic Impacts of Oil Supply Interruptions; Reply," <u>The Energy Journal</u>, April, Vol. 4, No. 2, pp. 59-61.

J.P. Weyant (1983). "The Energy Crisis is Over ... Again?" <u>Challenge: The Magazine of</u> <u>Economic Affairs</u>, September/October, Vol. 26, No. 4, pp. 12-17.

J.P. Weyant (1983). "Comment on the International Energy Agency's World Energy Outlook," <u>The Energy Journal</u>, Vol. 4, No. 4, pp. 91-94.

J.P. Weyant (1984). "The Continuing Threat of Oil Supply Interruptions," <u>Journal of Policy</u> <u>Analysis and Management</u>, Vol. 3, No. 3, pp. 393-405.

T.E. Daniel, H.G. Goldberg, and J.P. Weyant (1984). "Canadian Gas Exports to the U.S.; A Monopolistic Intertemporal View," <u>The Energy Journal</u>, October, Vol. 5, No. 4, pp. 21-34.

A.S. Manne, J.P. Weyant, C. Nelson, and R. So (1985). "A Contingency Planning Model of the International Oil Market," <u>Applications of Management Science</u>, Vol. 4, pp. 1-35.

S.C. Peck and J.P. Weyant (1985). "Electricity Growth in the Future," <u>The Energy Journal</u>, Vol. 6, No. 1, January, pp. 23-43.

J.P. Weyant (1985). "General Economic Equilibrium as a Unifying Concept in Energy-Economic Modeling," <u>Management Science</u>, May, Vol. 31, No.5, pp. 548-563.

J.P. Weyant (1985). "Using Data Analysis and Modeling in Planning," <u>Petroleum Management</u>, July, Vol. 7, No. 7, pp. 35-37.

J.P. Weyant (1986). "The Price Collapse of '86," <u>Petroleum Management</u>, June, Vol. 8, No.6, pp. 20-23.

M.A. Beltramo, A.S. Manne, and J.P Weyant (1986). "A North American Gas Trade Model: GTM," The Energy Journal, June, Vol. 7, No. 3, pp. 15-32.

S.C. Peck, D.K. Bosch, and J.P. Weyant (1988). "Industrial Energy Demand: A Simple Structural Approach," <u>Resources and Energy</u>, June, Vol. 10. No. 2, pp.111-134.

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"Climate and Energy Policy & Strategy Research at Stanford/MS&E" Presentation at the 10 Year Anniversary Celebration of the Department of Management Science and Engineering, October 16, 2010.

"Overview on the Progress of the EMF 24 (US) and EMF 27 (Global) Climate Policy Transition

Scenarios With Advanced Technology Impacts Studies," EMF 24/27 Working Group Meeting, Washington, DC, October 24, 2010.

"Progress of the EMF 24 (US) and EMF 27 (Global) Climate Policy Transition Scenarios with Advanced Technology Impacts Studies," Fourth Annual Meeting of the Integrated Assessment Modeling Consortium, Washington, D.C., October 27, 2010.

"Overview of the Activities of the Program on Integrated Assessment Modeling Development, Diagnostics and Inter-Comparison," Fourth Annual Meeting of the Integrated Assessment Modeling Consortium, Washington, D.C. October 28, 2010.

"Climate and Energy Policy Analyses: Current Status and Future Directions," Key note address at the Institute for Operations Research and Management Science (INFORMS) 2010 Annual Meeting, Austin, Texas, November 7, 2010.

"Sources of Technological Change," presentation at the Workshop on R&D Portfolio Analysis Tools and Methodologies, Washington, DC, December 2, 2010

"Perspectives on the Intergovernmental Panel on Climate Change," plenary penal at the Annual Meetings of the American Economics Association, Denver, January 7, 2011.

"Overview of EMF Activities," American Statistical Association Advisory Board to the Energy Information Administration Annual Meeting, March 7, 2011.

"Perspectives on Federal Energy Technology Innovation Policies," panel presentation on the occasion of the retirement of William Perry from the MS&E Department, April 6, 2011.

"The International Energy Workshop at Age Thirty," annual meeting of the International Energy Workshop, Stanford University, Stanford, CA, July 6, 2011.

"Approaches for Dealing with Uncertainty in Energy-Environmental Policy Analyses," Snowmass Colorado, August 1, 2011.

"Progress Report on Integrated Assessment of Climate Change," Symposium Honoring the career of Steven H. Schneider, National Center for Atmospheric Research, Boulder, Colorado, August 26, 2011.

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"Perspectives on Energy-Environmental Analysis," Annual Symposium of the Joint Institute for Strategic Energy Analysis, National Renewable Energy Laboratory, Golden, Colorado, March 20, 2013.

"The Future of Natural Gas from a Global Energy Perspective," Global Technology Strategy Workshop on the Shale Gas Revolution, Joint Global Change Research Program, Maryland Eastern Shore, April 15, 2013.

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"An IA Perspective on New Global Scenario Development," Snowmass Workshop on Climate Change Impacts and Integrated Assessment, Snowmass, Colorado, July 29, 2013.

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"Overview of EMF Climate Change Studies," Washington D.C Roll Out of EMF 24 – U.S. Technology Strategies and Climate Policy, Washington D.C., September 16, 2013.

"Progress Report on the Development of the Integrated Assessment Modeling Consortium," sixth annual meeting of the Integrated Assessment Modeling Consortium (IAMC), Tsukuba, Japan, October 28, 2013.

"Progress Report on the Work of the Precourt Energy Efficiency Center" sixth annual meeting of the Integrated Assessment Modeling Consortium (IAMC), Tsukuba, Japan, October 29, 2013.

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"The role of simulation models and big data in mitigation and adaptation planning, and how they can be opened up to influence the general public," Conference on "Crowds and Climate Mobilizing Crowds to Develop Ideas and Take Action on Climate Change," Massachusetts Institute of Technology, Cambridge, Massachusetts USA November 7, 2013.

"An Integrated Assessment Community View on the Development of New Global Scenarios," Workshop on the Development of New Global Scenarios, National Academy of Sciences, Keck Center, Washington, DC, December 13, 2013.

"Energy Modeling Forum Study 27: The Role of Technology for Achieving Climate Policy Objectives," White House International Policy Development Group, Old Executive Office Building, Washington, DC, December 20, 2013.

"Evaluation of EU AMPERE Climate Policy Analysis Project by AMPERE External Science Advisory Panel," EU Headquarters, Brussels, Belgium, January 21, 2014

"Perspectives on Energy-Environmental Analysis," Annual Symposium of the Joint Institute for Strategic Energy Analysis, National Renewable Energy Laboratory, Golden, Colorado, March 23, 2014.

"Summary Assessment of the Latin American modeling Project," Bogota, Columbia, April 29.

"Progress Report on the Development of the Program on Integrated Assessment Modeling Assessment Development, Diagnostics and Inter-comparisons," DOE Biological and Environmental Research Program PI Meeting, Rockville, Maryland, May 30, 2014.

"Overview of IPCC Mitigation Work for Governors Briefing on Climate Policy Analysis," Sacramento, California, May 29, 2014.

"Overview of Integrated Assessment," Snowmass Workshop on Climate Change Impacts and Integrated Assessment," Snowmass, Colorado, July 28, 2014.

"An IA Perspective on New Global Scenario Development," Snowmass Workshop on Climate Change Impacts and Integrated Assessment, Snowmass, Colorado, July 31, 2014.

"Climate Policy Scenarios; Past, Present and Future," Stanford Center at Peking University, Peking China, September 17, 2014.

"Overview of EMF 32 Study on US Power Plan and Revenue Recycling Climate Policies," Washington, D.C., October 22, 2014.

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"Progress Report on the Work of the Precourt Energy Efficiency Center" sixth annual meeting of the Integrated Assessment Modeling Consortium (IAMC), Tsukuba, Japan, October 29, 2013.

"Contributions of Integrated Assessment and the Energy Modeling Forum," Center for Climate and Energy Decision Making, Department of Engineering and Public Policy Carnegie Mellon University, December 1, 2014.

"The State of the Art in Integrated Climate Impacts Analysis," Snowmass Annual Meeting on Climate Change Impacts and Integrated Assessment, Snowmass Colorado, July 28, 2015.

"An Integrated Assessment Perspective on High Resolution Climate Projects for Stakeholder Climate Impact Analyses," Aspen Global Change Institute, August 1, 2015.

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"The State of the Art in Integrated Climate Impacts Analysis" Snowmass Annual Meeting on Climate Change Impacts and Integrated Assessment, Snowmass Colorado, July 28, 2016.

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"Advisory Committee Assessment of Progress of the European CD-LINKS Project on Climate and Development Linkages" CD-LINKS Project Annual Meeting, Potsdam, May 16, 2017.

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"Analysis and Modeling: What has analysis and modeling really taught us about deriving impact from technical innovation?" Workshop on Accelerating Climate-Mitigating Technology Development and Deployment, University of Maryland, College Park, June 6, 2018.

Appendix B

Appendix B Documents Relied Upon by John P. Weyant

Pleadings

First Amended Complaint for Declaratory and Injunctive Relief, Kelsey Cascadia Rose Juliana et al., Plaintiffs, v. The United States of America et al., Defendants, September 10, 2015

Federal Defendants' Answer to First Amended Complaint for Declaratory and Injunctive Relief, Kelsey Cascadia Rose Juliana et al., Plaintiffs, v. The United States of America et al., Defendants, January 13, 2017

Expert Reports / Declarations

Expert Report of Frank Ackerman, April 13, 2018

Expert Report of Peter Ericson, April 12, 2018

Expert Report of James E. Hansen, Ph.D., April 13, 2018

Expert Report of Mark Jacobson, Ph.D., April 6, 2018

Expert Report of Steven W. Running, Ph.D., April 3, 2018 and associated supporting materials

Expert Report of Joseph E. Stiglitz, Ph.D., April 13, 2018

Expert Report of Kevin E. Trenberth, Sc.D., April 11, 2018 and associated supporting materials

Expert Report of James H. Williams, Ph.D., April 13, 2018

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Data Sources

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Software

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Any other documents or materials cited in this report.

Exhibit 1

Exhibit 1 Dr. Trenberth and Prof. Running's Alleged Climate Change Impacts and Injuries to Plaintiffs

	Dr. Trenberth			Dr. Running		
	Youth Plaintiffs Identified in the Complaint	Alleged Climate Change Effect	Alleged Plaintiff Injury/Impact	Alleged Climate Change Effect	Alleged Plaintiff Injury/Impact	
1	Aji P. West Seattle, Washington			Wildfires, Ecological Changes	Recreation, Air Quality	
2	Alexander Loznak Kellogg, Oregon			Wildfires, Drought, Excessive Heat, Freshwater Degradation, Ecological Changes	Recreation, Air Quality, Economic Loss	
3	Avery M. Eugene, Oregon			Wildfires, Excessive Heat, Ecological Changes, Freshwater Degradation	Recreation, Air Quality	
4	Hazel V. Eugene, Oregon			Wildfires, Excessive Heat, Ecological Changes, Freshwater Degradation	Recreation, Air Quality	
5	Isaac V. Beaverton, Oregon					
6	Jacob Lebel Roseburg, Oregon	Wildfires	Air Quality	Wildfires, Drought, Excessive Heat, Freshwater Degradation Ecological Changes	Recreation, Air Quality, Economic Loss	
7	Jaime B. Flagstaff, Arizona	Drought, Wildfires, Excessive Heat	Water Quality & Scarcity	Wildfires, Excessive Heat, Ecological Changes	Recreation, Air Quality, Water Quality & Scarcity, Economic Loss	
8	Jayden F. Rayne, Louisiana	Storms & Hurricanes	Economic Loss			
9	Journey Z. Kaua'i, Hawai'i	Storms & Hurricanes	Economic Loss, Safety			
10	Kelsey Cascadia Rose Juliana Eugene, Oregon			Wildfires, Ecological Changes	Recreation, Air Quality	
11	Kiran Isaac Oommen Eugene, Oregon					
12	Levi D. Indialantic, Florida	Storms & Hurricanes, Coastal Erosion	Economic Loss, Recreation			
13	Miko V.					

Beaverton, Oregon

Exhibit 1 Dr. Trenberth and Prof. Running's Alleged Climate Change Impacts and Injuries to Plaintiffs

		Dr. Trenberth		Dr. Running	
	Youth Plaintiffs Identified in the Complaint	Alleged Climate Change Effect	Alleged Plaintiff Injury/Impact	Alleged Climate Change Effect	Alleged Plaintiff Injury/Impact
14	Nathaniel B. Fairbanks, Alaska	Wildfires, Excessive Heat	Economic Loss	Wildfires, Ecological Changes	Recreation, Air Quality
15	Nicholas V. Lakewood, Colorado			Wildfires, Ecological Changes	Recreation, Air Quality
16	Sahara V. Eugene, Oregon			Wildfires, Ecological Changes	Recreation, Air Quality
17	Sophie K. Allentown, Pennslyvania				
18	Tia Marie Hatton Bend, Oregon				
19	Victoria B. White Plains, New York	Storms & Hurricanes	Economic Loss, Safety		
20	Xiuhtezcatl Tonatiuh M. Boulder, Colorado	Storms & Hurricanes	Economic Loss	Wildfires, Ecological Changes	Recreation, Air Quality, Spiritual & Cultural Practice
21	Zealand B. Eugene, Oregon	Wildfires	Economic Loss	Wildfires, Ecological Changes	Recreation, Air Quality, Economic Loss

Source: Complaint, pp. 6-33; Trenberth Report, pp. 20-22; Running Report, pp. 6-17

Exhibit 2



During a cool or "negative" phase, the west Pacific Ocean becomes warmer and part of the eastern ocean cools; temperatures cool over North America.

Exhibit 3



Energy Outlook 2017, "January 2017; National Oceanic and Atmospheric Administration, Earth System Research Laboratory Global Monitoring Division.

Note:

- [1] Projections are from the MAGICC6 model using the RCP45 concentration pathway as a baseline and historical concentration data through 1989. Actual CO₂ emissions from fossil fuels from 1990 2015 and projected emissions from 2015 2020 are subtracted from the baseline RCP45 emissions path to predict CO₂ concentration with no US Emissions. Actual U.S. emission data is from the EIA.
- [2] In 2015, actual CO₂ Atmospheric Concentration was 399 ppm as measured by the Earth System Research Laboratory; Predictions from the model only use historical concentration data through 1989, which causes a deviation from the measured concentrations.



Source: Author's calculations using MAGICC6; U.S. Energy Information Administration ("EIA"), "International Energy Outlook 2017," September 2017; EIA, "Annual Energy Outlook 2017," January 2017; National Oceanic and Atmospheric Administration, Earth System Research Laboratory Global Monitoring Division.

Note:

- [1] Projections are from the MAGICC6 model using the RCP45 concentration pathway as a baseline and historical concentration data through 1989. Actual CO₂ emissions from fossil fuels from 1990 2015 and projected emissions from 2015 2020 are multiplied by .25 and subtracted from the baseline RCP45 emissions path to predict CO₂ concentration with a 25% reduction in U.S. emissions. Actual U.S. emission data is from the EIA.
- [2] In 2015, actual CO₂ Atmospheric Concentration was 399 ppm as measured by the Earth System Research Laboratory; Predictions from the model only use historical concentration data through 1989, which causes a deviation from the measured concentrations.