ORAL ARGUMENT SCHEDULED FOR JUNE 2, 2016
No. 15-1363 (and consolidated cases)

**IN THE UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT**

STATE OF WEST VIRGINIA, ET AL.,
Petitioners,
v.

ENVIRONMENTAL PROTECTION AGENCY, ET AL.,
Respondents.

On Petition for Review of a Final Rule of the
United States Environmental Protection Agency

BRIEF OF AMICUS CURIAE CLIMATE SCIENTISTS DAVID BATTISTI, MARSHALL BURKE, KEN CALDIERA, NOAH DIFFENBAUGH, WILLIAM E. EASTERLING III, CHRISTOPHER FIELD, JOHN HARTE, JESSICA HELLMANN, DANIEL KIRK-DAVIDOFF, DAVID LOBELL, PAMELA MATSON, KATHERINE MACH, JAMES C. MCWILLIAMS, MARIO J. MOLINA, MICHAEL OPPENHEIMER, JONATHAN OVERPECK, SCOTT R. SALESKA, NOELLE ECKLEY SELIN, DREW SHINDELL, AND STEVEN WOFSY, IN SUPPORT OF RESPONDENTS

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Certificate as to Parties, Rulings, and Related Cases

Pursuant to Circuit Rule 28(a)(1), *Amicus Curiae* Climate Scientists state as follows: All parties and amici, rulings under review, and related cases are set forth in the Brief for Respondents Environmental Protection Agency, with the exception of the amici at present: Climate Scientists David Battisti, Marshall Burke, Ken Caldiera, Noah Diffenbaugh, William E. Easterling III, Christopher Field, John Harte, Jessica Hellmann, Daniel Kirk-Davidoff, David Lobell, Pamela Matson, Katherine Mach, James C. Mcwilliams, Mario J. Molina, Michael Oppenheimer, Jonathan Overpeck, Scott R. Saleska, Noelle Eckley Selin, Drew Shindell, and Steven Wofsy. Others have also moved for amicus status after the filing of EPA's brief and their parties are listed on their respective motions.

Statement Regarding Consent to File

Pursuant to D.C. Circuit Rule 29(b), undersigned counsel for *Amici Curiae* Climate Scientists represents that all parties have been sent notice of the filing of this brief. All parties have either consented or taken no position; no party has objected to the filing of the brief.[1]

[1] Pursuant to Fed. R. App. P. 29(c), *amici curiae* state that no counsel for a party authored this brief in whole or in part, and no person other than *amici curiae* or their counsel made a monetary contribution to its preparation or submission.

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Glossary of Terms

CO_2	Carbon dioxide
EPA	Environmental Protection Agency
IPCC	Intergovernmental Panel on Climate Change
NCA	National Climate Assessment
pH	numeric scale used to specify the acidity or basicity of a solution

Interests of Amici Curiae

Amici Curiae Climate Scientists are David Battisti, Marshall Burke, Ken Caldiera, Noah Diffenbaugh, William E. Easterling III, Christopher Field, John Harte, Jessica Hellmann, Daniel Kirk-Davidoff, David Lobell, Pamela Matson, Katherine Mach, James C. Mcwilliams, Mario J. Molina, Michael Oppenheimer, Jonathan Overpeck, Scott R. Saleska, Noelle Eckley Selin, Drew Shindell, and Steven Wofsy (hereinafter "Climate Scientists"). The Climate Scientists are individual climate scientists who are actively involved in research on changes to the Earth's climate that are being caused by anthropogenic emissions of carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons, and perfluorocarbons ("greenhouse gases" or "GHGs") and the effects of those changes.

As practicing scientists who study the Earth's climate, we—and many in our profession—have long recognized that human emissions of greenhouse gases (primarily carbon dioxide, but also methane, nitrous oxide, and fluorocarbons) can significantly change the Earth's climate. We have approached our research with the critical perspective associated with our profession, gradually adding to our understandings of our climate system and testing our hypotheses through multiple layers of probing peer review[2] and discussion in scientific journals and conferences.

But the extent to which we have already been observing the ongoing impacts of human-caused climate change has led us to participate in this case right now. We are observing increasing global temperatures; shifting plant and animal ranges; worsening droughts; global retreat of glaciers and ice sheets; shrinking Arctic sea ice; rising sea levels; acidification of our oceans; and many other serious impacts of global climate change. These phenomena are all directly connected to our human alteration of the atmosphere. Yet they are just the beginning of the developments that could occur if we as humans do not more aggressively curb emissions of greenhouse gases.

We recognize that scientific knowledge is always in development, and that additional research can always allow us to better understand the extent to which greenhouse gases contribute to climate change.

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[2] *See, e.g.,* David Goodstein, Federal Judicial Center, *How Science Works*, in *Reference Manual on Scientific Evidence* 44 (3d ed. 2011) ("In the competition among ideas, the institution of peer review plays a central role.").

However, an overwhelming consensus has developed within the scientific community: climate change is occurring, and human activities are extremely likely the dominant cause. Uncertainty regarding particular aspects of our climate system does not undercut this consensus, because all of science can be characterized as uncertain, to some extent. Nor does the existence of some uncertainty mean that societal actions are unwarranted, given widely scientifically recognized likelihoods of certain effects. *See* Inst. of Med., *Environmental Decisions in the Face of Uncertainty* (2013). We are not lawyers or policymakers, and we are not attempting to present ourselves as such. But we weigh in, in this amicus brief, to elaborate on the need to address anthropogenic emissions of greenhouse gases, based on our current understanding of the science. We believe that the Clean Power Plan, 80 Fed. Reg. 64,662 (Oct. 23, 2015), is a welcome beginning.

Many of us contributed to an *amicus* brief in the case *Massachusetts v. EPA.* Since the Supreme Court issued its ruling in that case, the evidence for significant harms from greenhouse gas emissions has grown stronger, while our ability to reduce carbon dioxide emissions has substantially improved. Thus, in the period since that case, the cost of inaction has been demonstrated to be higher than anticipated (because confidence in damage from carbon dioxide has increased), while the cost of action has come down.

Summary of Argument

As scientists, we have observed that human-related emissions have increased greenhouse gases in the Earth's atmosphere. We have also observed numerous connections between these rising anthropogenic greenhouse gas emissions and changes in the Earth's climate. Evidence suggests that the continuing increase in greenhouse gas concentrations could have devastating effects around the world, including changes to the United States.

For example, rising temperatures exacerbate the impact of droughts, including recent droughts in California and elsewhere in the United States have been growing hotter, and this, in turn, is exacerbating the impacts of droughts on water supplies, ecosystems, and human health. At the same time, coastal flooding is becoming more common along U.S. coasts as global sea level rise accelerates; by the end of this century, sea level rise along U.S. coasts could exceed three feet and lead to huge economic impacts around the country.

Actions to reduce climate change, such as the Clean Power Plan, 80 Fed. Reg. 64,662 (Oct. 23, 2015), are necessary to slow these consequences and prevent worse from occurring. Indeed, the Clean Power Plan is the only current policy that can produce reductions in our country's greenhouse gas emissions. The Clean Power Plan is also the only currently implemented policy that can enable the United States to meet the reduction targets agreed to with the other nations of the world at the Paris 5th Conference of the Parties to the U.N. Framework Convention on Climate Change in December 2015.

Argument

I. Human Emissions Have Led to Rising Greenhouse Gas Levels and Fossil Fuel Combustion Is One of the Largest Sources

The basic physics of the greenhouse effect is well established. Greenhouse gases—such as carbon dioxide—are so named because of their particular properties. They absorb radiation in the area of the electromagnetic spectrum known as the "infrared window." This window is so described because it is the area of the infrared spectrum in which the Earth's outgoing thermal radiation is normally released back into space. That is, greenhouse gases, due to their physical properties, trap energy that would otherwise leave the Earth's climate system, similar to how greenhouses retain energy and keep warm the plants inside. But in contrast with greenhouses, this additional retained energy can lead to far more complicated effects than simply rising temperatures, because of the complexity of the Earth's climate system, and its interacting components: the atmosphere, oceans, ice, and biosphere.

Although greenhouse gases are emitted from naturally occurring processes, human-related sources of greenhouse gases have significantly added to our naturally existing atmospheric concentrations. Studies estimate that concentrations of one of the primary greenhouse gases, carbon dioxide, have increased globally by approximately 40 percent over the last 250 years, which is roughly the period during which humans have increasingly used fossil fuels. *See* Hartmann, D.L, et al., *Observations: Atmosphere and Surface*, in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., et al. eds] [hereinafter IPCC Climate Change]; *id.* at 166 (describing observed changes up till 2011); *see also* Earth System Research Laboratory, Nat'l Oceanic and Atmospheric Administration [hereinafter NOAA], *Trends in Atmospheric Carbon Dioxide* (2016), http://www.esrl.noaa.gov/gmd/ccgg/trends/ *and* NOAA, *Trends in Atmospheric Carbon Dioxide: History* (2016), http://www.esrl.noaa.gov/gmd/ccgg/trends/history.html (showing current atmospheric carbon dioxide levels to be anomalously high as compared over the last 800,000 years).

While estimates of earlier levels of atmospheric carbon dioxide are based primarily upon ice core data, levels over the past nearly sixty years are based on well-established methods for measuring carbon dioxide concentrations directly from air. Beginning with the use of a high-precision non-dispersive infrared gas analyzer in Mauna Loa, Hawaii, continuous on-site measurements of atmospheric carbon dioxide concentrations. *See* IPCC Climate Change at 166; *see also* NOAA, *In Situ Carbon Dioxide (CO_2) Measurements*, http://www.esrl.noaa.gov/gmd/obop/mlo/programs/esrl/co2/co2.html. Using such methods, we have observed the increase of global atmospheric carbon dioxide concentration by approximately 11.5 parts per million between 2005 to 2011 alone. *See* IPCC Climate Change at 166. The current measured atmospheric concentration of carbon dioxide is 404.02 parts per million. NOAA, *Trends in Atmospheric Carbon Dioxide* (2016), http://www.esrl.noaa.gov/gmd/ccgg/trends/. The overall 40 percent rise, as we will explain later, is important in terms of climactic effects.

In turn, numerous studies, using intersecting methodologies, have demonstrated that the primary source of human's carbon dioxide emissions in the United States is fossil fuel combustion. *See* Pieter Tans, *An Accounting of the Observed Increase in Oceanic and Atmospheric CO_2 and an Outlook for the Future*, 22 Oceanography 26, 26-35 (Dec. 2009); *see also* Environmental Protection Agency [hereinafter EPA], *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014* (Apr. 15, 2015), https://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2015-Main-Text.pdf. This reflects basic college chemistry, as the primary outputs of fossil fuel combustion are carbon dioxide and water. *See, e.g.,* Morris Hein & Susan Arena, *Foundations of College Chemistry* 158 (2013) (describing the fossil fuel combustion process and its role in contributing to atmospheric carbon dioxide concentrations). In addition, carbon dioxide generated from fossil fuel combustion, as opposed to other sources, has a unique isotopic signature, and research has unambiguously connected the rise in carbon dioxide concentrations with increased carbon dioxide emissions that bear that fossil fuel signature. *See* G.J. Bowen et al., *Isoscapes to Address Large-Scale Earth Sci. Challenges*, 90 EOS Transactions 109, 109-116 (2009).

In 2015, the EPA published a comprehensive inventory of greenhouse gas emissions. *See* EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014* (Apr. 15, 2015). This inventory, in turn, was based on based on hundreds of peer-reviewed studies published in reputable journals, *see id.* at 10-1 to 10-71 (presenting the full bibliography upon which the report was based), and used the rigorous guidelines for national greenhouse gas inventories established by the IPCC. *See id.* at 1-14 to 1-15 (describing the EPA's use of the IPCC guidelines as a benchmark); *see also* IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (2006).

Power plants, the facilities regulated under the Clean Power Plan, are a key contributor to greenhouse gases in the Earth's atmosphere. As the EPA report describes, "CO_2 is the primary gas emitted from fossil fuel combustion and represents the largest share of U.S. total greenhouse gas emissions…. In 2013, CO_2 emissions from fossil fuel combustion were 5,157.7 MMT CO_2 Eq., or 8.8 percent above emissions in 1990." EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014* at 3-5 (Apr. 15, 2015). The report also breaks down the fossil fuel carbon dioxide contributions into individual sectors, and concluded that the electricity generation sector provided the largest source of carbon dioxide, out of all U.S. fossil fuel sources. *See id.* at 3-10 to 3-15. In addition, the report observes, "The direct combustion of fuels by stationary sources in the electricity generation, industrial, commercial, and residential sectors represent the greatest share of U.S. greenhouse gas emissions," and further observes that extraction, processing and handling of fossil fuels for combustion by stationary sources also contribute to rising concentrations of methane, another greenhouse gas. *Id.* at 3-12.

II. Rising Greenhouse Gas Levels Have Led to Changes to the Earth's Climate and Physical and Biological Systems

Scientists attempt to better understand the world through "systematic observation and experimentation, inductive and deductive reasoning, and the formation and testing of hypotheses and theories." Hanne Andersen & Brian Hepburn Brian, *Scientific Method* in *The Stanford Encyclopedia of Philosophy* (Edward N. Zalta ed. 2015), http://plato.stanford.edu/archives/win2015/entries/scientific-method/. The principle behind relying upon multiple methods to explore scientific phenomena is to allow theoretical models to be tested and strengthened through independent research, empirical observations, and experimental replication. *See* Federal Judicial Center, *Reference Manual on Scientific Evidence* at 44 ("[S]cience is, above all, an adversarial process. It is an arena in which ideas do battle, with observations and data the tools of combat."). Our work in the area of climate systems is no exception.

Decades of research have established a link between increased emissions of greenhouse gases and key biogeochemical cycles. The Earth's climate is a complex system, involving a number of connected physical, chemical and biological processes occurring in our air, lands, and oceans. Thus our research of this system must be conducted through a coupling of scientific models (that capture our understanding of empirical relationships between these processes) with independent empirical measurements such as satellite data, airborne observations, and on the ground measurements to establish the validity of our models.

While refinements based on physical data have improved our models over time, thus providing more detail about the exact effects of rising anthropogenic greenhouse gas emissions, these models have consistently demonstrated net changes to the Earth's climate resulting from these emissions. *See, e.g.,* Reto Knutti & Jan Sedláček*, Robustness and Uncertainties in the New CMIP5 Climate Model Projections*, 3 Nature Climate Change 369, 369-73 (2013) (examining the complex models for the 2013 IPCC Fifth Assessment Report and determining that "projected global temperature change from the new models is remarkably similar to that from those used in [the Fourth IPCC Assessment Report]" and that "[t]he spatial patterns of temperature and precipitation change are also very consistent").

Indeed, the scientific community has taken great care to present the extent to which our models have been empirically tested and validated in as transparent and accurate a manner as possible. The IPCC Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties, for example, presents these two figures:

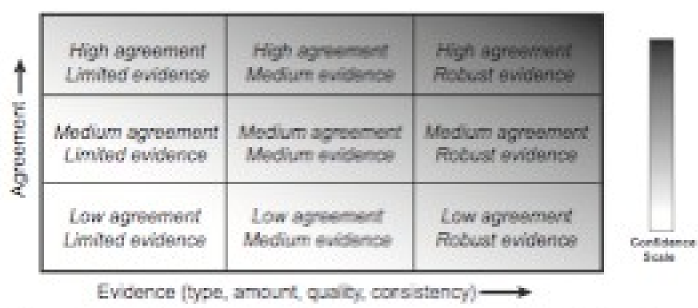

Figure 1: A depiction of evidence and agreement statements and their relationship to confidence. Confidence increases towards the top-right corner as suggested by the increasing strength of shading. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality evidence.

Table 1. Likelihood Scale

Term*	Likelihood of the Outcome
Virtually certain	99-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely as not	33 to 66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

* Additional terms that were used in limited circumstances in the AR4 (*extremely likely* – 95-100% probability, *more likely than not* – >50-100% probability, and *extremely unlikely* – 0-5% probability) may also be used in the AR5 when appropriate.

Table i. Michael D. Mastandrea et al., IPCC, *Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties* at 3 (2010), https://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf.

This guidance was created with the recognition that "[s]ound decisionmaking that anticipates, prepares for, and responds to climate change depends on information about the full range of possible consequences and associated probabilities. Such decisions often include a risk management perspective." *Id.* at 1.

The 2014 IPCC Climate Change Synthesis Report followed this same transparent rubric to present a synthesis of the thousands of peer-reviewed scientific studies considered and evaluated by the three

Working Groups of the IPCC in its working history. Using this guidance and summarizing the state of climate system research such as those we conduct, the Report provided a number of observations using qualitative confidence descriptors described in the tables, including:

> Evidence of observed climate change impacts is strongest and most comprehensive for natural systems. In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality (*medium confidence*). Many terrestrial, freshwater and marine species have shifted their geographic ranges, seasonal activities, migration patterns, abundances and species interactions in response to ongoing climate change (*high confidence*). Some impacts on human systems have also been attributed to climate change, with a major or minor contribution of climate change distinguishable from other influences . . . Assessment of many studies covering a wide range of regions and crops shows that negative impacts of climate change on crop yields have been more common than positive impacts (*high confidence*). Some impacts of ocean acidification on marine organisms have been attributed to human influence (*medium confidence*).

IPCC, *Climate Change 2014: Synthesis Report Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* at 6 (R.K. Pachauri & L.A. Meyer eds. 2014) (emphasis in original).

A number of our other observations are summarized in the full text of the IPCC Synthesis Report. It is very likely that 1983 to 2012 was the warmest 30-year period of the last 800 years in the Northern Hemisphere. *Id.* at 40. It is also "virtually certain that the upper ocean (0−700 m) warmed from 1971 to 2010." *Id.* We have high confidence that the rate of sea level rising since rapid industrialization in the mid-19th century has been larger than the mean rate during the previous two thousand years. *Id.* Moreover, we have high confidence that glaciers have been shrinking worldwide due to climate change and medium confidence that this has been affecting downstream runoff and water resources. *Id.* at 51.

Our research has also connected these physical changes on our planet with biological changes. For example, we have high confidence that many plant and animal species have shifted their geographic ranges, physical activity patterns, populations, and inter-species interactions in response to climate change. *Id.* We also have high confidence that climate change is affecting worldwide agricultural patterns, as most studies suggest more negative impacts on crop yields than positive impacts due to climate change. *Id.* We are still developing our understandings of the relationship between human ill-health and climate change, but currently, we have medium confidence that regional climate developments stemming from global climate changes have changed the "distribution of some water-borne illnesses and disease vectors." *Id.*

Finally, the report synthesizes the current state of scientific research on relationships between increased human emissions of greenhouse gases and extreme climactic events. It is very likely that our emissions have more than doubled the probability of the occurrence of heat waves in some locations. *Id.* at 53. Moreover, we have very high confidence that extreme heat events currently leads to increases in mortality and morbidity in North America. *Id.* There is a medium likelihood that emissions have led to increasing trends in extreme precipitation, causing flooding on a regional level. *Id.* It is likely that extreme sea level events such as storm surges result from the rising sea levels related to climate change. *Id.* And we have a very high confidence that "[i]mpacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones and wildfires, reveal significant vulnerability and exposure of some ecosystems and many human systems to current climate variability." *Id.*

III. If Left Unaddressed, These Changes to the Earth's Climate Will Have Serious Effects on the United States

A. The Impacts of Climate Change in the United States Have Already Been Observed

The United States is no exception to being affected by climate change, and in some cases, is seeing greater changes than documented elsewhere around the globe. Again, our research suggests that we are vulnerable in a number of ways, and in a number of regions. Much of this research is summarized in two other consensus reports, the 2014 National Climate Assessment Development Advisory Committee Report, Our Changing Climate, Climate Change Impacts in the United States: The Third National Climate Assessment (2014), and, to some extent, the 2011 National Academy of Sciences National Research Council America's Climate Choices, which focuses more on mitigation and adaptation strategies. *See* U.S. Global Climate Change Research Program, *2014 National Climate Assessment* (2014), http://nca2014.globalchange.gov/report [hereinafter *NCA*]; National Academies Press, *America's Climate Choices* (2011), http://www.nap.edu/download.php?record_id=12781#. Both of these reports developed through reviewing other synthesis reports, incorporating U.S.-specific peer-reviewed literature, and using technical inputs of those in the scientific community.

Some of these effects in the United States have already been observed. For example, "U.S. average temperature has increased by 1.3°F to 1.9°F since record keeping began in 1895; most of this increase has occurred since about 1970. The most recent decade was the nation's warmest on record." J. Walsh et al., *Our Changing Climate, Climate Change Impacts in the United States: The Third National Climate Assessment* 28 (2014). The report is transparent about the various factors involved with climate variability, describing the complexities of characterizing a system that is nonlinear, with different types of temporal responsiveness. *Id.* (observing that "[b]ecause human-induced warming is superimposed on a naturally varying climate, the temperature rise has not been, and will not be, uniform or smooth across the country or over time.")

Extreme weather events such as heat waves and hurricanes have also become more intense and occur in greater frequency. *Id.* at 38 (describing the frequency of record-breaking events in the Midwest, the

Southwest, and the East Coast); *id.* at 41 (describing increase since the early 1980s of the intensity, frequency, and duration of North Atlantic hurricanes). The latter phenomena, the report acknowledges, may not be related to increased greenhouse gas emissions, given the complexity of the relationship between rising ocean temperatures and hurricanes, *id.* at 41-42; additional research in this area, however, is still being conducted.

Globally rising sea levels, discussed earlier in this brief, also affect the United States. For example, based on data collected from the coast of North Carolina (and elsewhere), the North Atlantic Ocean has risen markedly in the last century. *Id.* at 45. As the 2014 Our Changing Climate Report observes, "[n]early 5 million people in the U.S. live within 4 feet of the local high-tide level (also known as mean higher high water). *Id.* In the next several decades, storm surges and high tides could combine with sea level rise and land subsidence to further increase flooding in many of these regions." *Id.* Finally, the United States is affected by the ocean acidification caused by increased emissions of carbon dioxide. Ocean acidification occurs because some of our excess carbon dioxide ends up getting absorbed by oceans, in turn, lowering ocean pH levels. *See id.* at 49, Fig. 2.30 (illustrating the close relationship between rising levels of carbon dioxide in the atmosphere and lowered ocean pH). Indeed, "the current observed rate of change is roughly 50 times faster than known historical change." This presents a problem for shellfish, corals, and zooplankton, by making it more difficult to make their calcified structures. These animals are essential elements of the marine food chain, and loss of these populations can put at risk many of the marine animals upon which U.S. citizens rely upon for protein and the fishing industry depends upon for its existence.

A number of consensus reports have also attempted to synthesize the results of available scientific studies on effects of climate change in particular regions of the United States. *See* NOAA, *National Environmental Satellite, Data, and Information Service, Regional Climate Trends and Scenarios for the U.S. National Climate Assessment* (2013), http://www.nesdis.noaa.gov/technical_reports/142_Climate_Scenarios.html. All of these reports show the differing effects of climate change effects in different regions of the United States; these studies explored changes in impacts such as temperature changes (including extreme temperature events), precipitation changes (including extreme precipitation events), water levels, and ice cover. *See generally* NOAA, *National Environmental Satellite, Data, and Information Service,* *Regional Climate Trends and Scenarios for the U.S. National Climate Assessment, Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 9. Climate of the Contiguous United States* (2013) (compiling the results of the individual geographic reports on climate change in the United States).

B. Our Current Models Project Increasing Impacts Unless We Reduce Greenhouse Gas Emissions

We recognize that making projections of future climate changes can be challenging. However, we can expect the impacts of climate change to increase with increased atmospheric concentrations of greenhouse gases. To make projections of future likely impacts, we do three things. *See* National Academies Press, *America's Climate Choices* 19 (2011). First, we have to develop different scenarios of how actual emissions are likely to evolve in the future based on specific assumptions about future social, economic, technological, and environmental changes. Next, we have to use the same climate models, capturing our understanding of interrelationships between greenhouse gases and climate effects, described earlier to estimate how climate patterns would evolve based on these emissions scenarios. To make these results useful for policy makers, we also often have to assess the impacts associated with these modeled climate changes based on other information about the vulnerability of various parts of our Earth's system, including human and biological aspects. *Id.* at 20.

As scientists, we address these complexities by using many state-of-the-art climate and earth system models, and also modeling multiple potential scenarios in order to provide as comprehensive a picture as possible; we also continuously refine our models using empirical data and improved theoretical understanding. This is why we often present these future projections of climate given multiple well-described emissions scenarios laid out, to provide transparency regarding how potential assumptions can change the likelihood of particular impacts and to allow other scientists to test these results against their own research. This is also why we have been able to improve our models, through this process of constant testing and refinement. What this means is that while science is indeed an iterative process, we end up developing a better understanding of potential risks over time.

A number of impacts are projected to occur even under a range of potential increased emissions scenarios and even using different climate models. These similar results, as mirrored by different assumptions and different studies, suggest to us that we as a society will be affected by these impacts unless greenhouse gas emissions levels are addressed. *See, e.g., NCA* at 33 ("Models unequivocally project large and historically unprecedented future warming in every region of the U.S. under all of the scenarios used in this assessment. The amount of warming varies substantially between higher versus lower scenarios, and moderately from model to model, but the amount of projected warming is larger than the model-to-model range" and exploring the likelihood of particular impacts based on differences between predictions made by different models.).

Such probable impacts, based on their reoccurrence in different modeled scenarios, were described in the National Academies Press synthesis report, *America's Climate Choices* (2011). They include the following observations, all based upon other studies and reports:

- Increasing intensity, frequency, and duration of heat waves in the United States, *id.* at 22 (citing IPCC, Climate Change 2007 Working Group 1 Report: Summary for Policymakers (2007));
- Rising sea levels leading to large effects on U.S. coastal infrastructure, beach erosion, wetland loss, and vulnerability to storm surge flooding in coastal regions, *id.* (citing R. J. Nicholls &

A. Cazenave, Sea-level Rise and Its Impact on Coastal Zones, 328 Science 1517-20 (2010);

- Submerging of many coastal and island features, *id.* at 23 (citing U.S. Global Change Research Program, Global Climate Change Impacts in the United States (2009), at 62-63 and references therein);
- Bleaching and stressing of coral reefs in the Florida Keys, Hawaii, and U.S. island possessions, already occurring because of pollution and overfishing, but exacerbated by climate effects of heat stress and ocean acidification, *id.* (citing U.S. Global Change Research Program, Global Climate Change Impacts in the United States (2009), at 84-85, and National Academies of Sciences, Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean (2010));
- Increasing desertification and drying of the Southwest, leading to additional pressures on existing water sources, *id.* (citing U.S. Global Change Research Program, Global Climate Change Impacts in the United States (2009), at 47, 83, and references therein);
- Changing agricultural dynamics in response to changes in carbon dioxide levels, temperature, and precipitation, as well as potential

increases in weeds, pests, and diseases, *id.* (citing U.S. Global Change Research Program, Global Climate Change Impacts in the United States (2009), at 71-78);

- Increasing forest fire risk in the West, *id.* (citing A. L. Westerling & B. P. Bryant, Climate Change and Wildfire in California, 81 Climatic Change 1-19 (2008));
- Increasing threats to endangered species, *id.* (citing National Research Council, Ecological Impacts of Climate Change (2008));
- Rising exposure to public health risks such as heat stress, elevated tropospheric ozone pollution, diseases, and extreme weather events, *id.* (citing U.S. Global Change Research Program, Global Climate Change Impacts in the United States (2009), at 89-98); *see also* EPA, *Climate Change in the U.S.—Benefits of Global Action* (2015), at 24, 27, https://www.epa.gov/sites/production/files/2015-06/documents/cirareport.pdf.
- Reduction in agricultural yields and economic harm to our agricultural sector. *See* EPA, *Climate Change in the U.S.—Benefits of Global Action* at 60-61 (2015), https://www.epa.gov/sites/production/files/2015-06/documents/cirareport.pdf.

These probable impacts alone give us cause for concern, particularly since there are signs that many of these impacts have already become noticeable. We find it troubling that substantial portions of our coasts will be submerged with further climate change, that water security and ecosystems in the U.S. West will be compromised by unprecedented warming, that strengthening major hurricanes may become the norm, that the health of Americans will suffer many climate-related stresses, that the ability of the planet to feed its growing populations will be compromised, and that whole island nations will be forced to move their populations as the habitable portions of their homelands become gradually, and eventually entirely, submerged. All of these concerns are supported by our science, and our confidence in this science has only strengthened with time and additional research.

Yet these probable impacts, understood because of scientific study, do not capture risks posed by climate change that have not been studied yet or anticipated. While we have tested and refined the predictive capacity of our existing models using empirical data, we also do not know if levels of carbon dioxide unprecedented in recorded human history (and, in fact, in millions of years) could lead to additional effects that we cannot even foresee. Thus, if anything, we expect that our existing models provide a conservative projection of events to come.

IV. Reductions in Carbon Dioxide Emissions Provide Additional Societal Benefits

Science also indicates that the Clean Power Plan will do more than help us avoid, or at least mitigate, serious climate impacts to our nation and fellow citizens. Addressing the carbon emissions resulting from power plants will also lead to a number of what are called "co-benefits." That is, the sorts of measures encouraged by the Clean Power Plan—reduction in carbon emissions from power plants and increased use of energy efficiency and renewable energy—will also lead to reductions in other pollutants, in ways that will have positive effects on human health. This is because the process of fossil fuel combustion leads to emissions of other pollutants with known health risks. In this way, the Clean Power Plan would yield positive benefits to human health.

Fossil fuel combustion produces emissions of various pollutants, especially nitrogen oxides (from all combusted fuels), sulfur dioxide (from coal combustion), and mercury (from coal combustion). These pollutants have direct effects on human health. In addition, nitrogen oxides contribute to the formation of ground-level ozone "smog" and nitrate particulate matter, both of which have known health impacts. Sulfur dioxide also contributes to particulate matter by forming particulate sulfates. As such, the co-benefits of the Clean Power Plan include reductions in nitrogen oxides, sulfur dioxide, mercury, ozone, and particulate matter (and the health benefits related to those reductions), in addition to the carbon dioxide focus of the Clean Power Plan.

In the past decade, these co-benefits have been increasingly recognized as a key part of climate mitigation strategies. *See, e.g.,* Greg Nemet et al., *Implications of Incorporating Air-Quality Co-Benefits into Climate Change Policymaking*. 5 Environ. Res. Lett. 1-9 (2010) (summarizing 37 peer-reviewed studies estimating the air quality co-benefits of climate change policy). An earlier meta-study of 37 peer-reviewed studies of co-benefits found a range of $2 to $147 in benefits per ton of carbon emissions reduced. *Id.* This wide range was in large part due to the wide variety of potential scenarios explored by independent researchers as well as the different types of co-benefits examined, but also to the ongoing refinement of the modeling methods themselves.

These co-benefit modeling methods, too, have been improving, based on our scientific process of refining these models based upon developing observational data. And several recent studies have modeled these co-benefits in additional detail. One example is a recent study that used a high-resolution electrical grid model to examine how four different energy efficiency/renewable energy scenarios would play out in the Mid-Atlantic and Lower Great Lakes of the United States. *See* Jonathan J. Buonocore et al., *Health and Climate Benefits of Different Energy-Efficiency and Renewable Energy Choices*, 6 Nature Climate Change 100-107 (2016). The researchers found that all of these scenarios led to benefits that could result in U.S. $5.7-$210 million (in total) in savings due to, among other factors, health benefits arising from reduction in other pollutants (such as nitrogen oxides and sulfur dioxides, both of which contribute to respiratory problems) associated with fossil fuel combustion. *Id.* at 100. Indeed, this study was limited in its exploration of health benefits, because it did not conduct a full lifecycle analysis of the process of fossil fuel combustion, such as fossil fuel extraction, facility construction and decommissioning, and waste disposal. *Id.* at 103. As such, we expect even integrated model assessments such as this one to provide a conservative estimate of the co-benefits that would be achieved by a move towards renewable energy and energy efficiency measures as encouraged by the Clean Power Plan.

Another similar study, which addressed the effect of climate mitigation strategies over the entire United States, finds similar ranges of co-benefits. *See* Tammy M. Thompson et al., *A Systems Approach to Evaluating the Air Quality Co-Benefits of U.S. Carbon Policies*, 4 Nature Climate Change 917-923 (2014). The researchers examined three possible climate mitigation scenarios. They found that the health co-benefits alone, monetized following recent regulatory analysis methods, could range from 26 percent of the cost of the policy to approximately ten times the cost of the policy. *Id.* Yet another study, focusing on co-benefits from reductions in fine particulate matter from carbon controls both targeted to the energy sector and economy-wide, explored regional variation between the "capture" of those health benefits. They concluded that a carbon policy similar to the Clean Power Plan, focused on the energy sector, could achieve a median benefit of $8 per ton of carbon from the reductions in fine particulate matter alone, using a valuation method that approximated real economic costs. *See* Rebecca K. Saari et al., *A Self-Consistent Method to Assess Air Quality Cobenefits from U.S. Climate Policies*, 65 J. Air & Waste Mgmt Ass'n 74-89 (2015); *see also* Charles T. Driscoll et al., *U.S. Power Plant Carbon Standards and Clean Air and Health Co-Benefits*, 5 Nature Climate Change 5, 535–540 (2015) (finding immediate regional and local health co-benefits resulting from the fine particulate matter and ozone concentration reductions associated with three alternative scenarios for U.S. power plant carbon standards).

These studies suggest to us that policy strategies such as the Clean Power Plan will not only help us avoid, or at least reduce, the negative impacts predicted to arise from climate change, but also do so in a way that achieves additional significant health and economic benefits.

V. Actions Such As the Clean Power Plan Are Necessary to Address Climate Change While Providing Additional Societal Benefits

As we stated from the outset, we are not lawyers or policymakers. Yet as members of society, we are worried about the societal implications of our own scientific findings. We view the Clean Power Plan, and its promise as an effective tool for reducing one of the primary sources of anthropogenic carbon, as a welcome tool for preventing and reducing the negative impacts of human-caused climate change. Accordingly, we write in support of the Clean Power Plan.

The Clean Power Plan is designed to achieve unprecedented reductions in greenhouse gas emissions from the electricity sector. According to EPA's estimates, the Clean Power Plan, in conjunction with existing preexisting trends such as the phase-out of older high emitting plants and low natural gas prices, will achieve a 32 percent reduction in greenhouse gases from the power sector under both a rate-based approach and the latter a mass-based approach. 80 Fed. Reg. at 64,736. No other policy vehicle currently exists that will achieve such large reductions in greenhouse gases within the U.S. electricity sector.

Conclusion

For the foregoing reasons, we write in support of upholding the Clean Power Plan.

Dated April 1, 2016

/s/ Stephanie Tai

Stephanie Tai[3]

Certificate of Compliance

[3] Steph Tai would like to express appreciation for their research assistant, Christopher Avallone, for his help on this brief.

Pursuant to Rule 32(a)(7)(C) of the Federal Rules of Appellate Procedure and Circuit Rules 32(a)(1) and 32(a)(2)(C), I hereby certify that the foregoing Brief of Amicus Curiae Climate Scientists in Support of Respondents contains 5863 words, as counted by a word processing system that includes headings, footings, quotations, and citations in the count, and therefore is within the word limit set by the court.

Dated: April 1, 2016

/s/ Stephanie Tai

Stephanie Tai

Certificate of Service

I hereby certify that, on this 1st day of April 2016, a copy of the foregoing Brief of Amicus Curiae Climate Scientists in Support of Respondents was served electronically through the Court's CM/ECF system on all ECF-registered counsel.

/s/ Stephanie Tai

Stephanie Tai

Addendum: *Amici* Background and Experience

David Battisti is the Tamaki Professor of Atmospheric Sciences at the University of Washington. He has a Ph.D. from the University of Washington in the field of atmospheric sciences. He has been involved in the field of climate dynamics and climate change since 1984 and his research involves climate variability (El Nino, drought in the Sahel, decadal variability in the climate system), paleoclimate (abrupt climate change during the last glacial period), dynamics of climate change, and the impact of climate change on global food production. He served for three years on the NAS Committee for Climate Research and for six years was co-chair of the United States Climate Variability and Predictability Science Steering Committee. He is a Fellow of the American Meteorological Society and the American Geophysical Union.

Marshall Burke is an assistant professor in the Department of Earth System Science, and Center Fellow at the Center on Food Security and the Environment at Stanford University. His research focuses on social and economic impacts of environmental change. His work has appeared in both economics and scientific journals, including recent publications in Nature, Science, the Proceedings of the National Academy of Sciences, and the Review of Economics and Statistics. He holds a Ph.D. in

Agricultural and Resource Economics from U.C. Berkeley, and a B.A. in International Relations from Stanford.

Ken Caldeira is a climate scientist at the Carnegie Institution for Science's Department of Global Ecology and Professor (by courtesy) in the Stanford University Department of Earth System Science. He studies the global carbon cycle; marine biogeochemistry and chemical oceanography; land-cover and climate change; the long-term evolution of climate and geochemical cycles; and energy technology. He received his B.A. from Rutgers College and both his M.S. (1988) and Ph.D. (1991) in atmospheric sciences from New York University.

Noah Diffenbaugh is an associate professor and Senior Fellow at Stanford University. He is currently Editor-in-Chief of the peer-review journal Geophysical Research Letters. He has served as a Lead Author for the IPCC and as a member of the National Academy of Sciences Ad Hoc Committee on Effects of Provisions in the Internal Revenue Code on Greenhouse Gas Emissions. He is a recipient of the James R. Holton Award from the American Geophysical Union and has been recognized as a Kavli Fellow by the National Academy of Sciences. He received his B.S. and M.S. degrees from Stanford University in 1997, and his Ph.D. from U.C. Santa Cruz in 2003.

William E. Easterling III is the Dean of the College of Earth and Mineral Sciences and Professor of Geography and Earth System Science at Penn State University. He was trained as an economic geographer and climatologist and holds three degrees from the University of North Carolina at Chapel Hill. He is an internationally recognized expert on how climate change likely will affect the Earth's food supply and was nominated by the White House to serve as a convening lead author on the IPCC Fourth Assessment Report's Chapter on Food, Fibre, Forestry, and Fisheries. The authors of the IPCC Assessment Report were co-awarded the 2007 Nobel Peace Prize with former Vice President Al Gore. He is also a Fellow of the American Association for the Advancement of Science, has authored more than 80 refereed scientific publications in the area of food and climate, has testified before the House Committee on Science and Technology on climate change, and has chaired or served on numerous international and national committees, including those of the United Nations, National Research Council, National Science Foundation, the U.S. Department of Energy and many other federal agencies.

Christopher Field is the founding director of Carnegie Science's Department of Global Ecology and Melvin and Joan Lane Professor for

Interdisciplinary Environmental Studies at Stanford University. His research focuses on climate change, ranging from work on improving climate models to prospects for renewable energy systems. From 2008 to 2015, he was co-chair of Working Group II of the IPCC, where he led the work on two IPCC reports. His Ph.D. is from Stanford University. His recognitions include election to the National Academy of Sciences, the Max Planck Research Award, and the Roger Revelle Medal.

John Harte is a professor in the Energy and Resources Group and the Ecosystem Sciences Division of the College of Natural Resources at the U.C. Berkeley. He received a B.A. in physics from Harvard University in 1961 and a Ph.D. in theoretical physics from the University of Wisconsin in 1965. He has been involved in the study of earth system science since 1973 and currently focuses on the ecological consequences of climate change and the climate consequences of ecological changes. He has served on six different panels of the NAS/NRC.

Jessica Hellmann (B.S. University of Michigan, Ann Arbor, Ph.D. Stanford University) is the Russell M. and Elizabeth M. Bennett Professor of Ecology, Evolution, and Behavior and the Director of the Institute of the Environment at the University of Minnesota. Her research examines the effects of climate change on species and ecosystems including methods to reduce negative impacts through climate change adaptation. She is a Woodrow Wilson Career Fellowship Recipient, a Leopold Leadership Fellow, and a Fellow of the AAAS Leshner Leadership Institute. She was a co-author of the Chicago Climate Action Plan and the 2014 National Climate Assessment.

Daniel Kirk-Davidoff is an Adjunct Associate Professor in the Department of Atmospheric and Oceanic Science at the University of Maryland. He received a Ph.D. in Meteorology from MIT in 1997. He is a climate dynamicist with interests in wind power forecasting and wind power-climate interactions, the stratospheric water vapor budget, paleoclimate modeling, satellite climate monitoring, and the use of satellite data to improve climate models.

David Lobell is an Associate Professor at Stanford University in the Department of Earth System Science, Senior Fellow at the Woods and Freeman Spogli Institutes, and Deputy Director of Stanford's Center on Food Security and the Environment. His research investigates climate change impacts and potential adaptations in agriculture and food security. He served in the recent IPCC Fifth Assessment Report as the U.S. lead author for the "Food Security and Food Production Systems" chapter and as core writing team member for the Summary for Policymakers. Dr.

Lobell received a Ph.D. in Geological and Environmental Sciences from Stanford in 2005, and a Sc.B. in Applied Mathematics from Brown University in 2000.

Pamela Matson is the Dean of the School of Earth, Energy & Environmental Sciences, Goldman Professor of Environmental Studies, and Senior Fellow at the Woods Institute for Environment at Stanford University. She was a lead author for the 2001 IPCC Working Group 1 report, and participated in the National Research Council's "America's Climate Choices" committee activites and reports, including as lead author of the "America's Climate Choices: Advancing the Science of Climate Change" report, published in 2010. She has been actively involved in research and assessment of climate change issues for three decades, including evaluating the importance of land use and agriculture in emissions of greenhouse gases, and evaluating the vulnerability of agricultural systems to climate change.

Katharine Mach is a Senior Research Associate at Carnegie Science's Department of Global Ecology. Her research is generating new possibilities for assessment of the risks of climate change, to empower decisions and actions in a changing climate. From 2012 to 2015, she was co-director of science for Working Group II of the IPCC, where she coordinated the work on two IPCC Reports. She received her Ph.D. in Biological Sciences from Stanford and A.B. in Biology from Harvard.

James C. McWilliams is an expert in the fluid dynamics of Earth's oceans and atmosphere and how they are depicted in computer simulation models. His college degrees are from Caltech and Harvard in applied mathematics. His current employment is as the Louis Slichter Professor of Earth Sciences at UCLA. He is a fellow of American Geophysical Union and a member of the U.S. National Academy of Sciences.

Mario J. Molina is a Professor at the UC San Diego (UCSD), with a joint appointment in the Department of Chemistry and Biochemistry and the Scripps Institution of Oceanography. Prior to joining UCSD he was an Institute Professor at MIT. He received a Ph.D. in Physical Chemistry from the University of California, Berkeley. He has been involved in developing our scientific understanding of the chemistry of the stratospheric ozone layer and its susceptibility to human-made perturbations, and his current research focuses on the chemistry of the atmosphere and with the various ways in which human society can affect it. He was a co-author, with F. Sherwood Rowland, of the 1974 publication in the British journal Nature, on the threat to the ozone layer from chlorofluorocarbon (CFC) gases, and received the 1995 Nobel Prize in Chemistry (with F. Sherwood Rowland and Paul Crutzen) for his "work on atmospheric chemistry, particularly concerning the formation and decomposition of ozone." He has served on the President's Committee of Advisors in Science and Technology, and on many other advisory boards and panels. He is a member of the NAS, the Institute of Medicine, and the Pontifical Academy of Sciences. He has received numerous awards for his scientific work in addition to the 1995 Nobel Prize in Chemistry, including the Tyler Ecology and Energy Prize in 1983 and the UNEP-Sasakawa Award in 1999.

Michael Oppenheimer is the Albert G. Milbank Professor of Geosciences and International Affairs at Princeton University. He earned a Ph.D. in chemical physics from the University of Chicago in 1970. He has been involved in atmospheric and air pollution research since 1975. His research on the climate system began in 1987 and has recently focused on the causes and consequences of sea level rise and other impacts of climate change. He has participated in every assessment report and one special report of the IPCC, most recently as a coordinating lead author of the Fifth Assessment.

Jonathan Overpeck is a climate scientist who has written over 190 published works on climate and the environmental sciences, served as a Working Group 1 Coordinating Lead Author for the Nobel Prize winning IPCC 4th Assessment (2007), and also as a Working Group 2 Lead Author for the IPCC 5th Assessment (2014). Other awards include the U.S. Dept. of Commerce Gold Medal, a Guggenheim Fellowship, and the Walter Orr Roberts award of the American Meteorological Society. Professor Overpeck has active climate research programs on five continents, examining drought and megadrought dynamics, and is also the lead investigator of two major programs focused on regional climate adaptation. He has appeared and testified before Congress multiple times, is a Fellow of American Geophysical Union, as well as of the American Association for the Advancement of Science.

Scott R. Saleska is an Associate Professor of Ecology and Evolutionary Biology and Agnese Nelms Haury Faculty Fellow in Environment and Social Justice at the University of Arizona, where he is director of the Ecosystem Genomics Initiative. He received a B.S. in Physics from MIT and a Ph.D. in Energy and Resources from the U.C. Berkeley. He has studied the effects of global change for over 20 years, focusing on how climate influences and is influenced by microbial and plant communities in tropical, temperate, and arctic ecosystems.

Noelle Eckley Selin is the Esther and Harold E. Edgerton Career Development Associate Professor of Data, Systems, and Society, and Atmospheric Chemistry, at the Massachusetts Institute of Technology. She has faculty appointments in MIT's Institute for Data, Systems, and Society and Department of Earth, Atmospheric and Planetary Sciences. Her research focuses on using atmospheric chemistry modeling to inform decision-making strategies on air pollution and climate change. She is the recipient of a CAREER award from the U.S. National Science Foundation, 2013 Leopold Fellow, and a 2015-2016 Fellow of the Leshner Leadership Institute of the American Association for the Advancement of Science. She received her Ph.D. from Harvard University in Earth and Planetary Sciences.

Drew Shindell is an expert in atmospheric and climate science who has worked extensively with both observations and computer simulations. His university degrees are from U.C. Berkeley and Stony Brook University, both in physics. His current employment is the Nicholas Distinguished Professor of Earth Science in the Nicholas School of the Environment at Duke University. He is a fellow of the

American Geophysical Union and the American Association for the Advancement of Science. He has testified on climate science before both houses of Congress and at the request of both parties.

Steven Wofsy is the Abbott Lawrence Rotch Professor of Atmospheric and Environmental Chemistry at Harvard University. His research focuses on greenhouse gases, including their emissions by natural and human-controlled processes, their distributions in the atmosphere, and the assessment of policies for mitigation. He was a principal author of the US Carbon Cycle Science plan and the North American Carbon Program plan. He is a member of the National Academy of Sciences and a recipient of the Roger Revelle Medal and NASA's Distinguished Service Award.