No. 19-1140 (and consolidated cases)

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

AMERICAN LUNG ASSOCIATION AND
AMERICAN PUBLIC HEALTH ASSOCIATION,

Petitioners,

v.

ENVIRONMENTAL PROTECTION AGENCY,
AND ANDREW WHEELER,

Respondents,

AEP GENERATING COMPANY, ET AL.,

Intervenors.

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

BRIEF OF AMICUS CURIAE CLIMATE SCIENTISTS DAVID BATTISTI, KIM COBB, ANDREW E. DESSLER, KERRY EMANUEL, JOHN HARTE, DANIEL KIRK-DAVIDOFF, KATHERINE MACH, MICHAEL MACCRACKEN, PAMELA MATSON, JAMES C. MCWILLIAMS, MARIO J. MOLINA, MICHAEL OPPENHEIMER, JOELLEN L. RUSSELL, NOELLE ECKLEY SELIN, DREW SHINDELL, ABIGAIL SWANN, KEVIN TRENBERTH, AND DIANA H. WALL.

IN SUPPORT OF PETITIONERS

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April 23, 2020

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 Petitioners American Lung Association and American Public Health Association, with the exception of the amici at present: Climate Scientists David Battisti, Kim Cobb, Andrew E. Dessler, Kerry Emanuel, John Harte, Daniel Kirk-Davidoff, Katherine Mach, Michael MacCracken, Pamela Matson, James C. McWilliams, Mario J. Molina, Michael Oppenheimer, Joellen L. Russell, Noelle Eckley Selin, Drew Shindell, Abigail Swann, Kevin Trenberth, and Diana H. Wall.

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]

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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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Table of Authorities

* This brief does not principally rely on any specific authorities.

Cases

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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, Kim Cobb, Andrew E. Dessler, Kerry Emanuel, John Harte, Daniel Kirk-Davidoff, Katherine Mach, Michael MacCracken, Pamela Matson, James C. McWilliams, Mario J. Molina, Michael Oppenheimer, Joellen L. Russell, Noelle Eckley Selin, Drew Shindell, Abigail Swann, Kevin Trenberth, and Diana H. Wall (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 and discussion in scientific journals and conferences. *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.").

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; heavier rainfalls, 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. 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 the substantial likelihood of of the specific damaging consequences will follow, as widely recognized in the scientific community. *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 urgent need to address anthropogenic emissions of greenhouse gases, based on our current understanding of the science. We believe that the Affordable Clean Energy Rule (hereinafter ACE Rule), 84 Fed. Reg. 32,520 (July 8, 2019), in repealing the Clean Power Plan (hereinafter CPP), 80 Fed. Reg. 64,662 (Oct. 23, 2015), fails to address the high risk that climate change poses for our society, nor even addresses its own failure to do so.

Many of us contributed to an *amicus* brief in the case *Massachusetts v. EPA*, 549 U.S. 497 (2007), as well as an *amicus* brief with respect to the CPP. Since the Supreme Court issued its ruling in *Massachusetts v. EPA*, 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 decreased.

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 and understand the 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 are already having devastating effects around the world, including changes to the United States.

For example, rising temperatures exacerbate the impact of droughts and increase risk of wildfires (or bush fires), including recent droughts in California and elsewhere in the United States, and places like Australia, which 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. The ACE Rule, in rescinding the CPP, fails to address or even acknowledge any of these threats.

Argument

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

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 infrared radiation in the electromagnetic 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 nearly 50 percent over the last 250 years, which is roughly the period during which humans have increasingly used fossil fuels. *See* Carbon Dioxide Information Analysis Center data, *available at* https://cdiac.ess-dive.lbl.gov/; *see also* 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 62 years are based on well-established methods for measuring carbon dioxide concentrations directly from air. *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. Concentrations of carbon dioxide are increasing and about half the total increase has occurred since 1985. *See* IPCC Climate Change at 166. The 2016 measured atmospheric concentration of carbon dioxide is about 410 parts per million. NOAA, *Trends in Atmospheric Carbon Dioxide* (2016), http://www.esrl.noaa.gov/gmd/ccgg/trends/. The overall rise, as we will explain later, is important in terms of climatic effects.

In turn, numerous studies, using independent 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).

The evidence is now crystal clear that climate change is genuine, caused by humans, and, as projected, the impacts have been intensifying rapidly. Our studies make it clear that climate change poses a tremendous threat to the United States as well as the rest of the world, as documented in the Climate Science Special Report released November 3, 2017. *See generally* U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment [hereinafter Climate Science Special Report] (2017), *available at* https://science2017.globalchange.gov/. This is a part of the National Climate Assessment led by the 13 U.S. Government agencies and subjected to intensive external reviews, including by the National Academy of Sciences. The report was also open to the public and scientific comment and review. The 470-page National Climate Assessment report evaluated the latest scientific evidence and concluded that storms, including hurricanes, have become more powerful; heavy rainfall has become more common in some parts of the United States; and heat waves, wildfires, and droughts are now more intense and happening more frequently.

> This assessment concludes, based on extensive evidence, that it is extremely likely that human activities, especially emissions of

> greenhouse gases, are the dominant cause of the observed warming since the mid-20th century. For the warming over the last century, there is no convincing alternative explanation supported by the extent of the observational evidence.

See U.S. Global Change Research Program, Climate Science Special Report: Fourth National Climate Assessment (2017), Executive Summary, *available at* https://science2017.globalchange.gov/chapter/executive-summary/.

These conclusions demonstrate a new level of scientific confidence for climate change assessments, and convincingly refute assertions that the primary cause of climate change and its consequent effects are natural or that humans play no or little role.

Over the 18-month period that the Climate Science Special Report was in development, the carbon dioxide concentration continued to climb rapidly, directly as a result of the combustion of fossil fuels. *See* World Meteorological Organization, *Greenhouse Gas Concentrations Surge to New Record* (Oct. 2017), *available at* https://public.wmo.int/en/media/press-release/greenhouse-gas-concentrations-surge-new-record. Even more recently, the IPCC issued a Special Report stating that if the current pace of climate change continues, we would exceed the onset of the "buffer zone" beginning around 1.5°C by approximately

2040. *See* Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C, [hereinafter IPCC Special Report] at 1-45 (2018).

The scientific evidence makes clear that if we want to avoid increasingly severe damage to the homes, lives, and livelihood of both human and other species, the world community, including the United States as the second largest emitter, needs to take more aggressive actions, not less, for reducing emissions. The ACE Rule fails to take any such actions.

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:

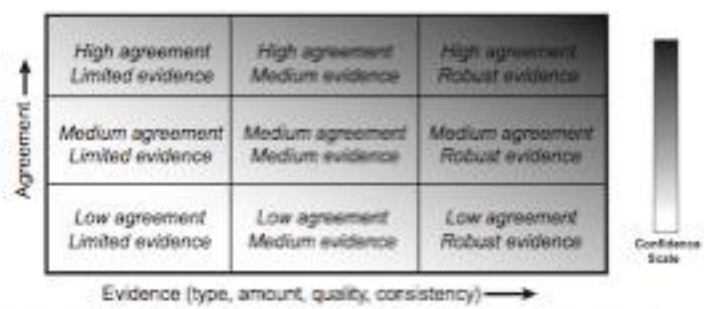

Figure 1: A depiction of evidence and agreement statements and their relationship to confidence. Confidence increases towards the top-right corner as suggested by the increasing strength of shading. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality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

The 2019 IPCC Special Report on the Ocean and Cryosphere in a Changing Climate updated our understanding of these changes. *See* IPCC, *Special Report on the Ocean and Cryosphere in a Changing Climate* (2019), *available at* https://www.ipcc.ch/srocc/. In it, we observed that the rate of global mean sea level rise for 2006-2015 is "unprecedented" and about "2.5 times the rate for 1901–1990." IPCC, *Special Report on the Ocean and Cryosphere in a Changing Climate, Summary for Policymakers* (2019), *available at* https://www.ipcc.ch/srocc/chapter/summary-for-policymakers/. We also observed that "Since 1993 the rate of ocean warming and thus heat uptake has more than doubled." *Id.* In addition, "[t]he ocean has taken up between 20–30% (very likely) of total anthropogenic CO2 emissions since the 1980s causing further ocean acidification." *Id.*

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

Again, since our 2016 participation as amici in support of the CPP, our own research, as well as the research of our esteemed colleagues, has provided even further support for our concerns about the ongoing impact of climate change on the United States. The following sections identify key research findings in areas of catastrophic environmental effects, biodiversity, agriculture, air quality, and other general observations that have been published since our earlier defense of the CPP.

A. Catastrophic societal effects (floods, droughts, fires)

Our research, as explained in our earlier amicus filing, has suggested that climate change can lead to catastrophic societal effects. The extent of these effects has been further characterized since the time we filed our amicus brief. That is, since our earlier amicus filing, we have developed methods to use physics-based risk assessment methods to assess the probabilities of extreme hurricane rainfall. *See* K. Trenberth et al., *Hurricane Harvey Links to Ocean Heat Content*, 6 Earth's Future, 730-44 (2018); Kerry Emanuel, *Assessing the Present and Future Probability of Hurricane Harvey's Rainfall*, 114 Proceedings of the National Academies of Sciences 12681-84. In conducting such studies, researchers have found that—due to climate change—extreme rainfall events along the Gulf Coast are on the rise. *See* Geert Jan van Oldenborgh, *Attribution of Extreme Rainfall from Hurricane Harvey*, 13 Envt. Res. Lett. 2-11 (2017). In addition, the 2018 IPCC Special Report recognizes a number of extreme climate outcomes if temperature-change extends beyond the buffer zone that begins around 1.5°C. *See* IPCC Special Report, at 3-22 to 3-37; 3-42 to 3-48; and 3-64 to 3-66.

B. Biodiversity and marine fisheries

Similarly, our own research and those of our colleagues, as described in our earlier amicus filing, supports concerns that climate change will harm biodiversity and marine fisheries. For example, a recent published article suggests that changes to ocean acidity due to carbon emissions already exceeds the range in natural seasonal variability over most of the ocean, thus leading to impacts on marine fisheries, and that "[w]arming ocean temperatures are associated with increased ocean stratification, which restricts nutrient supply to photosynthetic organisms in surface waters." *See, e.g.*, Stephanie H. Hensen, Rapid Emergence of Climate Change in Environmental Drivers of Marine Ecosystems, Nature Communications (2017).doi:10.1038/ncomms14682; *see also* William J. Chivers, Mismatch Between Marine Plankton Range Movements and the Velocity of Climate Change, Nature Communications (2017) doi:10.1038/ncomms14434; *cf.* Denise Breitburg et al., Declining Oxygen in the Global Ocean and Coastal Waters, 359 Science DOI: 10.1126 (2018); *see also* Department of Transportation, Safer Affordable Fuel-Efficient (SAFE) Draft Environmental Impact Statement at 5-16 (2018), *available at* https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_my2021-26_deis_0.pdf ("Although research on the ultimate impacts of declining ocean pH is limited, available observational, laboratory, and theoretical studies indicate that acidification could interfere with the calcification of coral reefs and inhibit the growth and survival of coral reef ecosystems").

In general, our colleagues have—since our earlier amicus filing—found that climate change will lead to significant redistribution of species. *See, e.g.*, Gretti T. Pecl *et al*, *Biodiversity Redistribution Under Climate Change: Impacts on Ecosystems and Human Well-being*, 355 Science DOI: 10.1126 (2017); David Tilman et al., *Future Threats to Biodiversity and Pathways to Their Prevention*, 546 Nature 73–81 (June 2017); *cf.* B. Martay et al., *Impacts of Climate Change on National Biodiversity Population Trends, Ecography* (2016) doi.org/10.1111/ecog.02411 (focusing on impacts beyond the United States). Likewise, the IPCC Special Report recognizes a number of significant changes to the ocean environment that could impact marine ecosystems resulting from extending beyond the buffer zone of 1.5°C. *See* IPCC Special Report, at 3-79 to 3-92.

More generally, we have also published studies that suggest that climate change can drive both local extinction and also presage "potentially widespread species losses in subalpine meadows as climate warming continues." *See* Anne Marie Panetta, Maureen Stanton, & John Harte, *Climate Warming Drives Local*

Extinction: Evidence from Observation and Experimentation, 4 SCI. ADV. 1-8 (2018); *see also* J. Keith Moore, *Sustained Climate Warming Drives Declining Marine Biological Productivity*, 359 Science 1139-1143 (2018). Studies by our colleagues have also identified threats to the Great Barrier Reef resulting from anthropogenic climate change. *See* Terry Hughes et al., *Global Warming Transforms Coral Reef Assemblages, Nature* doi:10.1038/s41586-018-0041-2 (Apr. 2018). We urge the EPA to consider such impacts in moving forward in developing its plan on addressing climate change.

C. Agriculture

Recent studies have found that climate change can affect the agricultural output of farms, leading to impacts on produce supply in this country. *See, e.g.*, Avery Cohn, *Smallholder Agriculture and Climate Change*, 42 Annual Review of Environment and Economics 347-375 (2017). Indeed, our own meta-studies have found that "Climate change will very likely cause large reductions in crop yields in numerous ways. [For example], for all plants, including domesticated crops, there are temperature and soil moisture conditions that produce the highest yields. Not surprisingly, farmers generally know this and grow crops on their land that achieve their optimal yields under the local climate. However, as shifts in climate 'push the climate envelope', yields will generally decline. Empirical studies indicate that even if we can prevent warming from exceeding 2◦C, the temperature effect alone will result in at least 10% declines in [average] yields of some important food crops." Paul R. Ehrlich & John Harte, *Pessimism on the Food Front*, 10 Sustainability 1120-24, doi:10.3390/su10041120 (2018). Empirical studies also show that a warming to 2°C will nearly double the year-to-year volatility of maize production worldwide. *See* Tigchelaar, M., D.S. Battisti, R.L. Naylor, and D.K. Ray, 2018: *Future warming increases global maize variability with implications for food security*. PNAS, doi 10.1073/pnas.1718031115. Similarly, the IPCC Special Report recognizes the detrimental impact that resulting from extending beyond the buffer zone of 1.5°C. *See* IPCC Special Report, at 3-99 to 3-105.

D. Air quality

The main contributors to climate change—power plants—are already affecting our air quality. *See, e.g.*, Maninder P. S. Thind et al., *Fine Particulate Air Pollution from Electricity Generation in the US: Health Impacts by Race, Income, and Geography*, 53 Environ. Sci. Technol., 14010−19 (2019); Meng Wang et al., *Association Between Long-term Exposure to Ambient Air Pollution and Change in Quantitatively Assessed Emphysema and Lung Function*, 322 JAMA 546-56 (2019); Yaguang Wei et al., *Short Term Exposure to Fine Particulate Matter and Hospital Admission Risks and Costs in the Medicare*

Population: Time Stratified, Case Crossover Study, 367 The BMJ 1-13 (2019). In contrast to the ACE Rule, our own research on climate change and air quality suggest that more stringent government actions, such as the CPP, will lead to positive impacts on air quality. *See* Brian Strasert et al., *Air Quality and Health Benefits from Potential Coal Power Plant Closures in Texas*, 69 J. Air & Waste Mgmt. Assn. 333-350 (2019); Fernando Garcia-Menendez, *U.S. Air Quality and Health Benefits from Avoided Climate Change under Greenhouse Gas Mitigation,* 49 Envtl. Sci.Tech. 7580–7588; *see also generally* M.C. Sarofim et al., *A Multi-Model Framework to Achieve Consistent Evaluation of Climate Change Impacts in the United States*, 131 Climatic Change (2015) (including a number of articles addressing various impacts of climate change on the United States). Moreover, as the IPCC Special Report points out, "there is high confidence that ozone-related mortality will increase if precursor emissions remain the same." *See* IPCC Special Report, at 3-107.

E. Other general observations

Finally, recent studies suggest that reaching climate change reduction goals, such as limiting warming to 1.5°C would reduce aggregate damages and lessen global inequality, and that failing to meet the 2°C target is likely to increase economic damages substantially. *See* IPCC Special Report; *see also* Marshall

Burke, W. Matthew Davis, & Noah S. Diffenbaugh, *Large Potential Reduction in Economic Damages under UN Mitigation Targets*, Nature (2018). The ACE Rule is inadequate for preventing these impacts.

IV. Residual uncertainty does not warrant rescinding the CPP in light of the significant impacts of climate change on the United States

The residual scientific uncertainty does not warrant inaction. While scientific uncertainties can also lead to uncertainties in the cost-benefit analyses, studies have demonstrated that compliance cost estimates have repeatedly overestimated the cost of compliance with regulatory approaches. For example, the National Academies of Sciences observed that, "A few studies have compared the compliance costs estimated in regulatory impact analyses to estimates of actual compliance costs incurred after a regulation has been put into effect. National Academies of Sciences, Environmental Decisions in the Face of Uncertainty 87 (2013) (citing W. Harrington, Resources for the Future, Grading Estimates of the Benefits and Costs of Federal Regulation (2006), available at https://www.nap.edu/catalog/12568/environmental-decisions-in-the-face-of-uncertainty. Those comparisons indicate that compliance costs are often overestimated." Thus, we caution against any reliance in the ACE Rule on cost analysis concerns as a justification for avoiding regulation in the face of scientific uncertainty.

Conclusion

None of the threats we have observed to our world and our livelihoods are remotely addressed in the ACE Rule. Thus we write in support of Petitioners challenging the ACE Rule.

/s/

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April 23, 2020

Certificate of Compliance

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 4701 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 23, 2020

/s/ Steph Tai

Steph Tai

Certificate of Service

I hereby certify that, on April 23, 2020, 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/ Steph Tai

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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.

Kim Cobb is a professor in the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology, and a Georgia Power Faculty Scholar. Her work focuses on oceanography, geochemistry and paleoclimate modeling. She is also the Director of the Georgia Institute of Technology Global Change Program.

Andrew E. Dessler is the Reta A. Haynes Chair in Geosciences and professor of atmospheric sciences at Texas A&M University. His research is on climate change, remote sensing, and climate change policy. He focuses on the role of water in climate change, and explores the complexity of water and its multiple interconnections with other parts of the atmospheric/oceanic system. He works to our understanding of the physics of the atmosphere, and provide "yardsticks" with which to test of the validity and accuracy of global climate models.

Kerry Emanuel is a professor of atmospheric science at the Massachusetts Institute of Technology. His work focuses on atmospheric convection and the mechanisms acting to intensify hurricanes. In 2007, He was elected as a member of the U.S. National Academy of Sciences in 2007, and a member of the American Philosophical Society in 2019. He is the author of Climate Science and Climate Risk: A Primer.

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.

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.

Katharine Mach is an Associate Professor at the University of Miami Rosenstiel School of Marine and Atmospheric Science and a faculty scholar at the UM Abess Center focused on environmental science and policy. Mach's research assesses climate change risks and response options to address increased flooding, extreme heat, wildfire, and other hazards. Through innovative approaches to integrating evidence, she informs effective and equitable adaptations to the risks. Mach is a lead author for the IPCC Sixth Assessment Report and the US Fourth National Climate Assessment. Mach previously was a Senior Research Scientist at Stanford University and Director of the Stanford Environment Assessment Facility. Before that from 2010 until 2015, Mach co-directed the scientific activities of Working Group II of the Intergovernmental Panel on Climate Change. Mach received her PhD from Stanford University and AB summa cum laude from Harvard College.

Michael MacCracken is Chief Scientist for Climate Change Programs for the Climate Institute in Washington DC, a non-governmental organization focused on finding effective solutions for dealing with climate change. He has served in this position since serving from 1993-2002 as senior scientist with the interagency Office of the US Global Change Research Program where he served as its first executive director and then as the executive director for the coordinating office of the first US National Assessment of the impacts of climate variability and change. His recent research has been on consideration of the possible benefits and disadvantages of regional or even global climate intervention as a result of the very slow pace of reducing global emissions, which is the most essential step in reducing the global deterioration due to human-induced climate change. His declaration relating to climate change damages is favorably cited and drawn upon in the majority opinion in Massachusetts v. EPA, 549 U.S. 497 (2007).

Pamela Matson is the Goldman Professor of Environmental Studies, and Senior Fellow at the Woods Institute for Environment at Stanford University. She served as Dean of the School of Earth, Energy & Environmental Sciences from 2002-2017. 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.

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.

Joellen Russell is the Thomas R. Brown Distinguished Chair of Integrative Science, and Professor in Geosciences, Planetary Science, Hydrology & Atmospheric Science, and Applied Math at the University of Arizona. Her research focuses on the ocean's role in climate. Her earlier work on the westerly winds led to her greatest research accomplishment so far: the creation of a new paradigm in climate science, namely that warmer climates produce stronger westerly winds. This insight solved one of the long-standing climate paradoxes, the mechanism responsible for transferring one-third of the carbon dioxide in the atmosphere into the ocean and then back out again during our repeated glacial-interglacial cycles.

Noelle Eckley Selin is Associate Professor of Data, Systems, and Society, and Atmospheric Chemistry, at the Massachusetts Institute of Technology, and the Director of the Technology and Policy Program. 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.

Abigail Swann is an atmospheric scientist and ecologist at the University of Washington College of the Environment who is interested in the transitions, thresholds, and feedbacks of the coupled ecosystem-climate system, or ecoclimate. More specifically, she works to understand when, where, and how plants influence the climate across a range of spatial and temporal scales. Her work is global in scale, considering the interactions between terrestrial ecosystems not only on their local environment, but also on other regions connected to the local ecosystem through atmospheric circulation.

Kevin Trenberth is a member of the Climate Analysis Section at the U.S. National Center for Atmospheric Research. He was a lead author of the 2001 and 2007 IPCC Scientific Assessment of Climate Change and serves on the Scientific Steering Group for the Climate Variability and Predictability program. He chaired the WCRP Observation and Assimilation Panel from 2004 to 2010 and chaired the Global Energy and Water Exchanges scientific steering group from 2010 to 2013. He has also served on the Joint Scientific Committee of the World Climate Research Programme, and has made significant contributions to research into El Niño-Southern Oscillation.

Diana H. Wall is the Director of the School of Global Environmental Sustainability and University Distinguished Professor at Colorado State University. Her 28 years of research in the Antarctic Dry Valleys continues to clarify the links between climate change and response of soil biodiversity across the landscape. Her PhD is from the University of Kentucky. She received the Tyler Prize for Environmental Achievement and is a member of the National Academy of Sciences.