No. 10-174

In The
Supreme Court of the United States

AMERICAN ELECTRIC
POWER COMPANY, INC., *et al.*,

Petitioners,

v.

STATE OF CONNECTICUT, *et al.*,

Respondents.

**On *Writ Of Certiorari* To The
United States Court Of Appeals
For The Second Circuit**

BRIEF OF JAMES G. ANDERSON, Ph.D., DAVID ARCHER, Ph.D., DAVID S. BATTISTI, Ph.D., MICHAEL L. BENDER, Ph.D., MARK A. CANE, Ph.D., PETER B. deMENOCAL, Ph.D., KERRY A. EMANUEL, Ph.D., INEZ Y. FUNG, Sc.D., PETER HUYBERS, Ph.D., RALPH F. KEELING, Ph.D., MARIO J. MOLINA, Ph.D., RAYMOND T. PIERREHUMBERT, Ph.D., DANIEL P. SCHRAG, Ph.D., AND STEVEN C. WOFSY, Ph.D., AS *AMICI CURIAE* IN SUPPORT OF RESPONDENTS

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INTEREST OF *AMICI CURIAE*[1]

Amici Curiae Climate Scientists are James G. Anderson, David Archer, David S. Battisti, Michael L. Bender, Mark A. Cane, Peter B. deMenocal, Kerry A. Emanuel, Inez Y. Fung, Peter Huybers, Ralph F. Keeling, Mario J. Molina, Raymond T. Pierrehumbert, Daniel P. Schrag and Steven C. Wofsy (hereinafter "Climate Scientists").[2] The Climate Scientists are individual climate scientists who are actively involved in research on changes to the Earth's climate in the past, present, and future. They are filing this brief to ensure that the Court understands the key scientific facts relevant to the issue before the Court.

Amicus James G. Anderson is the Philip S. Weld Professor in the Departments of Chemistry and Chemical Biology, Earth and Planetary Sciences and the School of Engineering and Applied Sciences at Harvard University. His climate research focuses on establishing the primary mechanisms that couple

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[1] All parties have consented to the filing of this brief. Pursuant to this Court's Rule 37.6, *Amici* state that no counsel for any party in this case authored this brief in whole or in part, and no person other than *Amici* and their counsel has made a monetary contribution to the preparation and submission of this brief.

[2] The Climate Scientists are appearing in their individual capacity and not as representatives of any institution with which any of them is affiliated. The assertions of science in this brief have been drafted, reviewed, and approved by the Climate Scientists, representing a distillation of the conclusions set forth in a multitude of scientific reports.

chemistry, dynamics, and radiation in the climate system, the establishment of a high-accuracy record of climate change using interferometry from low Earth orbit, and strategies for testing long-term climate forecasts using absolute spectrally resolved radiance in the infrared. He was elected to the National Academy of Sciences in 1992, the American Philosophical Society in 1998, and the American Academy of Arts and Sciences in 1985. He is also a Fellow of the American Association for the Advancement of Science and the American Geophysical Union. He has served on several National Research Councils, including the National Research Council Committee on Global Change Research.

Amicus David Archer is a Professor in the Department of the Geophysical Sciences at the University of Chicago and a Fellow of the American Geophysical Union. His work focuses on the Earth's carbon cycle and its interaction with global climate. He has written several books on climate change, including *Global Warming: Understanding the Forecast*, a text for non-science major undergraduates; *The Long Thaw: How Humans are Changing the Next 100,000 Years of Earth's Climate*; *The Climate Crisis*, a summary of the IPCC Scientific Assessment; *The Global Carbon Cycle*, a primer in climate science; and *The Warming Papers: The Scientific Foundation for the Climate Change Forecast*. He teaches classes on global warming, environmental chemistry, and global biogeochemical cycles, and is a regular contributor to the climate science blog site realclimate.org.

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Amicus Michael L. Bender is a Professor in the Department of Geosciences, Princeton University. His research focuses on the modern ocean carbon cycle and the uptake of fossil fuel carbon dioxide by the oceans and forests, and also on past climates as recorded in ice cores. He has served on the Board on Atmospheric Science and Climate of the National Research Council. The author of over 100 scientific papers, he has been awarded the Patterson Medal of the Geochemical Society and the Roger Revelle Medal of the American Geophysical Union. He was elected to the National Academy of Sciences in 2002.

Amicus Mark A. Cane is the G. Unger Vetlesen Professor of Earth and Climate Sciences at Columbia University. He devised the first numerical model able to simulate El Niño. He continues to work on El Niño prediction, and has also worked extensively on the impact of El Niño on human activity, especially agriculture and health. He is the Chief Physical

Scientist for the International Research Institute for Climate and Society. He has received the Sverdrup Gold Medal of the American Meteorological Society (1992), the Cody Award in Ocean Sciences from the Scripps Institution of Oceanography (2003), and the Norbert Gerbier-MUMM International Award from the World Meteorological Organization (2009). He is a Fellow of the American Meteorological Society; the American Association for the Advancement of Science, the American Geophysical Union, and the American Academy of Arts and Sciences.

Amicus Peter B. deMenocal is a Professor and Vice Chair in the Department of Earth and Environmental Sciences at Columbia University. At Lamont-Doherty Earth Observatory of Columbia University he uses stable isotopic and other geochemical analyses of marine sediments to understand how and why past climates have changed, with a specific interest in placing contemporary climate change trends within the context of climate changes during the prehistoric past. He was awarded the Lenfest Columbia Distinguished Faculty award in 2008 and is Editor-in-Chief of the scientific journal *Earth and Planetary Science Letters.*

Amicus Kerry A. Emanuel is a Professor of atmospheric science at the Massachusetts Institute of Technology, where he has been on the faculty since 1981. His research focuses on tropical meteorology and climate, with a specialty in hurricane physics. His interests also include cumulus convection, and advanced methods of sampling the atmosphere in aid of numerical weather prediction. He is the author or co-author of over 100 peer-reviewed scientific papers, and two books, including *Divine Wind: The History and Science of Hurricanes* and *What We Know about Climate Change*.

Amicus Inez Y. Fung is Director of the Berkeley Institute of the Environment and Professor of Atmospheric Science in the Department of Earth Planetary Science and Department of Environmental Science Policy and Management, at the University of California, Berkeley. Fung's research specializes on climate and biogeochemical cycles, geophysical fluid dynamics, large-scale numerical modeling, remote sensing of earth systems, and atmosphere-ocean interactions and atmosphere-biosphere interactions. She received her Sc.D. in Meteorology from the Massachusetts Institute of Technology. She was one of the authors of the National Academy of Sciences report on climate change science in 2001 that led to President Bush's Rose Garden speech that global warming is a serious problem. Fung is a member of the National Academy of Sciences and a Fellow of the American Geophysical Union and the American Meteorological Society. From 1997 to 2002 she was the Richard and Rhoda Goldman Distinguished Professor in the Physical Sciences at Berkeley, and in 2002 she was the Henry W. Kendall Memorial Lecturer in Global Change Science at MIT.

Amicus Peter Huybers is a Professor of Earth and Planetary Sciences at Harvard University. He focuses on understanding why and how Earth's climate changes, particularly with respect to glaciation, ocean circulation, and surface temperature. He graduated from the United States Military Academy at West Point, subsequently serving in the U.S. Army before receiving a Ph.D. from the Massachusetts Institute of Technology. He is a recipient of the James B. Macelwane Medal from the American Geophysical Union and a MacArthur Foundation Fellowship.

Amicus Ralph F. Keeling is a Professor at Scripps Institute of Oceanography at the University of California, San Diego whose research interests include climate change, changes in atmospheric composition, ocean biogeochemistry, and carbon cycling. He was the first to demonstrate that the oxygen concentration of the global atmosphere is decreasing due to the burning of fossil-fuels and has directed a program to track this decrease since 1989. Since 2005 he has also directed the Scripps CO_2 program which sustains the iconic record of carbon dioxide at Mauna Loa and other sites, begun by his father, Charles D. Keeling. He is engaged in ongoing research to refine estimates of sources and sinks of carbon dioxide using atmospheric measurements. He has given keynote addresses to the American Geophysical Union in 2004, and to the G8 Legislators and Business Leaders Climate Change Forum in London in 2005. In 1997, he received the Rosenstiel Award for his work on atmospheric oxygen.

Amicus Mario J. Molina is a Professor of Chemistry and Biochemistry at the University of California, San Diego and the Center for Atmospheric

Sciences at the Scripps Institution of Oceanography, as well as Director of the Mario Molina Center for Energy and Environment in Mexico City. He received the Nobel Prize in Chemistry in 1995 for his role in elucidating the threat to the Earth's ozone layer of chlorofluorocarbon gases. The only Mexican-born Nobel laureate in science, he served on the President's Council of Advisors for Science and Technology (PCAST) for both Clinton terms and currently serves on PCAST for President Obama. He is a member of both the National Academy of Sciences and the Institute of Medicine.

Amicus Raymond T. Pierrehumbert is the Louis Block Professor in Geophysical Sciences at the University of Chicago. He received a Ph.D. from the Massachusetts Institute of Technology in the area of theoretical fluid mechanics. He is a Fellow of the American Geophysical Union and was named Chevalier de l'Ordre des Palmes Academiques by the Republic of France. He has published extensively on theory and modeling of Earth and planetary climate, including most recently the textbook *Principles of Planetary Climate*. He was also a Lead Author on the IPCC Third Assessment report, and a co-author of the National Research Council Report, Climate Stabilization Targets.

Amicus Daniel P. Schrag is the Sturgis Hooper Professor of Geology and Professor of Environmental Science and Engineering at Harvard University and the Director of the Harvard University Center for the Environment. He studies climate change over the broadest range of Earth's history, including work on a broad set of questions about the early climate history of the Earth, and about how environmental conditions affected the evolution of life in the past. He is the author or co-author of over 100 journal articles, including research on new technological approaches to mitigating future climate change. He was the recipient of the James B. Macelwane Medal from the American Geophysical Union and was named a MacArthur Foundation Fellow in 2000. He currently serves on President Obama's Council of Advisors on Science and Technology.

Amicus Steven C. Wofsy is the Abbott Lawrence Rotch Professor of Atmospheric and Environmental Chemistry at Harvard University in the School of Engineering and Applied Science and the Department of Earth and Planetary Sciences. He studied chemistry at the University of Chicago and Harvard. His work has focused on changes in the composition of the atmosphere, using theory and modeling as well as field and laboratory studies. His current research emphasizes the effects of terrestrial ecosystems on the global carbon cycle, and the impacts of climate change and land use on ecosystems and atmospheric composition, including measurements of ecosystem carbon fluxes and forest responses to climate variations. He was the recipient of the James B. Macelwane Medal from the American Geophysical Union and NASA's Distinguished Public Service Medal.

INTRODUCTION AND SUMMARY OF ARGUMENT

This brief reviews the key scientific facts and shows why, under established law, plaintiffs have standing to seek reductions in carbon dioxide emissions from the petitioners' power plants for their contribution to global warming. Tracking the traditional legal enquiry to determine standing, we discuss the current and future harm to plaintiffs associated with climate change; the traceability of that injury to carbon dioxide emissions, including those of petitioners; and the extent to which reducing petitioners' carbon dioxide emissions will reduce the magnitude and severity of the future harms.

As the scientific studies discussed below demonstrate, human activities are causing a rise in the carbon dioxide concentration in the atmosphere that is already causing injuries to the plaintiffs. These injuries will continue to accumulate over the next century and beyond because of the long lifetime of carbon dioxide in the ocean-atmosphere system, and because of inertia in the climate system that can delay some of the most serious impacts. If action is not taken to curtail greenhouse gas emissions, today's children will face a world that is dramatically different from the Earth as it exists today. Sea level will be much higher; agricultural productivity will be much lower; and many other impacts will occur because of higher average temperature.

It is therefore virtually certain that carbon dioxide emissions from many sources, including petitioners' power plants, are already causing harm to the plaintiffs, and will cause increasing harm in the future unless measures are taken soon. The only reasonable option to abate climate change is to lower the net inputs of greenhouse gases, chiefly carbon dioxide, into the atmosphere.

These issues are not new to the Court. Four years ago, in *Massachusetts v. EPA*, 549 U.S. 497 (2007), the Court dealt with the harms caused by global warming in its inquiry into standing. The Court explained that the framework for establishing standing in the climate change context is no different than in any other: it requires only that a litigant "demonstrate that it has suffered a concrete and particularized injury that is either actual or imminent, that the injury is fairly traceable to the defendant, and that it is likely that a favorable decision will redress that injury." *Id.* at 517. Applying this framework, the Court concluded that the *Massachusetts* plaintiffs had demonstrated that they faced significant and real risks of harm from unchecked greenhouse gas emissions from new vehicles and that reducing such emissions would in turn reduce their risks of harm, even though new vehicle emissions constitute only a fraction of total global emissions. *Id.* at 526. The Court therefore found that the plaintiffs comfortably satisfied the familiar standing requirements. *Id.*

In reaching this conclusion, the Court had no difficulty finding that "[t]he harms associated with climate change are serious and well recognized." *Id.* at 521. As alleged, those harms included "retreat of mountain glaciers, reduction in snow-cover extent, the earlier spring melting of ice on rivers and lakes, and the accelerated rate of rise of sea levels." *Id.* As explained below, in the four years since this Court decided *Massachusetts*, the scientific data have grown stronger and confirmed that, absent intervention, these injuries will occur.

We show that if this Court applies the same legal standard as it applied in *Massachusetts,* it should reach the same result with regard to standing. This follows because: (1) the injuries alleged by plaintiffs here, which are similar to those alleged in *Massachusetts*, have already begun to occur and will become more severe over the next century; (2) emissions of greenhouse gases, mainly carbon dioxide emitted by petitioners and others, are directly responsible for these injuries; and (3) the reduction in total carbon emissions achieved by the specific relief sought here could result in more significant reductions in domestic carbon dioxide emissions than will be achieved by the transportation rule enabled by *Massachusetts*. In turn, those reductions will reduce the rate and severity of future injuries to the plaintiffs to a similar or greater extent than the transportation rule. Thus, if this Court applies the same standing requirements it applied in *Massachusetts*, it should reach the same result and find that plaintiffs have standing to advance their claims.

ARGUMENT

I. PLAINTIFFS' ALLEGED INJURIES ARE OCCURRING AND WILL BECOME MORE SEVERE.

A. Average Global Temperatures Have Increased and Will Continue to Increase.

Global average temperature has been rising since the late 19th century, and most steeply since the mid 1970s. The temperature rise is not uniform; some areas have warmed more quickly than others, and a few locations such as Antarctica may have experienced slight cooling, but the vast majority of regions have experienced overall warming.[3] The calendar year 2010 was tied with 2005 for the warmest year on record.[4] The nine hottest years in the historical record for which there exist good instrumental measurements (going back to 1850) have all occurred since 1997.[5] A wide range of different climate models

[3] Hansen, J., Ruedy, R., Sato, M. and Lo, K., *2010: Global surface temperature change,* Reviews of Geophysics, 48, RG4004, 2010.

[4] NASA Goddard Institute for Space Studies, Research News, *Despite Subtle Differences, Global Temperature Records in Close Agreement*, Jan. 13, 2011, *available at* http://www.giss.nasa.gov/research/news/20110113/

[5] Hansen, *et al.*, 2010.

calibrated on the historical temperature record predict that global average temperatures will rise as much as 9°F by 2100 if no actions are taken to reduce carbon dioxide emissions.[6] As an indication that a temperature change on this scale can have enormous consequences, this increase is equivalent to the difference in the global average temperature between today and the last glacial maximum, 20,000 years ago, when half of North America was covered with ice.[7] Importantly, the transition from the glacial climate to the pre-industrial climate occurred over 10,000 years, allowing plants, animals and human societies to adapt.[8] The rate of change experienced in the last few decades is 100 times faster, making adaptation much more difficult. The rate of change projected for the next 100 years is faster still and

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[6] Meehl, G.A., *et al.*, *The WCRP CMIP3 multimodel dataset – a new era in climate change research*, Bulletin of the American Meteorological Society, 88, 1383-1394, 2007; Stainforth, D., *et al.*, *Uncertainty in predictions of the climate response to rising levels of greenhouse gases*, Nature, 433, 403-406, 2005.

[7] Schneider von Deimling, T., *et al.*, *How cold was the Last Glacial Maximum?* Geophysical Research Letters, 33, L14709, 2006; Ballantyne, A.P., Lavine, M., Crowley, T.J., Liu, J. and Baker, P.B., *Metaanalysis of tropical surface temperatures during the Last Glacial Maximum*, Geophysical Research Letters, 32, L05712, 2005; Otto-Bliesner, B.L., *et al.*, *A comparison of PMIP2 model simulations and the MARGO proxy reconstruction for tropical sea surface temperatures at last glacial maximum*, Climate Dynamics, 32, 799-815, 2009.

[8] Prentice, I.C., Bartlein, P.J. and Webb, III, T., *Vegetation and climate change in eastern North America since the last glacial maximum*, Ecology, 72, 2038-2056, 1991.

beyond anything that human civilization has experienced.[9] The warmer temperatures that are observed now, as well as those predicted for the next century and beyond, will have a wide range of direct and indirect impacts on the citizens of the plaintiff States.

As the Court reviewed many of the impacts of climate change in the *Massachusetts* decision, we describe only a small number of examples of present and future injuries resulting from higher average temperatures, focusing also on new information developed since that case. We discuss the cause of those injuries in Section II.

B. Sea Level Is Rising and Will Continue to Rise, Which Will Lead to Increased Flooding of Coastal Regions.

Global warming causes sea level to rise because seawater expands as it warms, and because the melting of ice sheets on land, in particular on Greenland and Antarctica, adds to the volume of water in the oceans. Over the last two decades, global average sea level has been rising at a rate of 0.12 inches per year (3 mm per year), as measured by satellites and tide gauges.[10] Models predict this trend will continue

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[9] Meehl, G.A., *et al.*, *The WCRP CMIP3 multimodel dataset – a new era in climate change research*, Bulletin of the American Meteorological Society, 88, 1383-1394, 2007.

[10] Nicholls, R.J. and Cazenave, A., *Sea-level Rise and Its Impact on Coastal Zones*, Science, 328, 1517-1520, 2010.

and produce at least 10 to 20 inches of additional sea level rise by 2100,[11] and perhaps much more,[12] as discussed below. Higher sea level increases the damages due to flooding during large storms.[13] The increase in flooding is also exacerbated by the tendency for warmer temperatures to increase the rainfall intensity of storms.[14] Connecticut, New York, Rhode Island, and California, four of the plaintiffs, are already experiencing the erosion of coastal land and expensive coastal management challenges due to storm damage made worse by rising sea level. As sea level continues to rise, these damages will get worse

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[11] IPCC, *Climate Change 2007: The Physical Science Basis*, Cambridge Univ. Press, 2007.

[12] Pfeffer, W.T., Harper, J.T. and O'Neel, S., *Kinematic Constraints on Glacier Contributions to 21st-century Sea-level Rise*, Science, 321, 1340, 2008; Rahmstorf, S., *A semi-empirical approach to projecting future sea-level rise*, Science, 315, 368-370, 2007.

[13] Zhang, K.Q., Douglas, B.C. and Leatherman, S.P., *2000: Twentieth-century storm activity along the U.S. east coast*, Journal of Climate, 13, 1748-1761; Zhang, K.Q., Douglas, B.C. and Leatherman, S.P., *2004: Global warming and coastal erosion*, Climatic Change, 64, 41-58; Wu, S.Y., Najjar, R. and Siewert, J., *Potential impacts of sea-level rise on the Mid-and Upper-Atlantic Region of the United States*, Climactic Change, 95, 121-138, 2009.

[14] Trenberth, K.E., *Conceptual framework for changes of extremes of the hydrological cycle with climate change*, Climatic Change, 42, 327-339, 1999; Pardeep, P., *et al.*, *Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000*, Nature, 470, 382-385, 2011.

and worse as flooding affects a larger fraction of the United States coastline.[15]

C. Agricultural Production Will Decline Due to Increased Summer Temperatures.

Warmer summer temperatures cause grain harvests to decline. For example, corn yields increase slightly up to daily temperatures of 85°F, but above this threshold, hotter conditions sharply reduce yields. A single day at 95°F diminishes the entire year's corn harvest by 3% on average.[16] Such heat-driven declines in harvests during summer heat waves around the world have already occurred. In 2003, a summer heat wave in Western Europe with temperatures 6°F above average caused a 30%

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[15] Ashton, A.D., Donnelly, J.P. and Evans, R.L., *A discussion of the potential impacts of climate change on the shorelines of the Northeastern USA*, Mitigation and Adaptation Strategies for Global Change, 13, 719-743, 2008; Cooper, M.J.P., Beevers, M.D. and Oppenheimer, M., *The potential impacts of sea level rise on the coastal region of New Jersey, USA*, Climatic Change, 90, 475-492, 2008; FitzGerald, D.M., *et al.*, *Coastal impacts due to sea-level rise,* Annual Review of Earth and Planetary Sciences, 36, 601, 2008.

[16] Schlenker, W. and Roberts, M.J., *Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change*, Proceedings of the National Academy of Sciences, 106, 15594, 2009.

reduction in grain yield.[17] This extreme weather is likely to be the average summer climate of Western Europe by the end of the century.[18] Similarly, the heat wave around Moscow in 2010 reduced the Russian wheat harvest last year by 40% and prompted Russia to ban grain exports.[19] A comparable heat wave located in the Midwest would cause a serious reduction in corn harvests, including in Iowa, a plaintiff here. The effect of warmer temperatures is not limited to basic agricultural commodities, but extends also to all manner of economically important crops. For example, future warming is likely to degrade the quality of wine production in nearly all premium wine regions, including the Napa and Sonoma valleys of plaintiff California.[20]

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[17] Battisti, D.S. and Naylor, R.L., *Historical Warnings of Future Food Insecurity with Unprecedented Seasonal Heat*, Science, 323, 240-244, 2009.

[18] *Id.*

[19] Wegren, S.K., *Food security and Russia's 2010 drought*, Eurasian Geography and Economics, 52, 140-156, 2011.

[20] White, M.A., *et al.*, *Extreme heat reduces and shifts United States premium wine production in the 21st century*, Proceedings of the National Academy of Sciences, 103, 11217, 2006; Lobell, D.B., *et al.*, *Impacts of future climate change on California perennial crop yields: Model projections with climate and crop uncertainties*, Agricultural and Forest Meteorology, 141, 208-218, 2006.

D. Natural Water Storage Has Decreased and Will Decrease Further.

Warmer temperatures are already causing seasonal and spatial shifts in water resources with enormous economic implications. Most western states, including California, rely on the accumulation of snow in their mountain regions to serve as a natural reservoir, holding and releasing water for use in the dry summer months. Warmer temperatures are already causing a higher fraction of wintertime precipitation in the mountains to fall as rain instead of snow, and causing mountain snow packs to melt earlier in the year.[21] This causes more intense spring runoff, leading to springtime flooding in locations such as the Columbia River basin and Sacramento delta, and to water shortages in late summer.[22] As

[21] Mote, P.W., *Climate-Driven Variability and Trends in Mountain Snowpack in Western North America*, Journal of Climate, 19, 6209-6220, 2006; Hamlet, A.F., Mote, P.W., Clark, M.P. and Lettenmaier, D.P., *Twentieth-Century Trends in Runoff, Evapotranspiration, and Soil Moisture in the Western United States*, Journal of Climate, 20, 1468-1486, 2007; Adam, J.C., Hamlet, A.F. and Lettenmaier, D.P., *Implications of global climate change for snowmelt hydrology in the twenty-first century*, Hydrological Processes, 23, 962-972, 2009; Regonda, S.K., *et al.*, *2005: Seasonal cycle shifts in hydroclimatology over the western United States*, Journal of Climate, 18, 372-384, 2005; McCabe, G. and Clark, M.P., *Trends and variability in snowmelt runoff in the western United States*, Journal of Hydrometeorology, 6, 476-482, 2005.

[22] Lee, S.Y., *et al., Optimized flood control in the Columbia River Basin for a global warming scenario*, Journal of Water Resources Planning and Management, 135, 440-451, 2009.

this trend continues, mountain snowmelt will be a less and less reliable source of water for late summer agriculture, imposing large economic costs on agricultural regions of the Western United States, including the Central Valley of California.[23] The natural reservoir currently provided by mountain snow is far too large to be replaced by building artificial reservoirs. Scarcer water resources will affect not only agriculture but also industry, for example, hampering operations of power generation facilities that rely on river water for steam turbines and for cooling purposes.

E. Ecosystems Are Changing.

Warmer temperatures are causing injuries to the natural ecosystems across the United States, transforming them at extraordinary rates and scales. Critical ecosystems services provided to the plaintiff States are at risk.[24] A recent National Research Council (NRC) report[25] reviewed the multitude of

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[23] Vicuna, S., *et al.*, *The sensitivity of California water resources to climate change scenarios*, Journal of the American Water Resources Association, 43, 482-498, 2007; Young, C.A., *et al.*, *Modeling the Hydrology of Climate Change in California's Sierra Nevada for Subwatershed Scale Adaptation,* Journal of the American Water Resources Association, 45, 1409-1423, 2009.

[24] Parmesan, C., *Ecological and evolutionary responses to recent climate change*, Annual Review of Ecology, Evolution, and Systematics, 37, 627-669, 2006.

[25] Committee on Ecological Impacts of Climate Change, *Ecological Impacts of Climate Change*, National Research Council, 70, 2009.

ecological impacts of climate change in the United States, including shifts in species' geographic ranges as they attempt to migrate to colder regions, and seasonal shifts such as changes in when many plants bloom or in when birds, butterflies, and other animals migrate. As individual species adapt differently to local environmental changes, there will be a range of indirect impacts caused by disruptions in the interactions between them. For example, a change in when plants bloom may deprive animals of critical food supplies. Conversely, a change in the timing of insect or bird migrations may deprive blooming plants of critical pollinators. These changes can affect population dynamics, and even drive extinctions.[26] As warming proceeds over the next few decades, additional extinctions are expected to occur as plants and animals are unable to adapt to such rapid climate changes.[27]

F. IPCC Estimates of Future Injuries Are Overly Conservative for Risk Assessment.

The injuries described above have already begun to occur and are likely to worsen over the course of the next century. The Intergovernmental Panel on Climate Change (IPCC) is the leading international

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[26] *Id.*

[27] Millennium Ecosystem Assessment, *Ecosystems and Human Well-being: General Synthesis*, Washington, D.C., 2005.

scientific body for the assessment of climate change. It was established by the United Nations Environment Programme and the World Meteorological Organization to provide the world with a scientific view on the current state of knowledge in climate change and its potential environmental and socioeconomic impacts.[28] In its report of 2007,[29] the IPCC reviewed many additional climate change impacts in great detail.[30] The IPCC assessment of climate change impacts, used by the Court in *Massachusetts,* is scientifically accurate. However, where there is a range of potential outcomes, the IPCC report often errs on the conservative side, tending to underestimate potential damages. In part, this is because the IPCC works by consensus, which means that controversial subjects are often avoided.

A good example of how the IPCC provides a conservative assessment of future climate risks is the 2007 IPCC report's projection of sea level rise for 2100. The authors of the chapter on future sea level rise chose to exclude from their projections the possibility that melting of ice from glaciers on Greenland or Antarctica might accelerate as the Arctic warmed because evidence was not considered certain enough

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[28] Solomon, S., *et al.*, IPCC, *Climate Change 2007: The physical science basis*, Contribution of working group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

[29] *Id.*

[30] *Id.*

to provide an accurate estimate.[31] By assuming that the current rate of ice loss, measured from satellite monitoring of the Earth's gravitational field,[32] would remain constant even as global average temperature rises, the authors provided only a lower bound on how much sea level will rise.[33] More recent, peer-reviewed scientific publications explore a more reasonable assumption that the ice sheets will melt more quickly as temperature warms and will track the observed historical relationship between global average temperature and sea level.[34] Such an assumption yields an estimate of sea level rise of 39 to 70 inches (1 to 1.8 meters) by 2100, more than *three times higher* than the range reported by the IPCC.[35]

G. Risks of Catastrophic Consequences Cannot be Neglected.

In addition to the injuries described above, there is a possibility that climate change could result in

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[31] *Id.*

[32] Cazenave, A., *et al.*, *Sea level budget over 2003-2008: A reevaluation from GRACE space gravimetry, satellite altimetry and Argo*, Global and Planetary Change, 65, 83-88, 2009; Velicogna, I., *Increasing rates of ice mass loss from the Greenland and Antarctic ice sheets revealed by GRACE*, Geophysical Research Letters, 36, L19503, 2009.

[33] Solomon, *et al.,* 2007.

[34] Rahmstorf, S., *A semi-empirical approach to projecting future sea-level rise*, Science, 315, 368, 2007.

[35] *Id.*

even more catastrophic impacts. These impacts are inherently uncertain because they have never been observed, so they are often ignored in scientific assessments when the process requires higher confidence, even though they do pose substantial risks to human society at a global scale. For example, scientists measure the Earth's climate sensitivity – how much the Earth warms for a given increase in greenhouse gas concentration – by historical observations of global temperature and carbon dioxide concentrations over the past century. The exact number for climate sensitivity remains uncertain; models used to predict future warming yield a range of values from 2.7°F to 8.1°F per doubling of carbon dioxide levels. However, it is possible that the sensitivity is as much as 20°F per doubling of carbon dioxide.[36] If this were true, the injuries discussed above could be far more extreme and occur much more rapidly.

Another effect that is hard to predict with precision is the probability of the collapse of ice sheets in Antarctica. For example, the Ross Ice Shelf is an enormous piece of ice roughly 3000 feet thick that currently floats over the Ross Sea, restraining some of the glaciers on West and East Antarctica from

[36] Roe, G.H. and Baker, M.B., *Why is Climate Sensitivity so Unpredictable?,* Science, 318, 629, 2007; Stainforth, D., *et al.*, *Uncertainty in predictions of the climate response to rising levels of greenhouse gases*, Nature, 433(7024):403-406, 2005; Knutti, R. and Hegerl, G.C., *The equilibrium sensitivity of the Earth's temperature to radiation changes*, Nature Geoscience, 1, 735-743, 2008.

flowing directly into the ocean.[37] If the Ross Ice Shelf were to collapse, the seaward movement of these glaciers would accelerate, greatly increasing the rate of sea level rise beyond what is already predicted,[38] causing serious coastal damage. This is often treated as a low probability event, when actually its probability is highly uncertain. It is possible that the Ross Ice Shelf is already disintegrating – there is currently insufficient knowledge to make an accurate determination.

In addition, oceans and ice sheets have not yet adjusted to the current greenhouse gas concentrations discussed below. Even if global greenhouse gas emissions were stopped completely, the Earth would continue to warm for several decades, particularly over the oceans.[39] Ice sheets would continue to melt; sea level would continue to rise. Thus, the plaintiffs have not yet experienced the full impact of the past actions of the petitioners. More injuries are inevitable, but their severity and timing will be affected by the ongoing emissions of greenhouse gases.

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[37] Alley, R.B., Clark, P.U., Huybrechts, P. and Joughin, I., *Ice-sheet and Sea-level Changes*, Science, 310(5747):456, 2005.

[38] Overpeck, J.T., *et al.*, *Paleoclimatic Evidence for Future Ice-sheet Instability and Rapid Sea-level Rise*, Science, 311(5768):1747, 2006.

[39] Winton, M., Takahashi, K. and Held, I.M., *Importance of ocean heat uptake efficacy to transient climate change*, Journal of Climate, 23(9):2333-2344, 2010.

II. IT IS A SCIENTIFIC CERTAINTY THAT ATMOSPHERIC CARBON DIOXIDE IS RISING, THAT THIS RISE IS CAUSED BY HUMAN ACTIVITIES TO WHICH PETITIONERS CONTRIBUTE, AND THAT THIS RISE IS CAUSING THE CLIMATE TO WARM.

A. Combustion of Fossil Fuels Is Causing Atmospheric Carbon Dioxide to Increase to Levels Unprecedented for Millions of Years.

The concentration of atmospheric carbon dioxide is rising, and it is certain that the rise is caused by human activities. The concentration at the end of 2010 (390 parts per million or ppm) is higher than it has been for at least 800,000 years, based on direct observations of carbon dioxide in air bubbles trapped in ice cores.[40] There are no direct observations older than 800,000 years, but indirect methods of reconstructing ancient carbon dioxide concentrations indicate that the levels reached by mid-century if society does not take action to reduce carbon dioxide emissions (roughly 500 ppm) are higher than have existed for tens of millions of years.[41]

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[40] Siegenthaler, U., *et al.*, *Stable Carbon Cycle-Climate Relationship During the Late Pleistocene*, Science, 310, 1313-1317, 2005; Lüthi, D., *et al.*, *High-resolution carbon dioxide concentration record 650,000-800,000 years before present*, Nature, 453, 379-382, 2008.

[41] Pagani, M., *et al.*, *Marked Change in Atmospheric Carbon Dioxide Concentrations During the Oligocene*, Science, 309, 600-603. 2005.

Before the industrial revolution, the carbon cycle had been essentially in balance for thousands of years, with atmospheric carbon dioxide remaining constant between 260 and 280 ppm. As human society accelerated its use of fossil fuels and cut down forests for agricultural activities, the carbon dioxide concentration started to rise, implicating human activities as the cause. We are certain that combustion of fossil fuels is responsible for most of this rise, as the isotopes of carbon (both carbon-13 and carbon-14) in carbon dioxide in the atmosphere provide a clear fingerprint of fossil fuel as the source.[42]

B. Future Emissions Will Have a Greater Impact on Atmospheric Concentrations of Carbon Dioxide.

We are not yet experiencing the full impact of past and current carbon dioxide emissions. To date, the oceans and the terrestrial biosphere have provided a buffer by absorbing roughly 55% of the carbon dioxide released each year.[43] This buffer has slowed the increase in atmospheric concentrations of carbon dioxide, but this buffering effect may not persist in

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[42] Tans, P.P. and Wallace, D.W.R., *Carbon cycle research after Kyoto*, Tellus B, 51, 562-571, 1999.

[43] Manning, A.C. and Keeling, R.F., *Global oceanic and land biotic carbon sinks from the Scripps atmospheric oxygen flask sampling network*, Tellus Series B, 58, 95-116, 2006; Le Quere, C., Raupach, M.R., Canadell, J.G., Marland, G., *et al.*, *Trends in the sources and sinks of carbon dioxide*, Nature Geosciences, 2, 831-836, 2009.

the future. As carbon dioxide emissions continue, studies suggest that a smaller fraction of carbon dioxide will be taken up by the ocean and terrestrial biosphere.[44] This means that the continued emissions of the petitioners will have a larger impact on concentrations of atmospheric carbon dioxide in the future.

C. Carbon Dioxide Remains in the Atmosphere for a Very Long Time.

The carbon dioxide from human emissions that remains in the atmosphere will endure for a very long time. Even if human society stopped carbon dioxide emissions altogether by the end of this century, more than 20% of cumulative carbon dioxide emissions will still be in the atmosphere 1,000 years from now.[45] In 10,000 years, at least 10% of cumulative emissions will remain and maybe as much as 25%.[46] The last remnants of anthropogenic carbon dioxide emissions will stay in the atmosphere for more than 100,000 years, slowly drawn down by silicate weathering that converts the carbon dioxide to calcium carbonate, as

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[44] Denman, K.L., *et al.*, *Couplings between Changes in the Climate System and Biogeochemistry, In Climate Change: The Physical Basis of Climate Change*, Contribution of Working Group I to the Fourth Assessment Report of the IPCC, 500-587, Cambridge Univ. Press, 2007.

[45] Archer, D. and Brovkin, V., *The millennial atmospheric lifetime of anthropogenic CO2*, Climatic Change, 90, 283-297, 2008.

[46] *Id.*

well as slow burial of organic carbon on the ocean floor.[47] Thus, the continued actions of the petitioners will affect the atmosphere for many thousands of years into the future.

D. The Increasing Concentration of Carbon Dioxide in the Atmosphere Is Causing Global Warming.

There is no scientific dispute that adding carbon dioxide to the atmosphere causes global warming. Carbon dioxide is a greenhouse gas, which means that it absorbs outgoing infrared radiation (i.e., heat) in the atmosphere but allows the Sun's visible light to penetrate, causing a rise in Earth's surface temperature. The basic physics of the greenhouse effect and the relationship between carbon dioxide and climate was worked out by Arrhenius in the late 19th century, drawing on previous work by Fourier and others.[48] Atmospheric research over the 20th century has served to confirm Arrhenius's basic conclusions.[49] Our neighboring planet, Venus, which has a surface temperature of 860°F, is hotter than the Earth not because it is closer to the sun (it has highly reflective clouds that reflect most incoming sunlight) but

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[47] *Id.*

[48] Pierrehumbert, R.T., *Infrared radiation and planetary temperature*, Physics Today, January 2011.

[49] *Id.*

because of its thick atmosphere composed almost entirely of carbon dioxide (96.5%).[50]

This Court's decision in *Massachusetts* correctly concluded that carbon dioxide emissions cause climate change. 549 U.S. at 523. The Court stated that "[b]y any standard," this country's motor-vehicle emissions "make a meaningful contribution to greenhouse gas concentrations and hence, . . . to global warming." 549 U.S. at 525.

The clear causal connection between carbon dioxide and surface temperature contradicts the central claim of the *amici* Southeastern Legal Foundation, which incorrectly claims that "the extent to which anthropogenic greenhouse gases cause global warming is substantially uncertain."[51] There is no scientific dispute that anthropogenic greenhouse gases cause global warming. What is uncertain is 1) exactly how much warming will occur in response to a particular amount of carbon dioxide released by human activities and 2) precisely how that will impact other aspects of the Earth's climate system. These uncertainties exist because it is difficult to predict some feedbacks in the climate system, such as cloud physics or water vapor effects that can amplify the direct effects of higher greenhouse gas concentrations, as

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[50] de Bergh, C., *et al.*, *The composition of the atmosphere of Venus below 100 km altitude: An overview*, Planetary and Space Science, 54, 1389-1397, 2006.

[51] Br. of Southeastern Legal Foundation at 20-37.

well as feedbacks in the carbon cycle that can add additional greenhouse gases to the atmosphere.

The argument from the *amici* that uncertainty weakens the claims of the plaintiffs is incorrect. In fact, the scientific uncertainty about climate change primarily concerns the risks of the most extreme impacts. We know the probabilities of these impacts are not zero and the consequences would be devastating. The danger is that these impacts could start to occur before global carbon dioxide emissions are sufficiently reduced. Therefore, the scientific uncertainty that exists regarding extreme impacts only strengthens the arguments for reducing emissions.

E. The Largest Uncertainties Relate to Impacts that Are Worse than Current Projections.

Because the concentration of carbon dioxide is already higher today than it has been at any other time in human history and is increasing, the situation is particularly difficult to model. There is some evidence that most climate models underestimate climate sensitivity in part because they do not take into consideration certain feedbacks that operate only during higher levels of atmospheric carbon dioxide. One example is the hypothesis that cloud feedbacks, either in the stratosphere[52] or in the polar

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[52] Kirk-Davidoff, D.B., Schrag, D.P. and Anderson, J.G., *On the feedback of stratospheric clouds on polar climate*, Geophysical Research Letters, 10, 1029-1032, 2002.

troposphere,[53] amplify greenhouse warming at the poles and over continental interiors when greenhouse gas concentrations are high. These feedbacks are not included in climate models simply because they have not yet been observed. Yet geological evidence from warm climates in Earth history suggests that such feedbacks must exist.[54] In contrast, climate feedbacks that mute the impact of carbon dioxide on temperature have been proposed,[55] but have been refuted by theory and observations[56] and are not supported by the geologic record. Indeed, the geologic history of climate change provides compelling evidence that climate models underestimate the effects of carbon dioxide emissions,[57] making the claims of the plaintiffs here even more urgent.

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[53] Abbot, D.S. and Tziperman, E., *A High Latitude Convective Cloud Feedback and Equable Climates*, Quarterly Journal of the Royal Meteorological Society, 134, 165-185, 2008.

[54] Observations of amplified warming, particularly in continental interiors support the existence of some additional amplification beyond what exists in current climate models. *E.g.*, Wing, S. and Greenwood, D.L., *Fossils and Fossils Climate: The Case for Equable Continental Interiors in the Eocene*, Royal Society of London Philosophical Transactions, 341, 243-252, 1993.

[55] Lindzen, R.S., Chou, M.D. and Hou, A.Y., *Does the earth have an adaptive infrared iris?*, Bulletin of the American Meteorological Society, 82, 417-432, 2001.

[56] Hartmann, D.L. and Michelsen, M.L., *No Evidence for Iris*, Bulletin of the American Meteorological Society, 83, 249-254, 2002.

[57] Schrag, D.P. and Alley, R.B., *Ancient Lessons for our Future Climate*, Science, 306, 821-822, 2004.

There are other feedbacks that affect the climate system by causing the release of additional greenhouse gases to the atmosphere, amplifying the impact of carbon dioxide originally released by human activities. One example is warming of the Arctic that allows organic carbon stored in arctic soils to be released as either carbon dioxide or methane (an even more potent greenhouse gas).[58] Another example is the possible drying of tropical rainforests, which would release the carbon stored in these massive ecosystems to the atmosphere.[59] In both cases, the amount and timing of additional carbon releases are uncertain, and so these feedbacks are generally not included in predictions of future warming in the IPCC. If these feedbacks do occur, the injuries to the plaintiffs will be substantially more serious than those described above.

F. Petitioners' Emissions Are Significant.

Petitioners currently emit approximately 2.5% of global carbon dioxide. In *Massachusetts*, this Court found that, on an annualized basis, the transportation sector in the United States emits approximately 6% of global carbon dioxide. 549 U.S. at 524. Neither of these emitters are *de minimis*, like individual

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[58] Zimov, S.A., Schuur, E.A.G. and Chapin, III, F.S., *Permafrost and the Global Carbon Budget*, Science, 312, 1612-1613, 2006.

[59] Cox, P.M., *et al.*, *Amazonian forest dieback under climate-carbon cycle projections for the 21st century*, Theoretical and Applied Climatology, 78, 137-156, 2004.

houses.[60] Instead, both classes of emitters – the vehicles at issue in *Massachusetts* and the petitioners' power plants here – are responsible for substantial aggregations of greenhouse gas emissions. As explained below, reducing petitioners' annual carbon dioxide emissions by as little as 1.5% annually would reduce emissions by an amount equivalent to that produced by the transportation rule enabled by *Massachusetts*. There is, therefore, no principled distinction between the levels of contribution and reduction in this case and those in *Massachusetts*. Applying the same standing requirements to this case that this Court found the *Massachusetts* plaintiffs met should yield the same result.

III. REDUCING PETITIONERS' CARBON EMISSIONS WOULD SIGNIFICANTLY SLOW AND REDUCE GLOBAL WARMING.

A. EPA Has Shown that the Reductions Achieved by the Domestic Transportation Rules Would be Significant.

The Environmental Protection Agency (EPA), following *Massachusetts*, has concluded that the rules

[60] *Amici* Southeastern Legal Foundation argue that owners or operators of individual buildings could be sued under the legal theory advanced by plaintiffs. This fails to recognize that most carbon dioxide emissions from buildings (aside from the relatively low emissions from natural gas or oil heating systems) actually come from the power plants that generate the electricity used in the buildings, including those power plants operated by the petitioners, and not the buildings themselves.

proposed for domestic transportation will reduce atmospheric carbon dioxide concentration, global mean surface temperatures, and sea level rise.[61] In reaching this conclusion, EPA rejected arguments that uncertainties in climate models meant that projected results were not meaningful. Instead, EPA found that "the reductions . . . are quantifiable . . . across a range of climate sensitivities."[62]

As discussed above, these conclusions represent only a lower bound of the benefits of emissions reductions because they do not take account of the full range of possible climate impacts based on several feedbacks that amplify the climate's sensitivity to increased carbon dioxide levels. *See* Sections I.F, I.G & II.E *supra.*

B. Emissions Reductions from This Case Could be Greater than from the EPA Rules Regarding Domestic Transportation.

Petitioners' total emissions are approximately 650 million short tons of carbon dioxide per year or 590 million metric tons. This accounted for approximately 10% of all United States carbon dioxide

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[61] *Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule*, 75 Fed. Reg. 25,324, 25,495 (May 7, 2010).

[62] *Id.*

emissions in 2004.[63] Plaintiffs seek to reduce the defendants' power plant emissions "by a specified percentage each year for at least a decade."[64]

The EPA transportation rules enabled by *Massachusetts* abate carbon dioxide emissions relatively slowly, because it takes time for the vehicle fleet to turn over and the standards only apply to new vehicles.[65] The net reduction in carbon dioxide that will be achieved by the EPA transportation rules amounts to 950 million metric tons over the lifetime of the vehicles sold.[66]

Achieving comparable emissions reductions from the petitioners' power plants would require an annual emissions reduction of only 1.5% per year for 15 years (roughly the average lifetime of cars and trucks in the United States), resulting in a cumulative reduction in emissions of 991 million metric tons. Thus, this case could provide comparable cumulative reductions in emissions and avoidance of climate change impacts relative to the transportation rule enabled by *Massachusetts*.

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[63] Compl. at ¶ 98.

[64] Compl. at ¶ 49.

[65] The *Massachusetts* court was fully aware of this limitation. Indeed, it was one of the issues cited by one of the dissenters. 549 U.S. at 544.

[66] *Proposed Rulemaking To Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Proposed Rule*, 74 Fed. Reg. 49,454, 49,512 (September 28, 2009).

IV. THE CUMULATIVE EFFECTS OF CARBON EMISSIONS CREATE A PERILOUS FUTURE.

Finally, it is important that this Court understand the unique challenge of addressing climate change that comes from the scale of the problem, as well as the long response time of the Earth's climate system. We can think of our situation as sitting at the helm of a huge supertanker. Because of the long lifetime of carbon dioxide, the long response times of oceans and ice sheets, as well as the long time required to change energy infrastructure, our vessel has enormous momentum; it takes a long time to slow down or adjust course. The science of climate change shows that the planet is headed for a shipwreck. There is no uncertainty in the cause of that wreck, but we don't know whether the damage will merely cause a severe oil spill, or destroy our ship entirely. The plaintiffs are demanding that the petitioners start to reduce the throttle to minimize their injuries. We support this demand, because we believe that evasive action is essential.

CONCLUSION

For the foregoing reasons, this Court should hold that plaintiffs have standing to allege that petitioners should reduce their carbon dioxide emissions to abate the effects of climate change.

Respectfully submitted,

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