No. 19-1644

United States Court of Appeals
For the Fourth Circuit

Mayor and City Council of Baltimore,

Plaintiff-Appellee,

v.

BP P.L.C.; et al.,

Defendants-Appellants.

On Appeal from The United States District Court,
For the District of Maryland
Case No. 1:18-cv-02357-ELH
(Hon. Ellen L. Hollander)

BRIEF OF AMICI CURIAE MARIO J. MOLINA, MICHAEL OPPENHEIMER, BOB KOPP, FRIEDERIKE OTTO, SUSANNE C. MOSER, DONALD J. WUEBBLES, GARY GRIGGS, PETER C. FRUMHOFF and KRISTINA DAHL IN SUPPORT OF PLAINTIFF-APPELLEE AND AFFIRMANCE

WILLIAM A. ROSSBACH
ROSSBACH LAW, PC
401 N. WASHINGTON STREET
P. O. BOX 8988
MISSOULA, MT 59807
(406) 543-5156

Counsel for Amici Curiae

CORPORATE DISCLOSURE STATEMENT

Pursuant to Fed. R. App. P. 26.1, amicus curiae Mario J. Molina, Michael Oppenheimer, Bob Kopp, Friederike Otto, Susanne C. Moser, Donald J. Wuebbles, Gary Griggs, Peter C. Frumhoff, and Kristina Dahl certify that they are individuals, not corporations.

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AMICUS CURIAE'S IDENTITY, INTEREST AND AUTHORITY TO FILE

Amicus curiae, as scientists and scholars, have devoted much of their professional life to studying, writing, and teaching one or more aspects of climate science, including sea-level rise and its impacts on coastal communities.

Mario J. Molina received the 1995 Nobel Prize in Chemistry (with F. Sherwood Rowland and Paul Crutzen) for his work on atmospheric chemistry. He is a Professor at the University of California, San Diego (UCSD), with a joint appointment in the Department of Chemistry and Biochemistry and the Scripps Institution of Oceanography. **Michael Oppenheimer** is the Albert G. Milbank Professor of Geosciences and International Affairs at Princeton University. He is a coordinating lead author on the Intergovernmental Panel on Climate Change's Special Report on Oceans, Cryosphere and Climate Change and is coeditor-in-chief of the journal *Climatic Change*. He is also the Director of the Center for Policy Research on Energy and the Environment at Princeton's Woodrow Wilson

School and the Kravis Senior Contributing Scientist at the Environmental Defense Fund. **Bob Kopp** is the Director of the Institute of Earth, Ocean, and Atmospheric Sciences and co-directs the Coastal Climate Risk & Resilience Initiative at Rutgers University as well as the Climate Impact Lab. He is a lead author of the U.S. Global Change Research Program's 2017 Climate Science Special Report and was a contributing author to the Intergovernmental Panel on Climate Change's Fifth Assessment Report. Prof. Kopp is a recipient of the American Geophysical Union's James B. Macelwane and William Gilbert Medals and the International Union for Quaternary Research's Sir Nicolas Shackleton Medal. **Friederike Otto** is the Acting Director of the Environmental Change Institute and an Associate Professor in the Global Climate Science Programme at the University of Oxford. She is a lead author on the Intergovernmental Panel on Climate Change's Sixth Assessment Report, contributing to the chapter Weather and Climate Extreme Events in a Changing Climate, and a co-investigator on the International World Weather Attribution Project, providing an assessment of the human-influence on extreme weather in the immediate aftermath of the event. **Susanne C. Moser** is on the Research Faculty in the Environmental Studies Department of Antioch University New England. With more than 120 publications, Dr. Moser is an expert on adaptation to sea-level rise. She has advised states and local communities) on coastal adaptation. **Donald J. Wuebbles** is The Harry E. Preble Professor of Atmospheric Sciences in the School of Earth, Society, and Environment, Department of Atmospheric Sciences at the University of Illinois at Urbana-Champaign. Dr. Wuebbles has over 500 scientific publications related to the Earth's climate, air quality, and the stratospheric ozone layer. He was a co-author on the 2013 Intergovernmental Panel on Climate Change, as well as the 2014, 2017, and 2018 U.S. National Climate Assessments. **Gary Griggs** is Professor of Earth & Planetary Sciences at the University of California Santa Cruz, where he also served as Director of the Institute of Marine Sciences for 26 years. He is an expert on sea-level rise, publishing over 180 articles in scientific journals and book chapters, and has written 11 books. He was a member of the National Academy of

Sciences committee that prepared the report: Sea-Level Rise for the Coasts of California, Oregon and Washington (2012). **Peter C. Frumhoff** is Director of Science and Policy and Chief Climate Scientist at the Union of Concerned Scientists (UCS). Dr. Frumhoff has published widely at the nexus of climate science and policy, including on the climate responsibilities of fossil fuel companies and the attribution of extreme events to climate change. He currently serves on the US National Academy of Sciences' Board on Atmospheric Sciences and Climate. He was lead author of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. **Kristina Dahl** is a Senior Climate Scientist in the Climate and Energy program at the Union of Concerned Scientists. Dr. Dahl's research focuses on the impact of climate change, particularly sea-level rise, on people and places. She was the lead analyst and co-lead author on UCS's report that quantified the risks of sea-level rise for communities and real estate in the contiguous United States and has performed detailed GIS analyses showing the projected extent of sea-level rise and chronic flooding along the U.S. coasts.

As courts address cases involving the damage to coastal communities caused by climate change and ongoing sea-level rise, we feel it is essential for judicial decisions to be based on an understanding of the relevant science and the unavoidable adaptation expenses these communities are facing. We submit this *amicus* brief in order to assist the Court in that regard.

All parties have consented to the filing of this brief. No party's counsel authored the brief in whole or in part, no party or party's counsel contributed money that was intended to fund preparing or submitting the brief, and no person other than counsel for amici contributed money that was intended to fund preparing or submitting the brief.

SUMMARY OF ARGUMENT

There is broad consensus among climate scientists that the impacts of global warming, including rising seas, are accelerating. Carbon dioxide (CO_2) from combustion of fossil fuels—of which the Appellants' products are a primary source—is the largest single contributor to this warming. Global warming has produced a well-documented rise in the world's sea levels through thermal expansion of ocean water, the melting of mountain glaciers, and losses of ice from the Greenland and Antarctic ice sheets.

The City of Baltimore faces the daunting and expensive challenge of protecting its citizens and its infrastructure—roads, bridges, airports, rail lines, port facilities, sewage treatments systems, drinking water supply systems, storm drainage systems, and public utilities—from these rising sea levels now and for decades to come. Even with huge reductions in fossil fuel use, the ocean will continue to rise because of the slow nature of the processes governing sea-level rise.

Despite the recent United Nations Paris Agreement, by which 195 governments agreed to reduce global emissions in order to keep global warming from progressing to dangerous levels, global CO_2 emissions grew to record levels in 2017 (1.6% increase) and increased again in 2018 (2.7% increase).[1] Continued production, marketing, and combustion of fossil fuels on this high emission path will likely result in at least 2 feet of mean global sea-level rise by 2100[2]. There is a small, but very real possibility, that collapse of parts of the Antarctic ice sheet could result in over 6 feet of global sea-level rise by 2100[3]. Even the most aggressive emissions reduction scenarios would likely result in at least one

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[1] Le Quéré, C., et al., "Global Carbon Budget 2018," 10(4) *Earth System Science Data* (2018).
[2] About 85% probability according to Kopp, R. E., et al., "Probabilistic 21st and 22nd Century Sea-Level Projections at a Global Network of Tide-Gauge Sites," 2 *Earth's Future* 383 (2014).
[3] Bamber, J. L., et al., "Ice sheet contributions to future sea level rise from structured expert judgement," 116 (23) *Proceedings of the National Academy of Sciences*, 11195 (2019).

foot of mean global sea-level rise by 2100[4,5] and these scenarios are generally recognized as unachievable with current policies.

These predictions mean that the damage already caused by coastal flooding will inevitably increase as global warming causes sea levels to rise further. This will compel coastal communities to take costly remedial steps to harden infrastructure so it can withstand flooding, or people and communities will have to retreat from coastal locations.

Baltimore seeks to recover from the fossil fuel companies, whose products cause global warming and the sea-level rise that threatens the city, a fair share of the cost of adapting its coastal infrastructure to these rising seas.

We detail in our brief the scientific evidence showing that Appellants' fossil fuels are a substantial factor in lobal warming and the sea-level rise affecting Baltimore. We also describe the

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[4] About 92% probability according to Kopp, R. E., et al., "Probabilistic 21st and 22nd Century Sea-Level Projections at a Global Network of Tide-Gauge Sites," 2 *Earth's Future* 383 (2014).
[5] Sweet, W.V., et al., "Global and Regional Sea Level Rise Scenarios for the United States," *Climate Science Special Report* (2017).

peer reviewed data showing the relative contribution of each of the top 90 producers of fossil fuels, including almost all the Appellants named herein, to the carbon dioxide in the atmosphere. Climate scientists have used that data to calculate the relative contribution of each of the top 90 to the increases in carbon dioxide in the atmosphere, surface temperature, and sea level from 1880 to 2010. These calculations prove that Appellants' fossil fuel products are a substantial factor in the injuries and damages that Baltimore has and will continue to suffer.

ARGUMENT

I. Advances In Climate Science Have Shown That During The Period of Human Civilization, Stable Levels of Atmospheric Carbon Dioxide and Relatively Stable Global Temperatures And Sea Level Permitted Civilization To Flourish.

The foundation of modern climate science can be traced back to the 19th century. In 1824, Joseph Fourier proposed that Earth's atmosphere acts to raise the planet's temperature. Fourier wondered how Earth could be so warm as it was so far from the sun. Fourier knew that energy from the sun was reflecting off Earth and escaping back to space. He hypothesized that the atmosphere must capture some of that radiation, otherwise the planet would be significantly cooler. Fourier was the first to describe what would become known as "the greenhouse effect."[6]

In 1856, Eunice Foote demonstrated experimentally that the presence of CO_2 in the atmosphere causes the sun to heat the air

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[6] Fourier, J., "General Remarks on the Temperature of the Earth and Outer Space," 32 *American Journal of Science* 1 (1824), Translation by Ebeneser Burgess.

to a higher temperature compared to atmosphere without CO_2.[7] Soon after, in 1861, John Tyndall expanded on Foote's discovery by studying the amount of infrared energy absorbed by different gas molecules, including CO_2.[8] In 1896, Svante Arrhenius used principles of physical chemistry to estimate the extent to which increases in atmospheric CO_2 would raise Earth's surface temperature through the greenhouse effect. Arrhenius calculated that a doubling of CO_2 in the atmosphere would increase surface temperatures of the Earth by 4 degrees Celsius (4˚C). That estimate remains within the range of today's state-of-the-art climate model predictions.[9,10]

The greenhouse effect is an atmospheric process that warms Earth's surface. The sun provides energy primarily in the form of

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[7] Foote, E., "Circumstances Affecting the Heat of the Sun's Rays," 46 *The American Journal of Science and Arts* 382 (1856).
[8] Tyndall, J. "On the Absorption and Radiation of Heat by Gases and Vapours, and On the Physical Connexion of Radiation, Absorption, and Conduction**,** 22 *Philosophical Magazine* 169 (1861)
[9] Arrhenius, S. (1896), "On the Influence of Carbonic Acid in the Air Upon the Temperature of the Ground", 41 *Philosophical Magazine* 237 (1986).
[10] Stocker., et al., "Technical Summary," C*limate Change 2013: The Physical Science Basis*, (2013).

visible light and ultraviolet radiation. Though some of that energy is reflected back to space (by snow, clouds, etc.), most is absorbed by Earth's surface. The planet's surface then emits infrared radiation back toward space. Greenhouse gases in the atmosphere, such as CO_2, absorb this emitted infrared radiation. This energy is then re-emitted in all directions in the form of infrared radiation, roughly half upwards towards space and half back down to Earth.

Carbon dioxide is the most important greenhouse gas due to its potency, longevity, and abundance in the atmosphere. Water vapor is the most abundant greenhouse gas and also plays an important role in regulating Earth's temperature. The amount of water vapor in the atmosphere is modulated by air temperature: warmer conditions cause liquid water to evaporate and warm air can hold more water vapor than cold air. Rising CO_2 leads to an increase in temperature, which in turn leads to increased water vapor in the atmosphere. This feedback loop amplifies the warming effect CO_2 has on the planet.[11] Without CO_2, water

[11] Solomon, S., et al., "Contributions of Stratospheric Water Vapor to Decadal Changes in the Rate of Global Warming," 327 *Science* 1219 (2010).

vapor, and other greenhouse gases in the atmosphere, the mean surface temperature of Earth would be 33˚C (60˚F) cooler than it currently is.[12,13]

Earth's history is punctuated by naturally driven climate change events. Large, continental ice sheets in the northern hemisphere have advanced and retreated many times during the last 2.6 million years. Periods with large ice sheets are called *glacial periods*, or *ice ages*, and those without are known as *interglacial periods*. This pattern of climate change was driven primarily by changes in incoming solar radiation due to variations in Earth's orbit. For the last 800,000 years, glacial periods have lasted around 100,000 years and have been separated by relatively warm interglacial periods that lasted between 10,000 to 30,000 years. The most recent glacial period occurred between

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[12] Schneider, S., "The Greenhouse Effect: Science and Policy," 243 *Science* 771 (1989).

[13] Collins, M., et al., "Long-Term Climate Change: Projections, Commitments and Irreversibility," *Climate Change 2013*: *The Physical Science Basis,* Chap. 12 (2013).

11,500 and 116,000 years ago. Since then, Earth has been in an interglacial period called the Holocene Epoch.[14]

At the end of the last glacial period (during a 12,000-year span beginning around 20,000 years ago), global mean sea level rose approximately 400–450 feet at an average rate of 0.4 inches per year.[15] However, this deglaciation was punctuated by episodes of very rapid sea-level rise. For example, 14,000 years ago, sea level rose between 28–48 feet over 350 years.[16] Around 7,000 years ago, in the midst of the subsequent interglacial period (the Holocene), the rate of sea-level rise markedly decreased. Between 6,700 and 4,200 years ago, sea level rose about 10 feet, at a rate of about 0.05 inches per year. Sea level rose no more than about 3 feet between 4,200 years ago and the time of onset of recent sea-

[14] Masson-Delmotte, V., et al., "Information from Paleoclimate Archives," *Climate Change 2013*: *The Physical Science Basis*, Chap. 5 (2013).
[15] Masson-Delmotte, V., et al., "Information from Paleoclimate Archives," *Climate Change 2013: The Physical Science Basis*, Chap. 5 (2013).
[16] Liu, J., et al., "Sea Level Constraints on the Amplitude and Source Distribution of Meltwater Pulse 1A," 9 *Nature Geoscience* 130 (2016).

level rise (about 150 years ago)[17], or less than approximately 0.01 inches per year.[18] Human civilization flourished during the Holocene period of sea-level stability and has never had to contend with rapid changes in sea level (Figure 1).[19]

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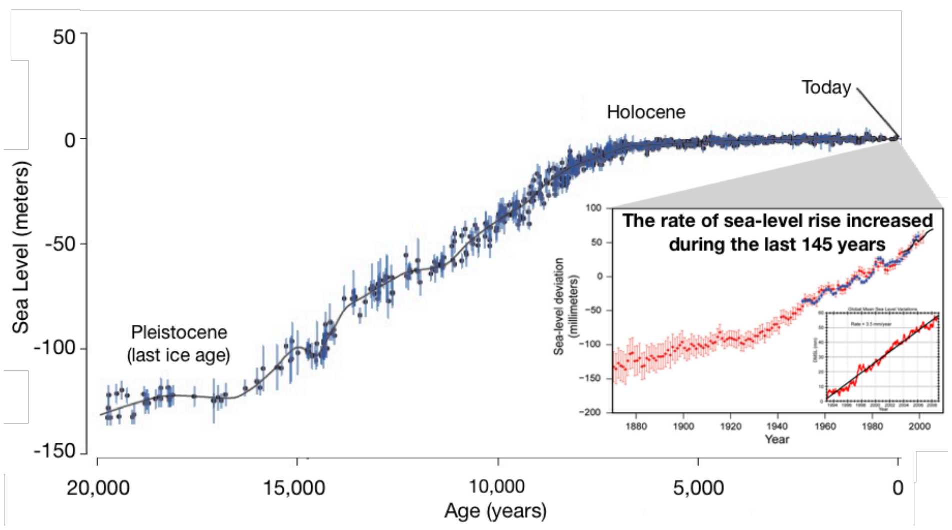
[17] Kopp, R., et al., "Temperature-driven global sea-level variability in the Common Era," 113(11) *Proceedings of National Academy of Science* E1434 (2016).

[18] Lambeck, K., et al., "Sea Level and Global Ice Volumes from the Last Glacial Maximum to the Holocene," 111(43) *Proceedings of the National Academy of Science* 15296 (2014).

[19] Masson-Delmotte, V., et al., "Information from Paleoclimate Archives," *Climate Change 2013: The Physical Science Basis*, Chap. 5 (2013).

Figure 1. Global mean sea level over the last 20,000 years. During the termination of the last ice age, massive continental ice loss led to 120–135 m (400–450 feet) of sea level rise. Around 7,000 years ago, the rate of sea level rise dropped to a "pre-industrial" rate of <1 mm per year. Figure inset depicts estimated sea level change (mm) since 1870. Global mean sea level has been rising at an average rate of 1.7 mm per year over the past 100 years. Since 1993, the rate increased to about 3.5 mm per year. Red: sea level since 1870. Blue: tide-gauge data. Black: satellite observations. Figures modified from: Clark, P., et al. (2016). Consequences of twenty-first-century policy for multi-millennial climate and sea level change, *Nature Climate Change*, *6*, 360-369, and NOAA https://www.ncdc.noaa.gov/monitoring-references/faq/indicators.php.



II. With The Commencement Of The Industrial Revolution, Previously Stable Atmospheric Carbon Dioxide Levels Began Increasing, Causing Rising Atmospheric And Ocean Temperatures And Sea-Level Rise That Is Unprecedented In The History Of Human Civilization.

For most of the history of human civilization, the amount of CO_2 in the Earth's atmosphere remained in a stable range between 260–280 parts per million (ppm).[20] During the past 200 years, commencing with the Industrial Revolution (1720–1800 CE), increased combustion of fossil fuels, cement production, and deforestation[21] have raised the average concentration of CO_2 in the atmosphere to greater than 410 ppm[22] – higher than any time in at least 800,000 years (Figure 2).[23] Most critically, however, more than half of all industrial emissions of CO_2 have occurred since 1988.[24]

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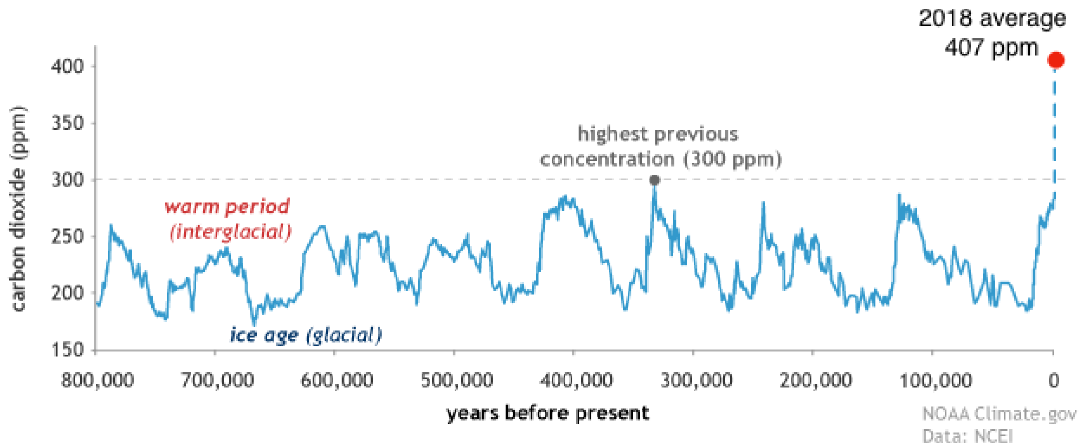
[20] Lourantou, A., et al., "Changes in Atmospheric CO_2 and Its Carbon Isotopic Ratio During the Penultimate Deglaciation," 29 *Quaternary Science Reviews* 1983 (2010).
[21] Le Quéré, C., et al., "Global Carbon Budget 2018," 10(4) *Earth System Science Data* (2018).
[22] Dlugokencky, E. & Tans, P., "Trends in Atmospheric Carbon Dioxide," NOAA/ESRL, www.esrl.noaa.gov/gmd/ccgg/trends/
[23] Masson-Delmotte, V., et al., "Information from Paleoclimate Archives," *Climate Change 2013*: *The Physical Science Basis,* Chap. 5 (2013).
[24] Frumhoff, P., et al., "The Climate Responsibilities of Industrial Carbon Producers," 132 *Climatic Change* 157 (2015).

Figure 2. Changes in atmospheric CO_2 concentrations over the last 800,000 years. Historic CO_2 levels are from ice core data, and current data are from the Mauna Loa Observatory. Average 2018 concentration indicated by red dot. Figure modified from NOAA.



Due primarily to the increased concentration of anthropogenic CO_2 from fossil fuel combustion, the mean surface temperature[25] of Earth has increased by 1˚C (1.8˚F) since the late nineteenth century.[26,27,28] One way to conceptualize the immense amount of heat that Earth is absorbing is to combine

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[25] *Global mean surface temperature* is calculated by combining measurements from the air above land and the ocean surface.
[26] Hawkins, E., et al., "Estimating Changes in Global Temperature Since the Preindustrial Period," 98(9) *Bulletin of the American Meteorological Society* 1841 (2017).
[27] Most of the same defendant corporations agreed to these facts at a "tutorial" before Judge William Alsup, in federal district court in the Northern District of California, in March 2018.
[28] Intergovernmental Panel on Climate Change, "Summary for Policymakers," *Global warming of 1.5°C* (2018).

measurements of ocean, land, atmosphere, and ice heating. Based on these data, over the last two decades Earth's climate system has been absorbing the heat equivalent, in joules, of detonating four Hiroshima atomic bombs per second, or nearly 400,000 Hiroshima A-bombs per day.[29,30]

If there is sustained greenhouse gas emissions growth, by the end of the century, global mean surface temperature is projected to increase between 3.6–5.8˚C above pre-industrial temperature.[31] The last time global mean surface temperature was comparable to today[32,33], global mean sea-level was 20–30 feet higher than today.[34]

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[29] Church, J. A., et al., "Revisiting the Earth's Sea-Level and Energy Budgets from 1961 to 2008," 38(18) *Geophysical Research Letters*, L18601 (2011).

[30] Nuccitelli, D., et al., "Comment on Ocean Heat Content and Earth's Radiation Imbalance II, Relation to Climate Shifts," 376(45) *Physics Letters A*, 3466 (2012).

[31] Collins, M., et al., "Long-term Climate Change: Projections, Commitments and Irreversibility," *Climate Change 2013*: *The Physical Science Basis,* Chap. 12 (2013).

[32] The Last Interglacial, 130,000–115,000 years ago.

[33] Hoffman, J., et al., "Regional and Global Sea-Surface Temperatures During the Last Interglaciation," 355 *Science* 276 (2017).

[34] Dutton, A., et al., "Sea Level Rise Due to Polar Ice-Sheet Mass Loss During Past Warm Periods," 349(6244) *Science* 153 (2015).

Global warming contributes to sea-level rise in multiple ways. As the ocean warms from climate change, seawater expands, takes up more space, and the oceans rise to accommodate this basic physical expansion. This process is known as *ocean thermal expansion*. Ocean thermal expansion accounts for about 50% of the increased volume of the world's oceans in the past 100 years. The remaining sea-level rise of the past century has been largely due to melting mountain glaciers (about 25%) and Antarctic and Greenland ice sheet loss (about 25%).[35,36]

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[35] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science," *California Ocean Science Trust* (2017), http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

[36] Church, J. A., et al., "Sea Level Change," *Climate Change 2013: The Physical Science Basis,* Chap. 13 (2013).

III. Even If All Carbon Dioxide Emissions Were To Cease Immediately, Sea Levels Would Continue To Rise For The Rest Of The Century Because Of The Additional Global Warming That Is Locked In By Cumulative Past Emissions

There is a delay between rising air temperatures and sea-level rise. Ocean thermal expansion and ice loss occur on timescales slower than the rate at which air temperature increases in response to increasing atmospheric CO_2 concentrations. It can take over a thousand years for ocean thermal expansion to equilibrate with warmer air temperatures.[37]

Since 1900, global mean sea level rose about 8 inches[38], but it was not a steady progression. The rate of sea-level rise is dramatically increasing. Since 1990, the rate of sea rise increased to about twice the rate of the last century, and the rate of sea rise

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[37] Levermann, A., et al., "The Multimillennial Sea-Level Commitment of Global Warming," 110(34) *Proceedings of the National Academy of Sciences* 13745 (2013).
[38] Church, J., White, N., "Sea Level Rise from the Late 19th to Early 21st Century," 32 *Surveys in Geophysics* 585 (2011).

is continuing to accelerate.[39,40] This sea-level rise can increase damages from daily tides, king tides, and extreme weather events. In superstorm Sandy, sea-level rise was estimated to have inflicted an additional $2 billion in flooding damage.[41]

Current atmospheric CO_2 concentrations have committed the world to significant levels of sea-level rise for centuries to come. There is no combination of emissions reductions, no matter how aggressive, that can prevent the now inevitable rise of seas over the next one hundred years or more. The recently published Fourth National Climate Assessment warns that:

> Even if significant emissions reductions occur, many of the effects from sea-level rise over this century (and particularly through mid-century) are already locked in due to historical emissions, and many communities are already dealing with the consequences. Actions to plan for and adapt to more frequent, widespread, and severe coastal flooding, such as shoreline protection and conservation of coastal ecosystems,

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[39] Nerem, R. S., et al., "Climate-Change-Driven Accelerated Sea-Level Rise Detected in the Altimeter Era," 115(9) *Proceedings of the National Academy of Sciences* 2022 (2018).
[40] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science," *California Ocean Science Trust* (2017), http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf
[41] Leifert, H., "Sea Level Rise Added $2 Billion to Sandy's Toll in New York City," 96 *Eos* 16 (2015).

> would decrease direct losses and cascading impacts on other sectors and parts of the country.[42]

The Intergovernmental Panel on Climate Change (IPCC), a body of the United Nations, is the internationally accepted authority on climate change science. The IPCC reviews the state of climate science and issues global consensus scientific assessment reports every five to seven years. The IPCC's Fifth Assessment Report utilized a set of future scenarios, known as Representative Concentration Pathways (RCPs) (Figure 3)[43] to help policy makers understand the impact of policies designed to reduce emissions.

The four RCPs in the Fifth Assessment describe scenarios based on different assumptions about energy consumption, energy sources, land use change, economic growth, and population. At one end of the spectrum, RCP 2.6 represents a suite of extremely

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[42] Fourth National Climate Assessment, (2018), Vol. II, Summary Findings, https://nca2018.globalchange.gov/#sf-12.

[43] RCPs are named for the associated radiative forcing level in watts per square meter (the difference between sunlight absorbed by Earth and energy radiated back to space) by the year 2100 relative to pre-industrial values.

aggressive reduction scenarios which require that CO_2 emissions worldwide plateau by 2020, just one year from now, and are reduced by 50% by 2050.[44,45] At the other end, RCP 8.5 represents a future in which there is no significant global effort to limit greenhouse gas emissions and a sustained growth of fossil-fuel emissions. Between the two extremes are RCPs 4.5 and 6.0, which represent stabilization scenarios in which total radiative forcing is stabilized shortly after 2100. Each RCP represents a family of climate outcomes, including temperature and sea-level rise.[46]

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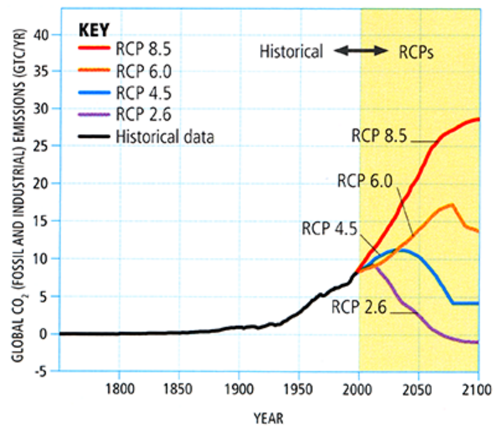
[44] Compared to 1990 CO_2 emissions.

[45] Jones, C., et al., "Twenty-First-Century Compatible CO_2 Emissions and Airborne Fraction Simulated by CMIP5 Earth System Models Under Four Representative Concentration Pathways," 26 *Journal of Climate* 4398 (2013).

[46] Collins, M., et al., "Long-term Climate Change: Projections, Commitments and Irreversibility," *Climate Change 2013*: *The Physical Science Basis*, Chap. 12 *(2013)*.

Figure 3. Observed and projected CO_2 emissions. Current rate of annual carbon emissions in gigatons (black line) compared to IPCC projected scenarios. Figure source: Mann & Kump, Dire Predictions: Understanding Climate Change, 2nd Edition © 2015 Dorling Kindersley Limited.



Under RCP 2.6, the IPCC's Fifth Assessment Report projects that global mean sea-level will likely rise 11–24 inches by 2100.[47,48] Under RCPs 4.5, 6.0, and 8.5, which are more plausible paths based on current policies, sea level is projected to likely rise 14–28 inches, 15–29 inches, and 20–39 inches, respectively, by 2100. [49,50]

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47 At least 66% probability, according to Church, J. A., et al., "Sea Level Change," *Climate Change 2013: The Physical Science Basis,* Chap. 13 (2013).

48 Relative to global mean sea level over 1986–2005.

49 At least 66% probability, according to Church, J. A., et al., 13: "Sea Level Change," *Climate Change 2013: The Physical Science Basis,* Chap. 13 (2013).

50 *Id.*.

The RCP scenarios produce conservative estimates of sea-level rise because they do not account for the possibility that changing Antarctic ice sheet dynamics could dramatically increase sea levels by the end of the century.[51,52,53] A scenario that accounts for Antarctic ice loss would yield the maximum physically plausible global mean sea-level during the latter half of this century. This scenario projects at least a 6.5-foot rise in global mean sea level by 2100.[54] The probability of this extreme scenario is currently unknown due to our limited understanding of the dynamics governing the magnitude and timing of Antarctic ice sheet loss.

In October 2018, the IPCC issued a special report assessing: 1) the possibility of restricting global warming to 1.5˚C above pre-industrial temperatures, and 2) what the avoided damages might

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[51] DeConto, R. & Pollard, D., "Contribution of Antarctica to Past and Future Sea-Level Rise," 531(7596) *Nature* 591 (2016).
[52] Shepherd, A., et al., "Mass Balance of the Antarctic Ice Sheet from 1992 to 2017, 556 *Nature* 219 (2018).
[53] Bamber, J. L., et al., "Ice sheet contributions to future sea level rise from structured expert judgement," 116 (23) *Proceedings of the National Academy of Sciences*, 11195 (2019).
[54] *Id.*

be between 1.5˚C and 2˚C warming, the two goals adopted at the 2016 Paris Climate Summit.[55,56]

Capping global warming at 1.5˚C would require exceptional measures, even more aggressive than those contemplated in the IPCC's RCP 2.6 scenario, which was the most aggressive emissions reduction pathway previously assessed by the group. To prevent the world from warming more than 1.5˚C above pre-industrial levels, global CO_2 emissions would need to decline about 45% by 2030 – just 10 years from now – and reach net zero emissions globally by 2050.[57] Given the current trajectory of global economic development and the weak voluntary commitments of the world's nations to curbing the problem communities faced with increasingly severe climate change impacts cannot rely on this level of emissions reductions being achieved. Indeed, between 2017 and 2018, global energy-related CO_2 emissions *increased* by

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[55] Intergovernmental Panel on Climate Change, "Summary for Policymakers," *Global warming of 1.5°C* (2018).
[56] U.N. Paris Agreement, https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[57] Intergovernmental Panel on Climate Change, "Summary for Policymakers," *Global warming of 1.5°C* (2018).

2.7% (range of +1.8% to +3.7%).[58,59] And even if global net emissions were cut to zero by 2050, the seas would continue to rise over at least the next few centuries to levels that would threaten billions of dollars of property and infrastructure in Maryland and beyond.

Local sea level may differ from global mean sea level due to a number of factors:

a. Large ice sheets exert a gravitational pull on the nearby ocean, drawing water towards it. If that ice melts, this gravitational force weakens, causing a lowering of sea level near the ice sheet and an enhanced sea-level rise further away. Consequentially, the loss of Antarctic ice has an enhanced effect on Northern Hemisphere sea-level rise, while the loss of Greenland ice has an enhanced

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[58] Le Quéré, C., et al., "Global Carbon Budget 2018," 10(4) *Earth System Science Data* (2018).

[59] International Energy Agency, "Global Energy and CO2 Status Report," https://www.iea.org/geco/emissions/

effect on Southern Hemisphere sea-level rise.[60,61] These detectible patterns of sea-level variability are known as "sea-level fingerprints."

b. *Glacial isostatic adjustment* is the ongoing vertical movement of land that was once beneath or adjacent to ice-age glaciers and ice sheets. Regions near the centers of ice sheets of the last ice age may experience post-glacial rebound, which is the rise of land masses that were depressed by massive ice sheets during the last ice age. Conversely, land pushed up during the building of ice sheets in the last ice age ("the forebulge") may now be sinking (e.g. Chesapeake Bay).[62]

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[60] Mitrovica, J. X., et al., "On the Robustness of Predictions of Sea Level Fingerprints," 187(2) *Geophysical Journal International* 729 (2011).

[61] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science," *California Ocean Science Trust* (2017), http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

[62] DeJong, B., et al., "Pleistocene Relative Sea Levels in the Chesapeake Bay Region and Their Implications for the Next Century," 25(8) *GSA Today* 4, (2015).

c. Prevailing winds can push water across oceans. For example, the Trade Winds in the Pacific blow water westward, increasing sea level in the western Pacific (e.g. the Philippines) by about 24 inches, and decreasing sea level in the eastern Pacific (e.g. northern South America).[63] In the long term, global wind patterns change as climate changes, geographically re-allocating mounds of sea water. Short term changes in winds, such as those associated with the North Atlantic Oscillation, can have large effects on local sea-level.[64]

d. In addition to ocean currents generated by surface wind, currents that are driven by differences in water density due to temperature and salinity variations in different

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[63] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science," *California Ocean Science Trust* (2017), http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf.

[64] Kenigson, J. S., et al., "Decadal shift of NAO-linked interannual sea level variability along the U.S. Northeast Coast," 31 *Journal of Climate* 4981 (2018).

parts of the ocean (*thermohaline circulation*) can have large effects on local sea level.[65]

e. Localized processes such as plate tectonics and sediment compaction can cause land masses to fall or rise.[66]

f. Oil and gas extraction, as well as groundwater withdrawal can cause the continental shelf to "deflate," raising sea level at coastal deltas (e.g. Louisiana).[67,68]

Sea-level in the mid-Atlantic region (the U.S. East Coast north of Cape Hatteras, NC) has been increasing at a rate greater than the global average. The primary reason for this enhancement in regional sea-level rise is due to glacial isostatic adjustment, but is also affected by subsidence due to groundwater

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[65] Levermann, A. et al., "The Multimillennial Sea-Level Commitment of Global Warming," 110(34) *Proceedings of the National Academy of Sciences* 13745 (2013).
[66] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science," *California Ocean Science Trust* (2017), http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf.
[67] Nienhuis, J. H., et al., "A New Subsidence Map for Coastal Louisiana," 27 *GSA Today 58* (2017).
[68] Kopp, R. E., et al., "Probabilistic 21st and 22nd Century Sea-Level Projections at a Global Network of Tide-Gauge Sites," 2 *Earth's Future* 383 (2014).

withdrawal and ocean currents.[69] All of these processes operate on different time scales, making it difficult to parse out the individual contributions to local sea-level rise.[70]

The mid-Atlantic region is in close proximity to the former Laurentide Ice Sheet and its associated forebulge. As a result, this coast undergoes vertical land motion due to glacial isostatic adjustment, leading to variable rates of sea-level rise within the region. Kopp (2013) estimates the rate of subsidence in the mid-Atlantic coastal plain area to be approximately 0.04 inches per year. Models predict that a slowdown in the Gulf Stream current would increase relative sea-level along the mid-Atlantic coast. [71] However, recent observational studies suggest that changes in relative sea-level along this coast are more likely driven by

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[69] Kopp, R. E., "Does the mid-Atlantic United States sea-level acceleration hot spot reflect ocean dynamic variability?", 40 *Geophys. Res. Lett.* 3981 (2013).
[70] Haigh, I. D., et al., "Timescales for detecting a significant acceleration in sea level rise," 5(3635) *Nature Communications* 1 (2014).
[71] Yin, J., et al., "Model projections of rapid sea-level rise on the northeast coast of the United States," 2 *Nature Geosciences* 262 (2009).

changes in local winds rather than a Gulf Stream slowdown.[72] Longer observational data sets are needed (i.e. twenty more years of data collection) in order to fully understand how Atlantic Ocean dynamic variability impacts sea-level rise along the mid-Atlantic coast, and whether the observed changes represent short-term variability or long-lived trends.[73]

Based on the long-term Baltimore tide-gauge station, sea level along the Baltimore shoreline rose 7.2 inches between 1950 and 2000 at a rate of approximately 0.14 inches per year (Figure 4).[74,75] Under RCP 2.6, an extremely aggressive emissions

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72 Piecuch, C. G., et al., "How is New England Coastal Sea Level Related to the Atlantic Meridional Overturning Circulation at 26˚N?," 46 *Geophysical Research Letters* 5351 (2019).

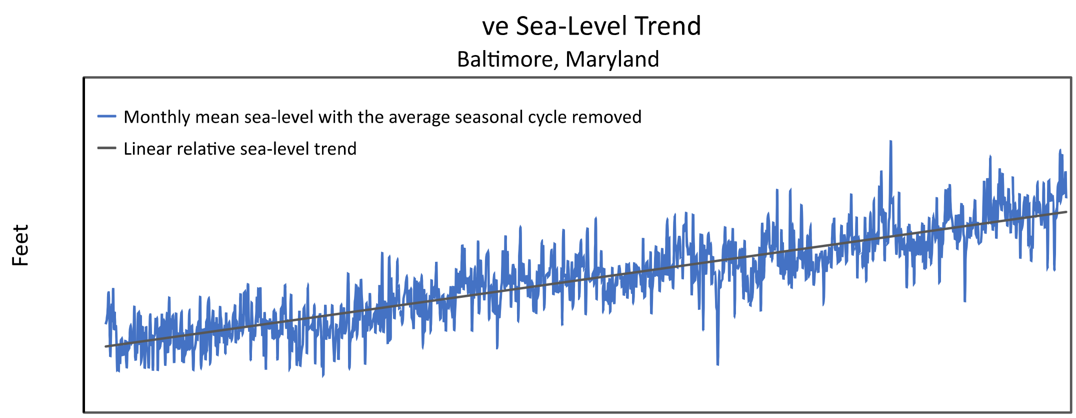
73 Kopp, R. E., "Does the mid-Atlantic United States sea-level acceleration hot spot reflect ocean dynamic variability?," 40 *Geophys. Res. Lett.* 3981 (2013).

74 Boesch, D. F., et al., "Sea-level Rise: Projections for Maryland 2018," (2018), https://www.umces.edu/sites/default/files/Sea-Level%20Rise%20Projections%20for%20Maryland%202018_0.pdf

75 NOAA Tides and Currents, https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=8574680

reduction scenario, sea level in the Baltimore area is likely to rise an additional 2.0 feet by 2100 (Figure 5).[76,77,78]

Figure 4. Relative Sea-Level Trend in Baltimore. Historical sea-level change (blue line) from 1902 to 2018 in Baltimore, Maryland, recorded by NOAA tide-gauge #8574680. The plot illustrates the long-term linear increasing trend in sea-level (black line), and excludes regular seasonal sea-level fluctuations due to water temperatures, salinities, winds, atmospheric pressures, and ocean currents. The relative sea-level trend in Baltimore is 0.14 inches per year. Figure modified from: NOAA Tides and Currents, https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=8574680

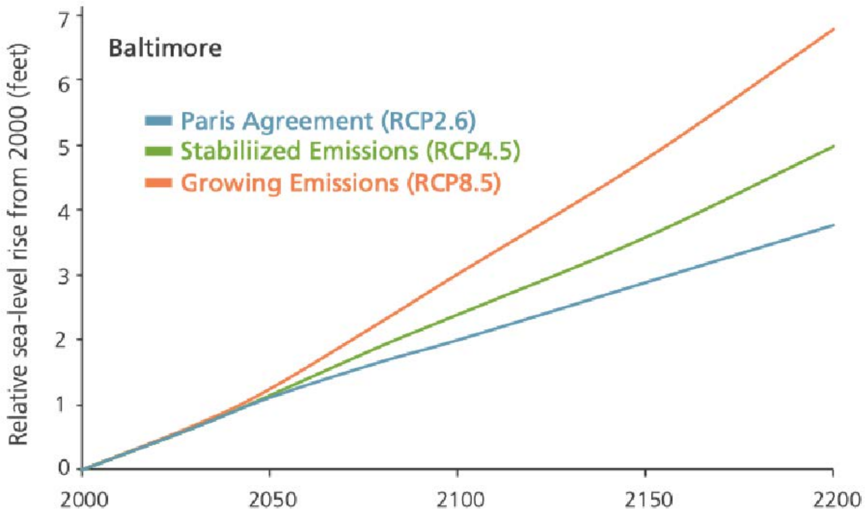


[76] 2.0 feet is a median value and has a 67% probability range of 1.2 – 3 feet, with a 1-in-20 chance of exceeding 3.7 feet.

[77] Relative to mean sea level between 1991–2009.

[78] Boesch, D. F., et al., "Sea-level Rise: Projections for Maryland 2018," (2018), https://www.umces.edu/sites/default/files/Sea-Level%20Rise%20Projections%20for%20Maryland%202018_0.pdf

Figure 5. Projected Sea-Level Rise in Baltimore, Maryland. Median projections of sea-level rise in Baltimore through 2200 under three greenhouse gas emissions pathways. Figure modified from: Boesch, et al. (2018).



Under RCP 8.5, a scenario that assumes sustained emissions growth, local sea level is likely to rise 2.0–4.2 feet by 2100 (Figure 5).[79,80,81] If warming triggers the rapid decay of the Antarctic ice sheet, local sea level could rise 5.7 feet or more.[82]

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[79] 3.0 feet is a median value and has a 67% probability range of 2.0 – 4.2 feet, with a 1-in-20 chance of exceeding 5.2 feet.
[80] Relative to mean sea level between 1991–2009.
[81] Kopp, R. E., et al., "Probabilistic 21st and 22nd Century Sea-Level Projections at a Global Network of Tide-Gauge Sites," 2 *Earth's Future* 383 (2014).
[82] Boesch, D. F., et al., "Sea-level Rise: Projections for Maryland 2018," (2018), https://www.umces.edu/sites/default/files/Sea-Level%20Rise%20Projections%20for%20Maryland%202018_0.pdf

IV. Sea-Level Rise Has Caused and Will Continue to Cause Substantial Injury and Damage to Baltimore That Will Require Massive Public Expenditures

The effects of sea-level rise are already apparent along the Maryland shoreline. In particular, nuisance flooding, defined as high-tide flooding that causes public inconvenience, is on the rise. The rate of nuisance flooding in Baltimore has increased by 920% since 1960.[83] Currently, Baltimore experiences nuisance flooding about 10 days per year. That is projected to increase to about 30 days per year by 2040 and nearly 100 days per year by 2050.[84]

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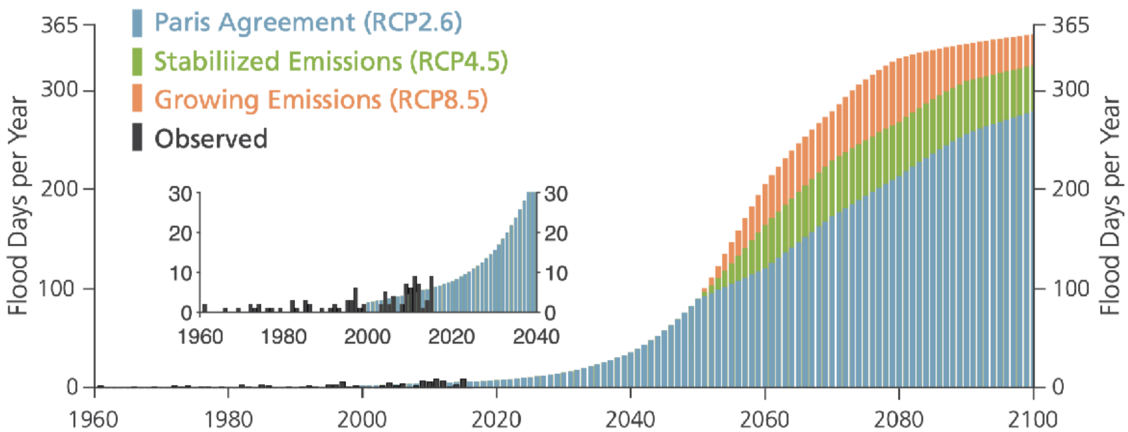
[83] Sweet, W.V., et al., "Global and Regional Sea Level Rise Scenarios for the United States," *Climate Science Special Report* (2017).

[84] Boesch, D. F., et al., "Sea-level Rise: Projections for Maryland 2018," (2018), https://www.umces.edu/sites/default/files/Sea-Level%20Rise%20Projections%20for%20Maryland%202018_0.pdf.

Figure 6. Observed and Projected Nuisance Flooding in Baltimore, Maryland. Sea-level rise has increased the frequency of nuisance flooding. Nuisance floods are defined as days on which water levels are 1.75 feet above the highest average tide ("Mean Higher High Water," or the average of the higher high-tide height for each tidal day over a designated 19-year period). Figure from: Boesch, et al. (2018).



With the current state of climate science and engineering assessments, the extent of coastal vulnerability can be reliably predicted. A study conducted by Resilient Analytics and The Center for Climate Integrity investigated the cost to protect Baltimore and other coastal communities from sea-level rise by 2040.[85] Sea-level rise estimates were produced using the same

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[85] LeRoy, S., and Wiles, R., "High Tide Tax: The Price to Protect Coastal Communities from Rising Seas," (2019), https://www.climatecosts2040.org/files/ClimateCosts2040_Report-v4.pdf.

model that generated the sea-level rise projections for Baltimore.[86] In addition to sea-level rise, the authors added a 1-year flood surge that represents the average annual storm surge that occurs along the shoreline of Baltimore. The study identified 97 total miles of tidal shoreline within Baltimore, of which 22 miles require protective infrastructure in order to prevent flooding. Using regional construction cost data, the study estimated the cost to build a linear foot of seawall in Baltimore is $1,135. By 2040 under RCP 4.5, Baltimore will need to invest at least $124 million in order to protect its most vulnerable shoreline from sea-level rise. This amount does not include the probable public cost of providing adaptations to protect major infrastructure including roads, bridges, rail lines, sewage treatment facilities, drinking water supply systems, storm drainage systems, and public utilities.

In 2015, the nations of the world, including the United States, signed the Paris Climate Agreement, committing to put

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[86] Kopp, R. E., et al., "Probabilistic 21st and 22nd Century Sea-Level Projections at a Global Network of Tide-Gauge Sites," 2 *Earth's Future* 383 (2014).

forward their best efforts to reduce greenhouse gas emissions with a goal of keeping global temperature rise below 2˚C over pre-industrial levels (roughly equivalent to RCP 2.6). Current national plans (nationally determined contributions, NDCs) fall far short of this goal and would lead to about a 3˚C temperature increase by 2100.[87] In the U.S., the Trump Administration has stated its intention to withdraw from the Paris Agreement.

As a consequence, responsible local governments must prepare for the consequences of global warming at least 2˚C above pre-industrial levels. Under 2˚C of warming, global mean sea-level is projected to rise between 19 to 39 inches by 2100.[88]

Even under the most ambitious emissions reductions scenario, the world's oceans will continue to rise as the climate system comes into balance with the roughly 50% increase in atmospheric CO_2 concentration since the dawn of the industrial

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87 Rogelj, J., et al., "Paris Agreement Climate Proposals Need a Boost to Keep Warming Well Below 2 C," 534(7609) *Nature* 631 (2016).

88 Bamber, J. L., et al., "Ice sheet contributions to future sea level rise from structured expert judgement," 116 (23) *Proceedings of the National Academy of Sciences*, 11195 (2019).

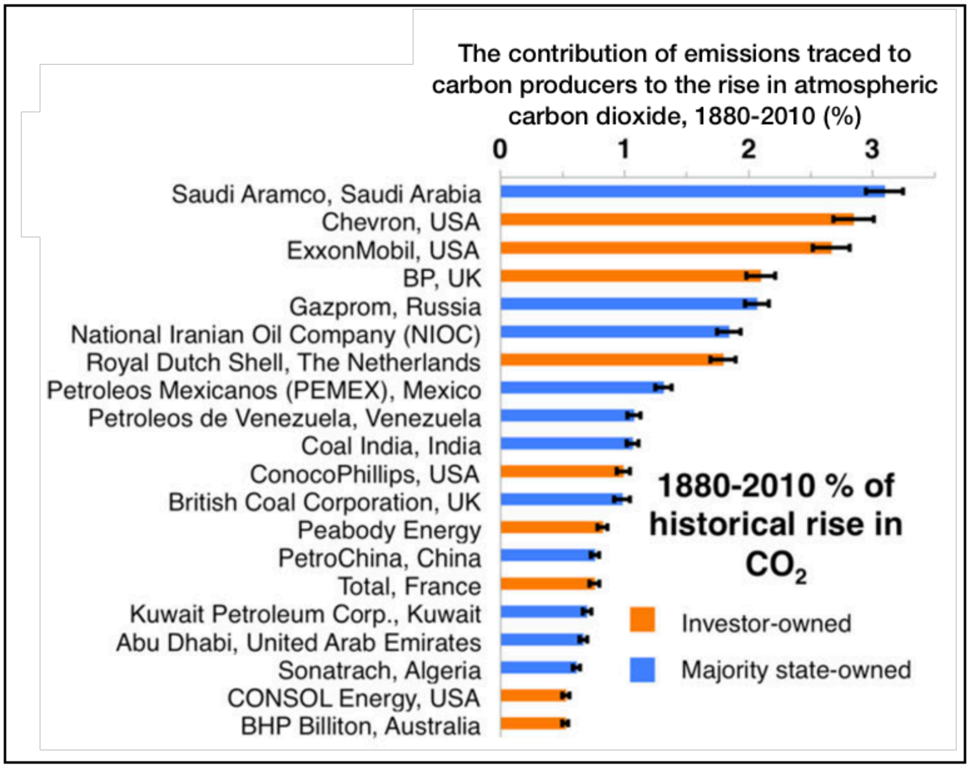
revolution. Given the inevitability of sea-level rise and Baltimore's vulnerability to sea-level rise of just one or two feet, there is no plausible emissions reduction scenario where Baltimore can avoid the substantial cost of adapting to and protecting itself from rising seas attributable primarily to the combustion of fossil fuels.

The portion of total CO_2 in the atmosphere attributable to each company's fossil fuel products is well established.[89] This work demonstrates that the emissions produced by the products of the 90 major carbon producers contributed 57 (±2.9) % of the total increase in atmospheric CO_2 from 1880 through 2010 (Figure 7). Nearly half of that was attributable to the 20 largest entities. And nearly half of that was attributable to five of the Appellants in this case. Chevron was the 2nd largest CO_2 producer during that period. ExxonMobil is the 3rd largest, BP is the 4th largest, Shell ranks 7th and ConocoPhillips is 11th. These calculations prove that Appellants' fossil fuel products are a substantial factor in the

[89] Ekwurzel, B, et al., "The Rise in Global Atmospheric CO_2, Surface Temperature, and Sea Level from Emissions Traced to Major Carbon Producers," *Climatic Change*, 144 Climatic Change 579 (2017).

injuries and damages that Baltimore has suffered and will continue to suffer for decades to come.

Figure 7. Top twenty investor- & state-owned entities and attributed CO_2 emissions. Emissions from these companies contributed about 27.2 (±2.9) % of increase in cumulative atmospheric CO_2 between 1880 and 2010. Figure modified from: Ekwurzel, B., et al. (2017).



CONCLUSION

In sum, we know that the present injuries and damage and future risk to coastal communities such as Baltimore posed by rising sea levels is caused in significant part by global warming. We know that the Appellants' production and marketing of fossil fuels is a substantial factor in global warming. We have peer reviewed data and calculations and broad scientific consensus that attribute a substantial percentage of sea-level rise to Appellants' products. Baltimore can thus prove these facts at trial through the introduction of well-established scientific facts, data, and calculations to justify its claims.

We, therefore, urge affirmance of the District Court's Order remanding these cases to state court for further pretrial proceedings and trial.

September 3, 2019

Respectfully submitted,

/s/ William A. Rossbach

William A. Rossbach
ROSSBACH LAW, P.C.
401 N. Washington Street
P. O. Box 8988
Missoula, MT 59807
Tel: (406) 543-5156
Fax: (406) 728-8878

CERTIFICATE OF SERVICE

I hereby certify that I caused the foregoing to be electronically field with the Clerk of the Court for the United States Court of Appeals for the Ninth Circuit by using the appellate CM/ECF system on September 3, 2019.

I certify that all participants in the case are registered CM/ECF users and that service will be accomplished by the appellate CM/ECF system.

/s/ William A. Rossbach
William A. Rossbach

CERTIFICATE OF COMPLIANCE

Pursuant to Federal Rule of Appellate Procedure 29(a)(4)(g), I certify that:

This Brief complies with Rule 29(a)(5)'s type-volume limitation, because it contains 6,436 words as determined by the Microsoft Word 2016 word-processing system used to prepare the brief, excluding the parts of the brief exempted by Rule 32(a)(7)(B)(iii).

This Brief complies with Rule 32(a)(5)'s typeface requirements, and Rule 32(a)(6)'s type-style requirements because it has been prepared in a proportionately spaced typeface using the 2016 version of Microsoft Word in 14-point Century Schoolbook font.

/s/ William A. Rossbach
William A. Rossbach