Petition to Phase Out Greenhouse Gas (GHG) Pollution to Restore a Stable and Healthy Climate

Table of Contents—Part II: Select Scientific and Economic Considerations

I. Executive Summary: Unreasonable Risk

The evidence adduced in this Part supports the conclusion that the subject chemical substances and mixtures – fossil fuels and their emissions, and greenhouse gases (GHGs), including legacy GHGs – present an unreasonable risk of injury to health and the environment.

That unreasonable risk arises from the production, importation, processing, distribution, use and disposal of the subject chemical substances and mixtures. These activities are causing or contributing to higher ambient temperatures, stronger storms, accelerated sea level rise, more severe wildfire, loss of crops, wider vector spread, degraded air quality, an acidifying and warming ocean, disruptions in the food web, alteration and loss of habitat, loss of polar ice, sea ice, and mountain glaciers, and accelerated species loss. The list is partial. To summarize:

Earth's Energy Imbalance: In Section II of this Part of the Petition, we observe that humanity's reliance on fossil fuels to meet fundamental energy needs has caused a global energy imbalance – more energy from the sun arriving by way of solar radiation than escapes from Earth back to space from the top of the atmosphere. In Section II of this Part of the Petition, we review the evidence for, and some of the implications of, this energy imbalance, including that global average temperatures have now risen past the high point of the Holocene (approximately the last 12,000 years), the period marked by a relatively stable climate with moderate temperatures and stable coastlines.

CO_2 Emissions: Section III concerns CO_2 emissions sources and what is required to protect and restore the climate system. The to-date unceasing commitment to fossil fuels, coupled with the still-small contribution of carbon-free energy to the global energy, has ensured continually high CO_2 emissions and an increasing atmospheric concentration of CO_2. In light of the long-lived nature of atmospheric CO_2, responsibility for present and future global warming is a matter of cumulative emissions. The largest quantity of recent annual GHG emissions stem from activity in China, but the United States, with the highest cumulative total (and very high per capita emissions) bears highest responsibility.

CH_4 and other Short-Lived Climate-Forcing Pollutants: In Section IV, Petitioners discuss how other pollutants, some relatively short-lived, substantially augment the climate-forcing effect of CO_2 emissions. This is especially true of methane (CH_4), nitrous oxide (N_2O), the halocarbons, and certain aerosols including, black carbon. Action to reduce these pollutants would be beneficial not merely to stem global warming, but in the cases of some pollutants, to improve air quality.

Unreasonable Land-Based Risk: A Short Survey: Petitioners explain, in Section V, that GHG emissions deriving from fossil fuel combustion and other sources threaten land-based human and natural systems. These threats arise from global warming-induced severe heat, drought, and wildfire. They also arise from sea-level-rise-induced risks, including coastal flooding, erosion, and salinization of water supplies. The risks of injury arise, as well, from climate-induced weather extremes, including change in the frequency or intensity of heat waves, enhanced precipitation with resulting flooding and drought, and changes in the frequency and severity of tropical storms. Economic loss is discussed, though Petitioners understand that a shortened life is not readily described in financial terms.

Ocean-Based Risks – A Short Survey: In Section VI, Petitioners review the deleterious impact to the ocean from fossil fuel combustion, and other GHG emissions sources. With respect to ocean acidification, there is a clear consensus among leading national and international scientific bodies that anthropogenic CO_2 causes changes in ocean chemistry. Unabated, there will be increasingly severe and detrimental impacts on marine ecosystems, the economy, and public health. Injury to the ocean environment from acidification is compounded by ocean warming, a development that is already impacting corals worldwide, as well as the entire food chain since reproduction in certain organisms at its base is diminished with rising sea temperature.

Air Quality: In Section VII, Petitioners draw attention to the air pollutants produced by fossil fuel combustion, particularly PM2.5 that contributes to more than 10 million premature deaths annually, including an estimated 483,000 premature deaths in North America for people over the age of 14. Replacing fossil fuel combustion with clean energy sources will materially advance human health and survival.

Risk Reduction Methods: Section VIII summarizes action available to reduce risks associated with current and past GHG emissions. Among the most important are the timely phase out of fossil fuels and the removal and secure sequestration of CO_2 along with other GHGs. Improving energy efficiency is also highly beneficial. We review certain plans to reverse global warming in thirty years using solutions already aiming to hold global temperature rise to 2.0°C or, preferably, 1.5°C. Natural climate solutions (NCS) also are discussed, including reforestation, improved forest management, and improvements in agriculture and soils management. Market incentives and regulatory controls can be effective in increasing the rate of innovation aimed at reducing GHG emissions.

Need for Regulations for GHG Emission Reductions and Sequestration: In Section IX Petitioners discuss the two-fold market failure of (1) the environmental cost arising wherein GHGs are not included in the price of fossil fuel energy and (2) the removal and sequestration of carbon not being valued by the market. Such underpricing, or failure to internalize real costs, results in excess emissions far beyond what the environment can bear. This market failure needs to be addressed through Agency action. Agency assessment of regulatory approaches, including the assignment of a carbon price that increases over time, should take account of the possibility of catastrophic effects of continued emissions. Some of these include amplified climate change stemming from positive feedbacks in physical and chemical processes, including decreased arctic ice albedo, release of soil carbon as frozen soil warms, potential collapse of the marine food web, changes in cloud albedo, alterations in ocean circulations, more rapid than expected sea-level rise driven by West Antarctic Ice Sheet collapse, shifts in weather patterns like the Indian Summer Monsoon or the West African Monsoon, ecological regime shifts in the Amazon or the Sahel, and the potential for massive release of carbon from seafloor methane hydrates.

Risk Reduction Costs and Benefits: In Section X, in accordance with the Agency's guidance for this petition, Petitioners provide a preliminary analysis of the cost and benefits of GHG reduction, and emissions removal and sequestration. We include excerpts from Volume II of the Fourth National Climate Assessment, a document delineating "the human welfare, societal, and environmental elements of climate change and variability for 10 regions and 18 national topics, with particular attention paid to observed and projected risks, impacts, consideration of risk reduction, and implications under different mitigation pathways." Petitioners also discuss the economic costs of sea level rise, ocean acidification and potential climate extremes. Co-benefits are also discussed, including improved health due to air pollutant reduction.

In the view of Petitioners, the continuing imposition of risks associated with the subject chemical substances and mixtures is unreasonable under the Toxic Substances Control Act (TSCA). 15 USC §§2601 to 2696.

The operative term "unreasonable" merits comment, in the context of the climate crisis. To be clear: allowing continued high GHG emissions from fossil fuels and other sources will render large swaths of our nation (and the planet) far less habitable, as it will undermine natural and human systems that support civilization.[1] These consequences, which we outline in some detail below, will not be avoided with business as usual. But an alternative path is available and, as indicated in Part I, the Administrator of the Environmental Protection Agency (EPA) retains ample authority under TSCA to pursue it.[2] Failure to pursue such an alternative path will ensure the continuing diminishment of our children's future, and **that** would be unreasonable.

Petitioners present part of the basis for this conclusion in the material below, including at times in material incorporated by reference. The Agency should take account, as well, of additional material that is undoubtedly within its reach where that further supports Petitioners' demand for meaningful action without further delay.

II. Earth's Energy Imbalance

Humanity's reliance on fossil fuels to meet fundamental energy needs is imposing an increasing threat to human and natural systems, in large part because of the energy imbalance that fossil fuel emissions have imposed on our planet. Additional emissions only amplify that imbalance, pressing human and natural systems further toward the brink. Accordingly, in order to safeguard a viable future for humanity and nature, we must restore energy balance and allow Earth to cool back to a temperature no warmer than the mid-twentieth century.

The implication with respect to the object of this petition is clear: GHG emissions, particularly CO_2 and CH_4 deriving substantially from fossil fuels, have induced an energy imbalance that itself presents a current and unreasonable risk of serious and widespread injury to health and the environment, along with an imminent risk of far worse still to come.

Earth has gained substantial energy over the past four decades. In a careful international effort, von Schuckmann *et al*. was able to calculate that approximately 90 percent of the excess energy is taken up by the ocean – due to its large mass and high heat capacity. The balance is expended in melting ice (3-4%) and stored in the land (5-6%) and in the atmosphere (1-2%)."[3]

Figure 1 below depicts Earth's current energy imbalance due to more energy arriving by way of solar radiation than escapes back to space from the top of the atmosphere.

[1] Business as usual emissions would also strike directly at US national security. Christopher Flavelle, Julian E. Barnes, Eileen Sullivan and Jennifer Steinhauer, *Climate Change Poses a Widening Threat to National Security: Intelligence and defense agencies issued reports warning that the warming planet will increase strife between countries and spur migration*, New York Times (Oct. 21, 2021, undated Nov. 1, 2021) https://www.nytimes.com/2021/10/21/climate/climate-change-national-security.html.

[2] The President appoints the EPA Assistant Administrator for Toxic Substances, TSCA §2625(g), and EPA in turn must report to the President annually about the rules it issues pursuant to TSCA §6, 15 USC §2605 -- including "a summary of major problems encountered" in their administration. The Agency is also required to waive compliance with a provision of TSCA if, in the President's determination, that is necessary in the interest of national security. TSCA §22, 15 USC §2621.

[3] Von Schuckmann, *et al.*, *Heat stored in the Earth system: where does the energy go?* Earth Syst. Sci. Data (September 7, 2020) https://essd.copernicus.org/articles/12/2013/2020/. Petitioner Hansen is a co-author.

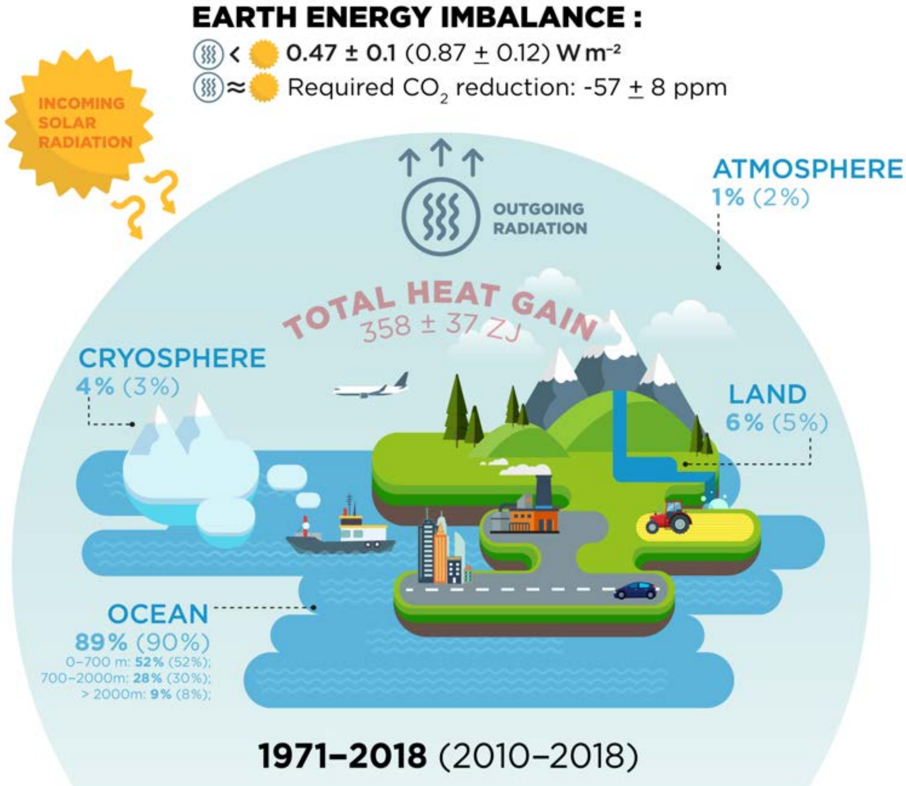


Fig. 1. Schematic presentation of Earth's heat inventory for the current human-caused energy imbalance. Graphic from von Schuckman *et al*.

As seen in Figure 1, GHGs cause an unimaginably large amount, about 358 Zettajoules (358 × 10_{21} Joules), of additional solar energy to be trapped within the Earth system of land, ocean, ice and atmosphere each year. In order to restore energy balance, we must act to reduce the atmospheric concentration of CO_2 to 353 ppm or less. That maximum safe GHG concentration value affirms the conclusion of an earlier study by Petitioner Hansen and colleagues: Target atmospheric CO_2: Where should humanity aim? (hereafter,"Hansen et al. (2008)").[4] That study concluded: "If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, paleoclimate evidence and ongoing climate change suggest that CO_2 will need to be reduced from its current [level] to at most 350 ppm." Petitioners hereby incorporate the principal conclusions and reasoning of von Schuckman et al. (2020) and Hansen et al. (2008) by reference. We also note that the average atmospheric CO2 concentration has risen from 385 to 416 ppm, an additional 31 ppm, since the publication of the Hansen et al. (2008) study.[5]

Earth's energy imbalance can be measured with good accuracy because of precise monitoring of the warming global ocean. The image in Fig. 1 reports that the average imbalance over the period 1971-2018 was 0.47 ±0.1 W/m^2, but Von Schuckmann *et al.* (2020) also report that, in the more recent period of 2010-2018, the imbalance was 0.87 ±0.1 W/m^2. As well, Petitioner Hansen argued in a recent widely distributed communication, "Earth's energy

[4] Hansen et al., Open Atmos. Sci. J. (2008), vol. 2, pp. 217-231, available at https://arxiv.org/abs/0804.1126

[5] NOAA CO_2 data available at https://gml.noaa.gov/ccgg/trends/data.html.

imbalance – which was less than or about half a watt per square meter during 1971-2015 – has approximately doubled to about 1 W/m^2 since 2015."[6]

This increased energy imbalance is the principal cause of global warming acceleration, which Petitioners illustrate in Figure 2 below.

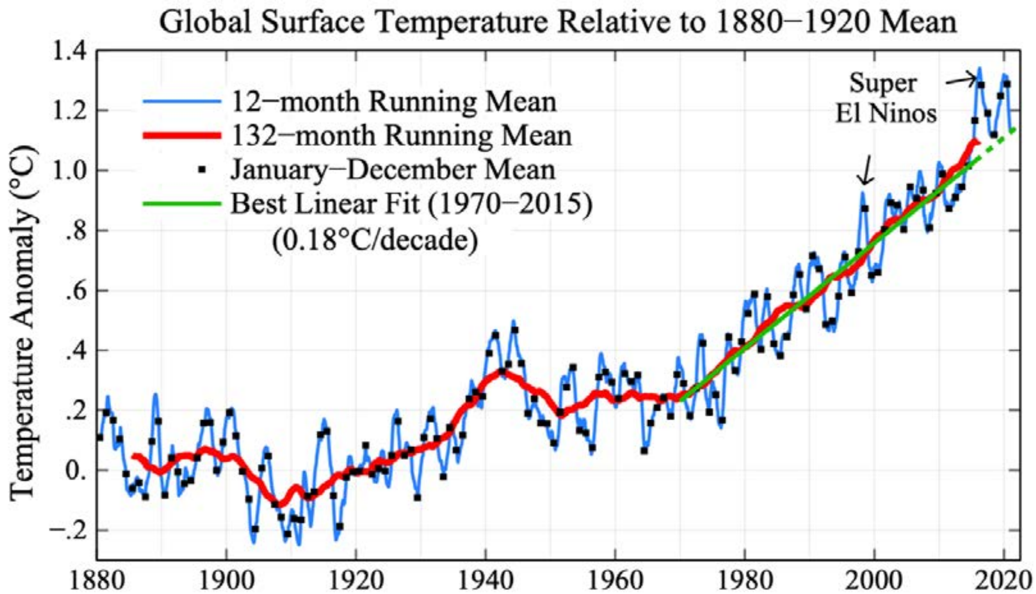


Fig. 2: From Climate Science Awareness and Solutions (CSAS) data pages.[7] Updated 8/13/2021.

The graphic shows global surface temperature relative to 1880-1920. The 1880-1920 mean temperature serves as our best estimate of the preindustrial level, because the small warming effect of anthropogenic GHGs that had been added by that period was approximately offset by greater than average volcanic activity in 1880-1920. The temperature in 1940-45 shown in the figure may be exaggerated by data inhomogeneity during WWII, but that does not materially distort the picture – which is a sharp rise in warming since 1960.

Global temperature is now well above the range that occurred in the balance of the Holocene, the last 11,700 years, as illustrated in Figure 3 below.

[6] Hansen and Sato, *July Temperature Update: Faustian Payment Comes Due* (Aug. 13, 2021) from http://www.columbia.edu/~mhs119/Temperature/Emails/July2021.pdf.

[7] As also maintained by Makiko Sato, op cit. available at http://www.columbia.edu/~mhs119/Temperature/.

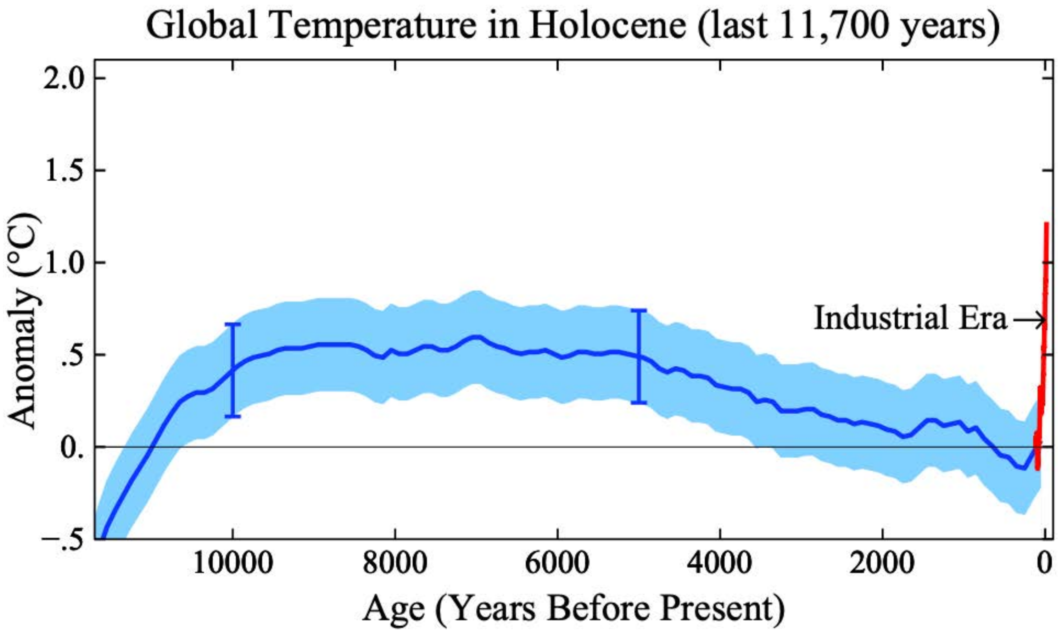


Fig. 3: Centennially smoothed Holocene temperature relative to 1880-1920.
From CSAS data pages.[8]

We should expect the global warming rate for the quarter of a century 2015-2040 to be about double the 0.18°C/decade rate during 1970-2015 (see Fig. 2) unless appropriate countermeasures are taken – including a phaseout of fossil fuel emissions and removal of excess atmospheric CO_2 and CH_4.

III. CO_2 Emissions: Sources and Required Reductions to Secure Safety

CO_2 emissions began to increase the global average atmospheric concentration beginning with the industrial revolution, in the mid-18th century, when coal began to be used as a fuel for home-heating, powering steam engines and eventually for electrical power generation. Petroleum (commonly, "oil"), another fossil fuel, began to contribute to CO_2 emissions at the beginning of the 20th century. Its products, including fuels like gasoline, kerosene, diesel fuel and jet fuel, made automobile and aircraft transportation possible. Natural gas, another fossil fuel extracted from the earth and consisting principally of methane (CH_4), has made heating of homes and commercial buildings convenient because of the ability to transport the gas from processing plants to end users via pipelines.

These fossil fuels – coal, petroleum and natural gas – are composed almost entirely of carbon and hydrogen that burn in the presence of oxygen to produce carbon dioxide and water.

The natural carbon cycle, in which carbon dioxide is removed from the atmosphere by the photosynthetic activity of land and ocean plants, and returned to it by respiration, also functions to return a portion of the CO_2 to soils and deeper earth formations by a wide range of processes. The cycling of carbon among the atmosphere, biosphere, hydrosphere and geosphere has many timescales, ranging from one year, for seasonal changes in photosynthetic uptake of CO_2, to tens to hundreds of millions of years, for exchange of fossilized carbon with the atmosphere and oceans. Over the past two centuries, and especially the past fifty years, humans

[8] As also maintained by Makiko Sato at http://www.columbia.edu/~mhs119/Burden_figures/.

have introduced an enormous perturbation in the carbon cycle by extracting fossil fuels and burning them to release vast quantities of CO_2 to the atmosphere at an unprecedented rate.[9]

The to-date unceasing commitment to fossil fuels is illustrated in Figure 4 below, showing that while the contribution of carbon-free energy to the global energy supply is growing, it yet remains a small fraction of that provided by fossil fuels (Fig. 4(a)). This fact, coupled with continued energy demand, has ensured continually high CO_2 emissions (Fig. 4(b)). Even coal emissions remain near their peak, which surprises people who think of coal as a 19th century fuel. It is still with us, infusing the atmosphere with even more CO_2 than does the consumption of oil or natural gas.

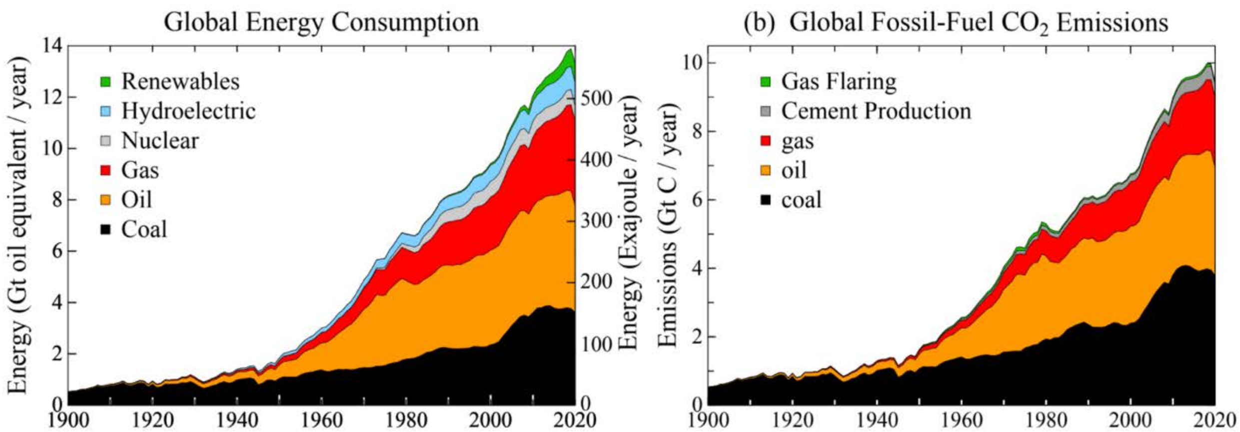


Fig. 4: From CSAS data pages.[10] Updated Aug. 18, 2021.

Accordingly, the extraction and burning of fossil fuels is overwhelming the natural carbon cycle. More than half of fossil fuel emissions is taken up by the Earth system, dissolved in the ocean (and there raising ocean acidity) and sequestered by the biosphere and soil. The balance of fossil fuel CO_2, approximately 44%,[11] *remains* in the atmosphere for centuries or millennia.[12] Figure 5, below, illustrates the fate of these emissions, the blue area showing the amount (a) and the fraction (b) of the emissions that remain in the air.

---

9 IPCC AR6 WGI, Climate Change 2021, The Physical Basis, p. TS-46.

10 As maintained by Makiko Sato at www.columbia.edu/~mhs119/CO2Emissions/.

11 IPCC AR6 WGI, Climate Change 2021, The Physical Basis, p. TS-47.

12 Unless, that is, a serious effort commences to remove all or a portion of such legacy emissions, as we discuss *infra*.

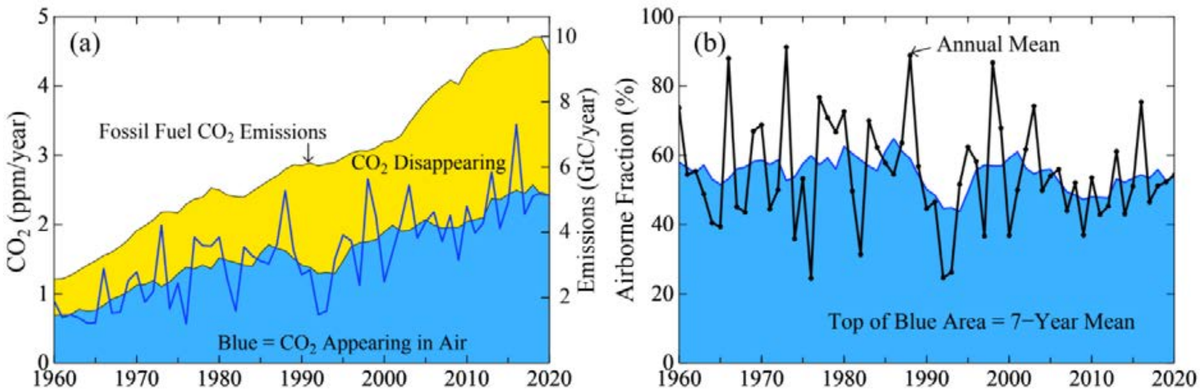


Fig. 5: From CSAS data pages.[13] Updated August 18, 2021.

One result is that the atmospheric CO_2 concentration is increasing, year after year, as shown in Figure 6 below, with data through April 2021. Indeed, the CO_2 concentration has risen 30 percent over the last six decades, from 316 ppm in 1959 to 416 ppm in 2021.[14]

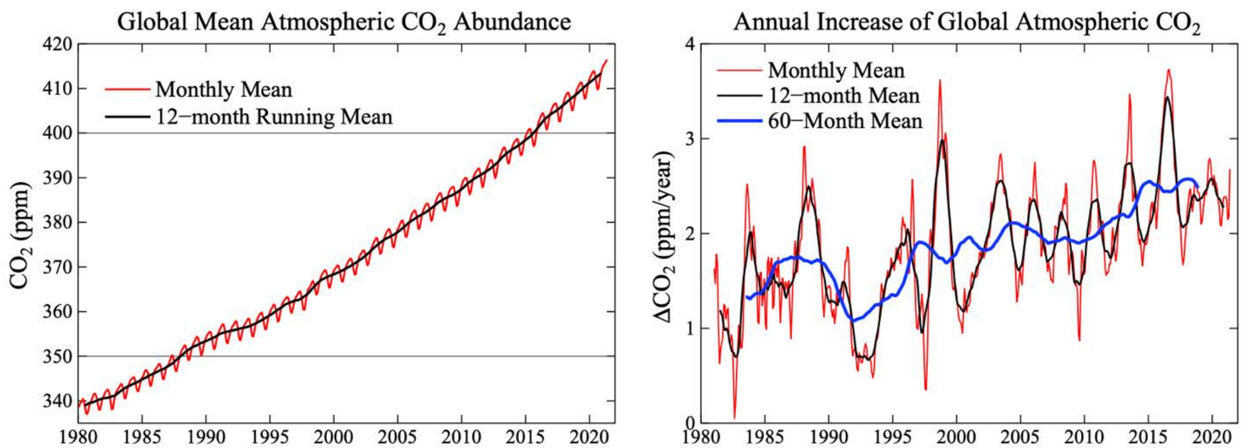


Fig. 6: Atmospheric CO_2 concentration. From CSAS data pages.[15] Updated August 18, 2021.

Moreover, atmospheric CO_2 is increasing today at least 10 times faster than the most rapid known prior change in Earth's history, that is, the rate of increase characterizing the Paleocene-Eocene Thermal Maximum (about 50 million years ago). The last time the atmospheric CO_2 concentration was this high, was more than 3 million years ago, when temperature was 2°–3°C (3.6°–5.4°F) higher than during the pre-industrial era, and sea level was 15–25 meters (50–80 feet) higher than today.[16]

---

[13] As also maintained by Makiko Sato, at http://www.columbia.edu/~mhs119/GHGs/.

[14] Global Monitoring Laboratory, Mauna Loa CO_2 Annual Mean Data, https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html.

[15] As also maintained by Makiko Sato, at http://www.columbia.edu/~mhs119/GHGs/.

[16] Rebecca Lindsay, *Climate Change: Atmospheric Carbon Dioxide*, Aug. 14, 2020 available at https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide.

The atmospheric CO_2 concentration has increased by 136 ppm (from 280 ppm to 416 ppm[17]) to date, corresponding to an excess in the atmosphere of ~1.0 x 10^{18} g (1,000 Gigatons, GT) of CO_2 – that is, one trillion metric tons. This overburden is currently increasing by about 18 billion metric tons (18 Gt) per year, based on the current trend of CO_2 concentration increasing by ~2.3 ppm/yr.[18] There is a comparably large excess quantity of CO_2 and bicarbonate ion in the oceans that, as discussed below, is already having an adverse effect on marine life. As with other toxic substances regulated by the EPA, much of this legacy CO_2 will need to be removed in order to cool the planet and restore the climate system so that human and natural systems may continue to function as required by our children and future generations.

Because of the long-lived nature of atmospheric CO_2,[19] responsibility for present and future global warming is a matter of cumulative emissions. The largest quantity of annual GHG emissions now stems from activity in China, but the United States, with the highest cumulative total (and very high per capita emissions) still bears the lion's share of responsibility for present and future global warming. *See* Figure 7 below.

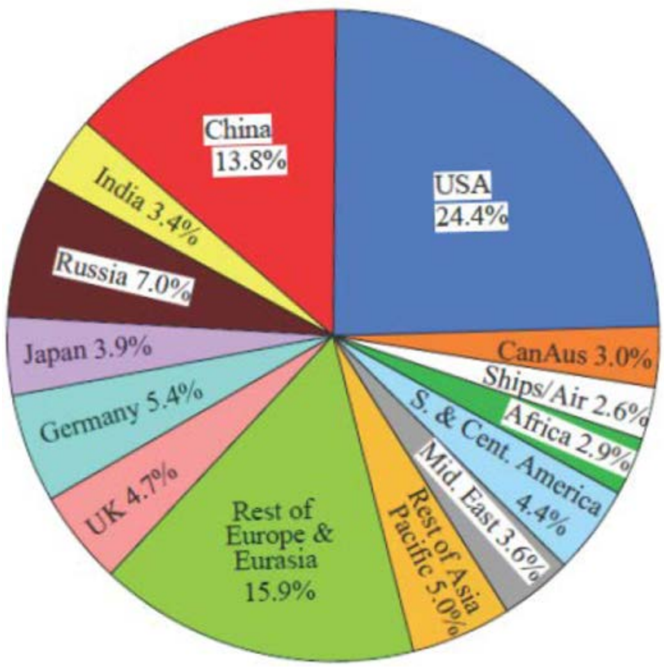


Fig. 7: 1751-2020 Cumulative Emissions (452 Gt). Source: Climate Science, Awareness and Solutions

[17] NOAA Global Monitoring Laboratory, Trends in Atmospheric Carbon Dioxide, as of Aug. 20, 2021, available at https://gml.noaa.gov/ccgg/trends/.

[18] *Id.*

[19] *See* Archer et. al., *Atmospheric Lifetime of Fossil Fuel Carbon Dioxide*, Annu. Rev. Earth Planet. Sci. 2009. 37:117–34, https://www.annualreviews.org/doi/pdf/10.1146/annurev.earth.031208.100206.

IV. Methane and Other Climate-forcing Pollutants

(A) Methane

Methane (CH_4) is the second most important anthropogenic greenhouse gas. The IPCC estimated that methane contributed about 0.5°C of warming during the period 2010-2019 in comparison to the period 1850-1900.[20]

Although its concentration in the atmosphere is relatively low, averaging about 1.89 ppm (1891.3 ppb) as of April 2021,[21] CH_4 absorbs infrared radiation much more strongly than CO_2 and thus has a much higher *global warming potential (GWP)*. Over a timescale of 20 years, on a mass basis, CH_4 is 82.5 times more effective at trapping heat[22] (30.1 times more effective on a molar basis) than CO_2.[23] Like CO_2, the atmospheric methane concentration has been increasing since the industrial revolution, from a level of about 0.73 ppm[24] to its current value of 1.89 ppm, a factor of 2.6. *See* Figure 8 below.

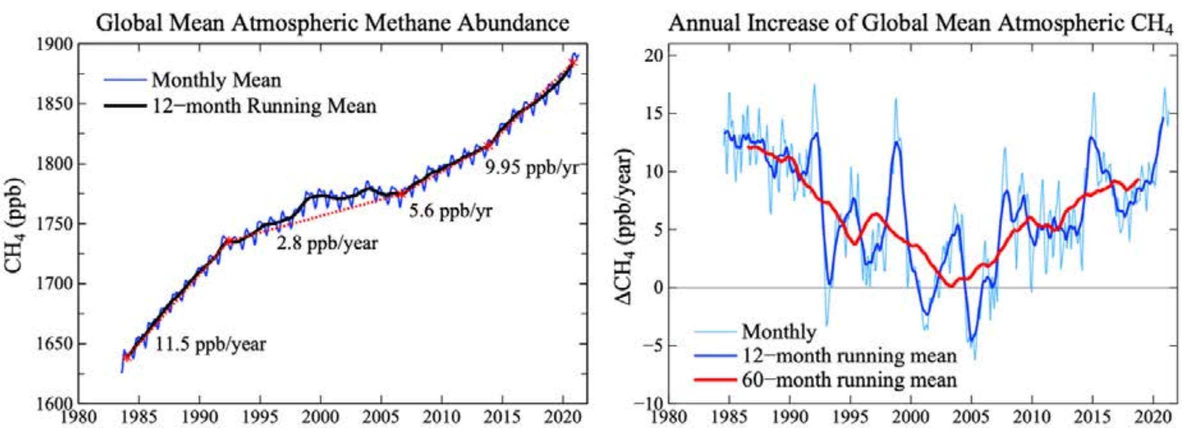


Fig. 8: Atmospheric CH_4 concentration. From CSAS data pages.[25] Updated June 24, 2021.

Since 2006, the annual increase in the global average atmospheric methane concentration has accelerated, increasing 15 ppb or 0.015 ppm between April 2006 and April 2021.[26]

---

[20] IPCC AR6 WGI, Climate Change 2021, The Physical Basis, p. SPM-8, Figure SPM.2.

[21] NOAA Global Monitoring Laboratory, Trends in Atmospheric Methane, as of Aug. 20, 2021, available at https://gml.noaa.gov/ccgg/trends_ch4/.

[22] IPCC AR6 WGI, Climate Change 2021, The Physical Basis, p. 7-125.

[23] "When looking at its impact over 100 years, one tonne of methane is still equivalent to about 28 tonnes of CO_2." Quirin Schiermeier, Global methane levels soar to record high, Nature News (July 14, 2020).

[24] Nakzawa et al., Differences of the atmospheric CH_4 concentration between the Arctic and Antarctic regions in pre-industrial/pre-agricultural era, *Geophys Res. Lett.* (2020) vol. 20, pp. 943-946, available at https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/93GL00776.

[25] As also maintained by Makiko Sato, at http://www.columbia.edu/~mhs119/GHGs/.

[26] NOAA Global Monitoring Laboratory, Trends in Atmospheric Methane, as of Aug. 20, 2021, available at https://gml.noaa.gov/ccgg/trends_ch4/.

Moreover, the period April 2020 to April 2021 saw the largest single-year increase for which accurate global measurements have been made. This increase in atmospheric methane is the equivalent (for a 20-year time scale) of ~0.47 ppm of CO_2 for that year. As a result, the effect of increasing emissions of CH_4 on the Earth's radiative balance during this past year amounted to about 20% of that of increasing levels of CO_2.

As with CO_2, there are both natural and anthropogenic sources of methane. Natural sources are dominated by anaerobic bacterial metabolism of organic matter, principally in wetlands and to a much lesser extent in the oceans (but also by termites).[27]

Anthropogenic sources are estimated to outweigh natural sources, though there remains some controversy.[28] Significant anthropogenic sources of methane include landfills, enteric fermentation in ruminants (livestock such as cattle), waste management, rice agriculture, biomass burning and fugitive emissions from oil and gas operations. The sum of all agricultural and waste management contributions to methane emissions constitutes about 65% of anthropogenic emissions while that of emissions from the oil and gas industry contribute about 35%.[29] The latter emissions have likely increased in recent years due to the advent of hydraulic fracturing ("fracking") and the increased production of natural gas. Fugitive emissions of natural gas include purposeful venting of wells, incomplete combustion of methane during flaring of wells, and leakage from capped wells, processing facilities, and the vast network of pipelines that transport natural gas to end users. According to the EPA, in 2019 U.S. methane emissions from oil and gas production amounted to a CO_2 equivalent of 197 million metric tons distributed as 48% gas production, 20% oil production, 6% processing, 19% transmission and storage, and 7% distribution.[30]

The excess atmospheric burden of CH_4 due to anthropogenic activities can be calculated as the difference in the current concentration of 1.89 ppm and the pre-industrial concentration of 0.73 ppm. This increase in atmospheric methane of 1.26 ppm corresponds to 3.5 billion metric tons of excess methane in the atmosphere or the GWP equivalent of 290 billion metric tons (0.29 Gt) of CO_2 – accounting for about 29% of the current excess burden (1,000 Gt) of CO_2 in the atmosphere.[31]

---

[27] Saunois et al., The global methane budget 2000-2017, *Earth System Science Data* (2020), vol.12, pp. 1561-1623, available at https://essd.copernicus.org/articles/12/1561/2020/. *See also*, NOAA, Increase in atmospheric methane set another record during 2021 (April 7, 2022) (discussing "the largest annual [methane] increase recorded since systematic measurements began in 1983," observing that "carbon dioxide pollution has always been the primary driver of human-caused climate change," and noting that there has been "scientific debate on the cause of the ongoing surge in methane levels") at https://www.noaa.gov/news-release/increase-in-atmospheric-methane-set-another-record-during-2021. *See also*, Hmiel et al., Preindustrial $^{14}CH_4$ indicates greater anthropogenic fossil CH_4 emissions, Nature (Feb. 19, 2020) at https://www.nature.com/articles/s41586-020-1991-8.

[28] Saunois et al. (2020).

[29] *Id.*

[30] U.S. Environmental Protection Agency, Estimates of Methane Emissions by segment in the United States (2021), https://www.epa.gov/natural-gas-star-program/estimates-methane-emissions-segment-united-states/.

[31] Calculated as follows: (Increased fraction of molecules that are CH_4, 1.26×10^{-6}) × (Number of molecules in the atmosphere, 1.04×10^{44}) ÷ (Avagadro's number for molec/mol, 6.022×10^{23}) × (molecular weight of CH_4, 16.04 g/mol) ÷ (g/metric ton, 10^6) = 3.49×10^9 tons of excess CH_4 in the atmosphere. Multiply this by the GWP of 82.5 to obtain 2.88×10^{11} equivalent ton of CO_2 or 0.288 million metric tons of CO_2.

An important difference between CH_4 and CO_2 is that CH_4 has a much shorter atmospheric lifetime, namely, approximately ten years,[32] due almost entirely to oxidation to CO_2 by the hydroxyl radical.[33] This means that if we were to stop emitting anthropogenic methane to the atmosphere, the burden of legacy CH_4 would be reduced by a factor of ~63% every ten years.[34]

In addition to relying on its relatively short lifetime, one possible approach to reducing the effect of legacy CH_4 is to catalytically oxidize atmospheric methane to CO_2, thereby avoiding the necessity of its disposal. This would reduce the 20-year global warming effect of any methane converted to CO_2 by a factor of ~30 and the 100-year effect by a factor of ~9. Oxidation of legacy CH_4 is simpler in one sense than removal of legacy CO_2 because no concentration and disposal step is required. However, CH_4 is far more scarce in the atmosphere than is CO_2, so removal of an equivalent quantity "leads to a higher minimum energy requirement."[35] On the other hand, "because of the higher radiative forcing of methane, removing one mole from the atmosphere has a greater short-term climate impact than removing one mole of CO_2."[36] Oxidizing the 1.3 ppm of excess methane in the atmosphere would produce the equivalent effect of removing ~39 ppm of CO_2, or an amount equal to the past ~18 years of CO_2 emissions.

(B) Halocarbons

Halocarbons, including chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and halons (HFCs),[37] have 1,000 to 9,000 times the global warming potential of CO_2. Similarly, the halocarbon family of refrigerants are chemical compounds derived from hydrocarbons by

---

32 Naik et al., *Preindustrial to present-day changes in tropospheric hydroxyl radical and methane lifetime form the Atmospheric Chemistry and Climate Model Intercomparison Project* (ACCMIP), Atmos. Chem. Phys. (2013), vol. 13, pp. 5277-5298, available at, https://acp.copernicus.org/articles/13/5277/2013/acp-13-5277-2013.pdf.

33 Fossil fuel CO_2, on the other hand, has an estimated mean atmospheric lifetime on order of tens of thousands of years, according to Archer et. al.: A burst of CO_2 takes 2 to 20 centuries to equilibrate with the ocean, but even after that process completes 20-40% of the CO_2 remains in the atmosphere subject only to far slower chemical reactions with CaCO3 and igneous rocks. Accordingly, the "climate effects of CO_2 releases to the atmosphere will persist for tens, if not hundreds, of thousands of years into the future." Archer et. al., *Atmospheric Lifetime of Fossil Fuel Carbon Dioxide*, Annu. Rev. Earth Planet. Sci. 2009. 37:117–34, https://www.annualreviews.org/doi/pdf/10.1146/annurev.earth.031208.100206.

34 In particular, it would be reduced to 1/*e* of its original amount in 10 years, where *e* is Euler's number. *See* https://en.wikipedia.org/wiki/E_(mathematical_constant). Accordingly, again assuming the halting of methane emissions, there would be left 37% of the original amount in 10 years, 13.5% of that amount in 20 years, and slightly less than 5% in 30 years. That is, more than 95% of the original CH_4 would be oxidized within three decades.

35 Robert B. Jackson, et al., 2021, Atmospheric methane removal: a research agenda, *Phil. Trans. R. Soc. A*.**379,** http://doi.org/10.1098/rsta.2020.0454 at 4.

36 *Id.*

37 Chlorofluorocarbons, hydrochlorofluorocarbons and halons are currently regulated under TSCA, in accordance with the Montreal Protocol and under the Clean Air Act (CAA), for their ability to destroy stratospheric ozone and thus allow increased levels of harmful UV radiation to reach the Earth's surface. Halogenated refrigerants that are much less destructive to stratospheric ozone but can have as great a global warming potential are being phased out under the Kilgali accord (not yet ratified by the US). Appliances discarded before 1/1/18 are not regulated under the CAA, and there is also illegal disposal that occurs. They are included in this petition because aggressive action to find and destroy discarded refrigerants in appliances and other disposed material can be required under TSCA section 2605 in the same way TSCA regulates discarded PCB-containing materials.

substitution of chlorine and fluorine atoms for hydrogen. EPA has taken action under TSCA to control other families/classes of compounds, before and after disposal, including poly-chlorinated biphenyls (PCBs), chlorofluorocarbons (because of their ozone depleting effects), friable asbestos in schools, and dibenzo-paradioxins/dibenzofurans.[38] The family of refrigerants shares common global warming effects and should be controlled and cleaned-up to prevent their additional climate impact.

Despite the decreased production of CFCs due to the regulatory control, over a million tons of CFCs remain in existing appliances (many disposed of in dumps), and these comprise a significant source of potential future emissions. Similarly, banks of HCFCs and HFCs are being established as some uses increase. The management of such CFC and HCFC stores are neither controlled by the Montreal Protocol nor taken into account in UNFCCC inventories. The problem is not small, as halocarbon releases are responsible for about 2-3% of the GWP of released gases.[39] It is estimated that there are over 57 GT[40] of carbon equivalents in disposed appliances that will be released as the appliances break down and emit their refrigerants.[41] These discarded units are physically an environmental problem similar to that of discarded capacitors containing PCBs and dioxin. EPA has a program to capture and destroy the latter such fluids under TSCA, and a similar program should be put in place as a matter of course for discarded refrigerants. Petitioners here request this be done without any delay; it need not await completion of the rulemaking requested herein.

(C) Nitrous Oxide

Nitrous Oxide (N_2O) is a long-lived species emitted to atmosphere by soil and sea microorganisms such as denitrifying bacteria and fungi. The atmospheric N_2O concentration has increased from about 270 ppb in 1750 to its present level of 335 ppb, and its concentration is currently increasing at a rate of about 1.3 ppb/year (1.35 ppb in 2020 and 1.26 ppb in 2021).[42] Nitrous oxide is unreactive in the lower atmosphere and thus has a long lifetime of slightly more than 100 years. Once mixed into the stratosphere, however, it undergoes photolysis and reaction with electronically excited oxygen atoms in the stratosphere where a small fraction is converted to nitric oxide (NO) which catalyzes ozone depletion.[43] Although N_2O has a very low atmospheric concentration, it contributes significantly to radiative forcing, with a global warming potential 273 times that of CO_2 over 20 years.[44] Thus, a 1.3 ppb increase in N_2O each

---

[38] https://www.brown.edu/health-safety/topics/environmental-compliance/toxic-substance-control-act-tsca Last accessed 2/8/2021.

[39] https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks Last accessed and https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data, last accessed 2/10/21.

[40] https://www.drawdown.org/solutions/refrigerant-management Last accessed 2/10/21. A gigatonne (GT), also known as a petagram, is 1 billion (10^9) tonnes, or 1,000 megatonnes (MT) or 1 trillion kilograms (kg).

[41] IPCC/TEAP Special Report: Safeguarding the Ozone Layer and the Global Climate System.

[42] NOAA Global Monitoring Laboratory, https://gml.noaa.gov/ccgg/trends_n2o/

[43] Ravishankara, A.R., Daniel, J.S. and Portmann, R.W., Nitrous Oxide (N_2O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century, Science 326, 123-125 (2009). https://www.science.org/doi/10.1126/science.1176985

[44] IPCC AR6 WG1 Ch72021

year produces the same degree of warming as an increase of 0.35 ppm of CO_2. Since CO_2 is currently increasing at a rate of ~2.3 ppm/yr, N_2O emissions contributes about 15% as much as CO_2 to additional global warming each year. Nitrous oxide emissions to the atmosphere have both natural and anthropogenic sources. It is estimated that 62% of emissions are natural and 38% are due to human activity.[45] The principal anthropogenic sources are agricultural soil management (e.g., application of fertilizers; 74%), wastewater treatment (6%), stationary combustion (5%), chemical production and other product uses (5%), manure management (5%), transportation (4%) and other sources (1%).[46] Thus, large reductions in N_2O emissions could be achieved by reduced use of nitrate fertilizers, better management of farm wastes, and reduced combustion of fossil fuels.

(D) Black Carbon

Black carbon (BC), or "soot", is a component of atmospheric aerosols derived from incomplete combustion of fossil fuels and biomass. It is the black smoke you sometimes see belching out of tailpipes of vehicles, especially those such as trucks that make use of diesel fuel. But it is produced with varying efficiency in combustion of all fuels, higher rates of production occurring under fuel-rich conditions. BC particles are in the submicron size range and make up typically 10-30% of PM2.5 (mass of particles have diameters $\leq$ 2.5 μm) in urban atmospheres. Black carbon is "black," in that it absorbs all wavelengths of visible light from the sun. Thus BC, heats the atmosphere differently that GHGs, that is, by absorption of visible light from the sun (reducing the planetary albedo) rather than by absorption of infrared radiation emitted by Earth's surface.

Black carbon also differs from GHGs in that it deposits, after a short residence time (days to weeks) in the atmosphere, onto Earth's surface where it reduces the albedo (reflectivity) and can continue to absorb visible light. This is especially a problem for glaciers where black carbon deposition enhances ice melt. Black carbon has been found in Arctic haze[47] and in Arctic snow,[48] for example. It has been claimed that in some regions, such as the Himalayas, the impact of black carbon on melting of snowpack and glaciers may be equal to that of CO_2.[49] Indeed, past IPCC reports placed black carbon ahead of methane in terms of radiative forcing, but the most recent report assigns black carbon a more modest role. The current IPCC best estimate for contributions to global warming during the period 2010-2019 relative to 1850-1900 based on radiative forcing studies is about 0.1°C, comparable to that of halogenated gases and nitrous oxide, but with larger error bars than for either of those GHGs.[50]

---

[45] K. L. Denman, G. Brasseur, et al. (2007), "Couplings Between Changes in the Climate System and Biogeochemistry." In Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

[46] EPA, Overview of Greenhouse Gases, https://www.epa.gov/ghgemissions/overview-greenhouse-gases#nitrous-oxide

[47] Rosen, H.; Novakov, T.; Bodhaine, B. (1981) Soot in the Arctic, *Atmos. Environ.* **15**, 1371–1374. https://www.sciencedirect.com/science/article/abs/pii/0004698181903437

[48] Clarke, A.D.; Noone, K.J. (1985). "Soot in Arctic snowpack: A cause for perturbation in radiative transfer". Atmos. Environ. 19 (12): 2045–2053. https://www.sciencedirect.com/science/article/abs/pii/S1352231007009752

[49] Ramanathan, V.; Carmichael, G. (April 2008). "Global and regional climate changes due to black carbon". Nature Geoscience. 1 (4): 221–227. https://www.nature.com/articles/ngeo156

[50] IPCC AR6 WGI, Climate Change 2021, The Physical Basis, p. SPM-8, Fig SPM.2.

(E) Short-Lived Gases

Short-lived air pollutant gases such as sulfur dioxide (SO_2), the oxides of nitrogen (NO and NO_2) and volatile organic compounds (VOCs) contribute to radiative forcing principally though aerosol formation and ozone formation. As discussed earlier, nitrate and sulfate aerosol, formed from SO_2 and oxides of nitrogen produced in fossil fuel combustion processes, currently mask about 0.4°C (or more) of warming that would have occurred to date in their absence. As we reduce fossil fuel emissions, simultaneous reductions of these negative radiative forcings (due to scattering of solar radiation back to space) will work against the gains we make in reducing GHGs, making it all that more important to remove legacy GHGs in addition to cutting emissions.

Ozone is a short-lived gas (a few hours to days) that is continuously produced in the lower atmosphere by the NO_x-catalyzed photooxidation of CH_4, carbon monoxide (CO) and VOCs.[51,52] Tropospheric ozone has contributed about 0.2-0.3°C of warming relative to pre-industrial times.[53] The U.S. already regulates ozone under the Clean Air Act and its amendments as one of six Criteria Pollutants.[54] The precursor CO is also a criteria pollutant, as is NO_2, which photochemically cycles with NO to catalyze ozone formation. On a global scale, however, ozone will continue to be elevated due to large contributions from low-income countries that have not yet imposed stringent air pollution regulations. It will be important for the U.S. to share technologies and expertise in helping those countries reduce emissions of ozone precursors as a means of reducing the global contribution to radiative forcing from this greenhouse gas. The co-benefit to those countries will be improvements in the health and increased lifespans of their citizens.

V. Unreasonable Land-Based Risk: A Short Survey

(A) Heat, Drought, Wildfire

Fossil fuel-driven heat, drought, and wildfire impose a current, imminent and unreasonable risk of serious or widespread injury to health or the environment.

In its 2018 Special Report, Global Warming on 1.5 Degrees Celsius (2.7 Degrees Fahrenheit), the IPCC noted that as the Earth warms to 1.5°C about 14 percent of Earth's population will be exposed to severe heatwaves at least once every five years.[55] This level of high temperature exposure may be unavoidable, at least for a period.[56] Additional GHG emissions will ensure that extreme heatwaves become widespread – with 37 percent of the Earth's people experiencing severe heatwaves at least once every five years. Indeed, in its 2021 report, the IPCC notes that with warming of 2.6ºC heatwaves now experienced only once in a decade will likely occur as often as 6 times per decade.[57] Compounding the problem,

---

51 A. J. Haagen-Smit, A.J. and Fox, M.M. (1954) Photochemical Ozone Formation with Hydrocarbons and Automobile Exhaust, Air Repair, 4:3, 105-136, DOI: 10.1080/00966665.1954.10467649.

52 Birks, J.W., "Oxidant Formation in the Troposphere," In *Perspectives in Environmental Chemistry*, D. L. Macalady, Ed., Oxford University Press, pp. 233-256 (1998).

53 IPCC AR6 WGI, Climate Change 2021, The Physical Basis, p. SPM-8, Fig SPM.2.

54 EPA, Criteria Pollutants, https://www.epa.gov/criteria-air-pollutants

55 From NASA article, https://climate.nasa.gov/news/2865/a-degree-of-concern-why-global-temperatures-matter/.

56 *See* July Temperature Update, *op cit* nte.34.

57 AR 6, SPM-23.

anthropogenic aerosols (fine particulate pollution) mask a significant fraction of global warming.[58] Accordingly, selective progress in combatting conventional air pollution – such as baghouse filters on coal plants – leads to additional warming, unless there are simultaneous efforts to eliminate GHG emissions.

Although the 2021 US wildfire season was not among the most severe in the modern era of consistent record keeping, four fires made the "Top 20 Largest California Wildfires" list in 2021, which includes the second largest wildfire in California's history – the Dixie Fire. Admittedly, the fires are the product of a number of relevant factors, including changes in meteorological conditions that carry their own internal variability, but climate warming and associated drought constitute two primary conditions. Petitioners illustrate the correlation between temperature change and wildfire over a 35-year period in Figure 9 below.[59]

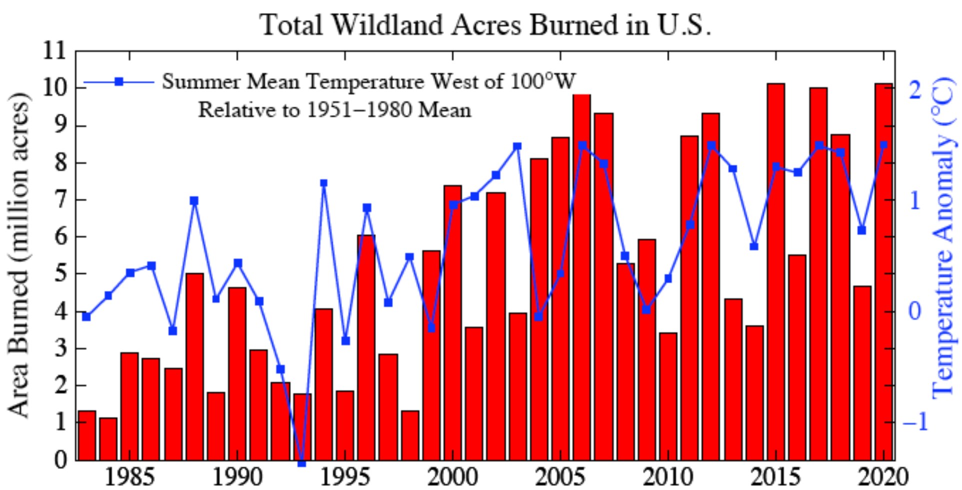


Fig. 9: Graphic by CSAS.[60]

We note that while the governmental dataset used for the histogram covers the continental U.S., the picture is reflective of western states where the vast majority of acres burned by U.S. wildfire are located. We illustrate this in Fig. 10 using the federal government's Monitoring Trends in Burn Severity tool, depicting over 25,000 fires in the 1984-2019 period.

[58] Petitioner Hansen and colleagues at Climate Science, Awareness and Solutions estimated in 2013 that the negative radiative forcing from aerosols could be up to 4x that amount, that is, ~ -1.6 ± 0.3 W/m². Hansen, J, Sato, M, Kharecha, P and von Schuckmann, K 2011 Earth's energy imbalance and implications Atmos. Chem. Phys. 11, 13421-13449.

[59] There were, of course, fires in western states prior to 1983, but we illustrate the point for the period during which the federal wildland agencies tracked the relevant data "using current reporting processes." https://www.nifc.gov/fire-information/statistics/wildfires (visited Aug. 18, 2021).

[60] As also developed by Makiko Sato, with wildland acreage data from the National Interagency Fire Center, https://www.nifc.gov/fire-information/statistics/wildfires.

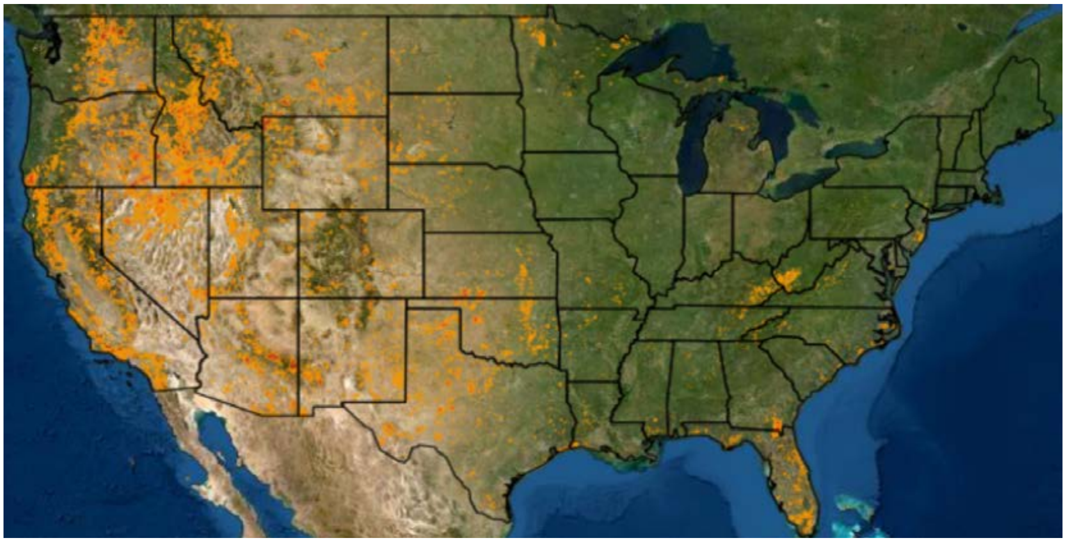


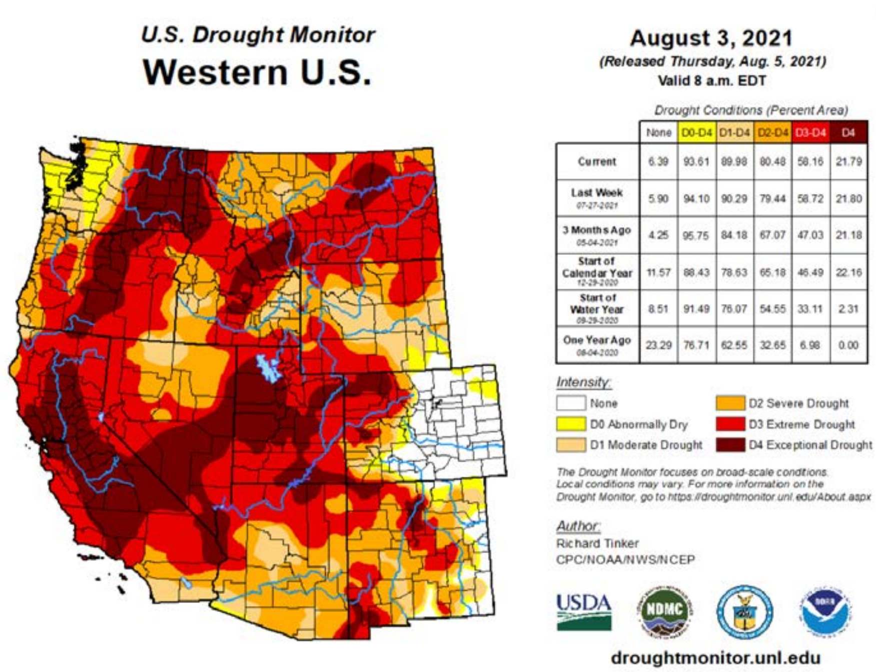
Fig. 10: USGS and Forest Service.[61]

Temperature and drought are related variables, and record warming led to severe to extreme drought conditions in much of the western states in recent years. Figure 11, taken from the United States Drought Monitoring (USDM) program, depicts the situation this past summer. If fossil fuel GHG emissions are not rapidly phased out and their atmospheric excess removed, then drought extent and severity will increase. The IPCC observed in 2018, as an implication of this, that about 61 million additional people in Earth's urban areas would be exposed to severe drought in a 2°C warmer world. [Relatedly, up to 270 million more people are projected to be exposed to increases in water scarcity in 2050 with warming at 2 ºC.[62]] Most recently, the IPCC observed that, with continued fossil fuel-driven warming, there will be an increase in the frequency and intensity of agricultural and ecological drought events. Where a drought occurred once in 10 years on average across drying regions in a climate without human influence, the IPCC anticipates that a drought of higher severity likely will occur 2.4 times more frequently in a 2°C world, and more than 4 times more frequently in a 4°C world.

Because wildfire is driven by such drought, in combination with heat, the risk of wildfire also is anticipated to be far higher in a 2°C warmer world than with warming of "only" 1.5 ºC.

61 Available at https://www.mtbs.gov/viewer/index.html. Visited August 18, 2021.

62 Again, from NASA here: https://climate.nasa.gov/news/2865/a-degree-of-concern-why-global-temperatures-matter/.



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	6.39	93.61	89.98	80.48	58.16	21.79
Last Week 07-27-2021	5.90	94.10	90.29	79.44	58.72	21.80
3 Months Ago 05-04-2021	4.25	95.75	84.18	67.07	47.03	21.18
Start of Calendar Year 12-29-2020	11.57	88.43	78.63	65.18	46.49	22.16
Start of Water Year 09-29-2020	8.51	91.49	76.07	54.55	33.11	2.31
One Year Ago 08-04-2020	23.29	76.71	62.55	32.65	6.98	0.00

Fig. 11. Image from National Drought Mitigation Center.[63]

As USDM observed,[64] the share of the Western US in "moderate to exceptional drought peaked at 90.3 percent on July 27, 2021. This value exceeded the previous peak in the 21-year USDM record that occurred in August and September of 2003. The percent area in extreme to exceptional drought (D3-D4) peaked at 59.5 percent on July 20, which is a USDM record. This is due to record low precipitation and excessively hot temperatures during the last several years."

Similarly, conditions during 2020 led NOAA to note, in its annual drought report for that year,[65] that:

> *The increasing temperature trend . . . means more evapotranspiration is occurring than before and this makes the dry spells, when they happen, result in increasingly more intense droughts. . . [E]xcessive evapotranspiration and lack of rain dried soils across the West, with two-thirds or more of the topsoil moisture dry or very dry across most western states by the end of October. Several large wildfires sparked to life in parts of the West in the spring, with the wildfires spreading during June. They were burning across all of the western states during the summer and fall, and some had yet to be extinguished in California as the year ended. Nationwide, over 10 million acres burned in 2020, which is more than the 2010-2019 average of 6.79 million acres and the largest acreage consumed in the U.S. since at least 2000. The three largest wildfires in Colorado history, and five of the six largest wildfires in California history, occurred in 2020.*

---

[63] Available at https://www.ncdc.noaa.gov/sotc/drought/202013#national-overview. Visited August 18, 2021.

[64] *Id.*

[65] National Centers for Environmental Information, Drought -Annual 2020. https://www.ncdc.noaa.gov/sotc/drought/202013#national-overview

While 2020 did not set the drought record for the western states as a whole, it did set wildfire records for west *coast* states.[66] The number and scale of California wildfires were unprecedented in that state's history, with its largest, the August Complex Fire, encompassing more than 1million acres – a gigafire.[67] In Oregon, fires broke out in areas not normally prone to fire, but many of these had experienced exceptional drought, and fire swept through them propelled by rare easterly winds during Sept. 8 to 9, 2020. A number of communities were simply wiped out. *See* Figure 12.

Fig. 12: Photos by wildlands ecologist Dominick DellaSala, Sept. 18, 2020, Talent, Oregon. (The trees weathered the fire storm better than many homes.) Used with permission.

The Western 2021 Fire Season was severe as the region was subjected to one heat wave after another – in some places, even before summer officially began.[68] Perhaps the worst of these resulted in part from the parking of a high-pressure system over the Pacific Northwest, a development caused in part by an undulation of the "normally" more tightly-wound jet stream. As Petitioner Hansen and his colleague Makiko Sato wrote in their *June 2021 Global Temperature Update:*

> *The jet stream is driven by the temperature gradient from middle to polar latitudes. An especially cold Arctic tends to cause a strong, tightly wound jet stream. However, an increased greenhouse effect warms the Arctic more than mid-latitudes, reducing the temperature gradient, thus slowing the jet stream and allowing it to have more extreme waggles. This was likely a contributing factor in the Pacific Northwest heat wave.*[69]

In the absence of climate change, according to the credible research of one rapid attribution analysis team, the extreme heat wave that followed would have been "virtually

66 *See Record Wildfires on the West Coast Are Capping a Disastrous Decade*, New York Times, Sept 24, 2020 (usefully showing time lapse images from Sept. 6-11).

67 *See California wildfires spawn first 'gigafire' in modern history* at https://www.theguardian.com/us-news/2020/oct/06/california-wildfires-gigafire-first

68 *Climate Change Batters the West Even Before Summer Officially Begins*, NY Times, June 17, 2021 (updated June 27, 2021) at https://www.nytimes.com/2021/06/17/climate/wildfires-drought-climate-change-west-coast.html?action=click&module=RelatedLinks&pgtype=Article.

69 http://www.columbia.edu/~mhs119/Temperature/Emails/June2021.pdf. *See also* Jacob and Reeder, "The North American heatwave shows we need to know how climate change will change our weather," The Conversation (July 2, 2021) at https://theconversation.com/the-north-american-heatwave-shows-we-need-to-know-how-climate-change-will-change-our-weather-163802.

impossible."[70] Record-eclipsing temperature followed: Lytton, British Columbia (121 °F on June 29, 2021); Portland, Oregon (116 °F on June 28); Seattle, Washington (108 °F on June 28); Lewiston, Idaho (115 °F on June 29); and Missoula, Montana (101 °F on June 29). Heat-related deaths were estimated in the hundreds for humans, in the billions for animals.[71]

A series of fires ensued, some engulfing small towns from British Columbia to Northern California. The plumes of smoke from western wildfires were transported thousands of miles, creating the worst air quality ever experienced in many locations. According to the Swiss air quality measuring company, IQAir, Denver, Colordo experienced the worst air quality in the world, on August 7, 2021, with an air quality index (AQI) of 167 due to smoke produced mostly in California. The Dixie fire burned over 963,000 acres of forest[72] – rendering it the largest single fire in California recorded history. Of California's ten largest fires in recorded history, nine have occurred within the most recent decade while eight have been within the last four years.[73]

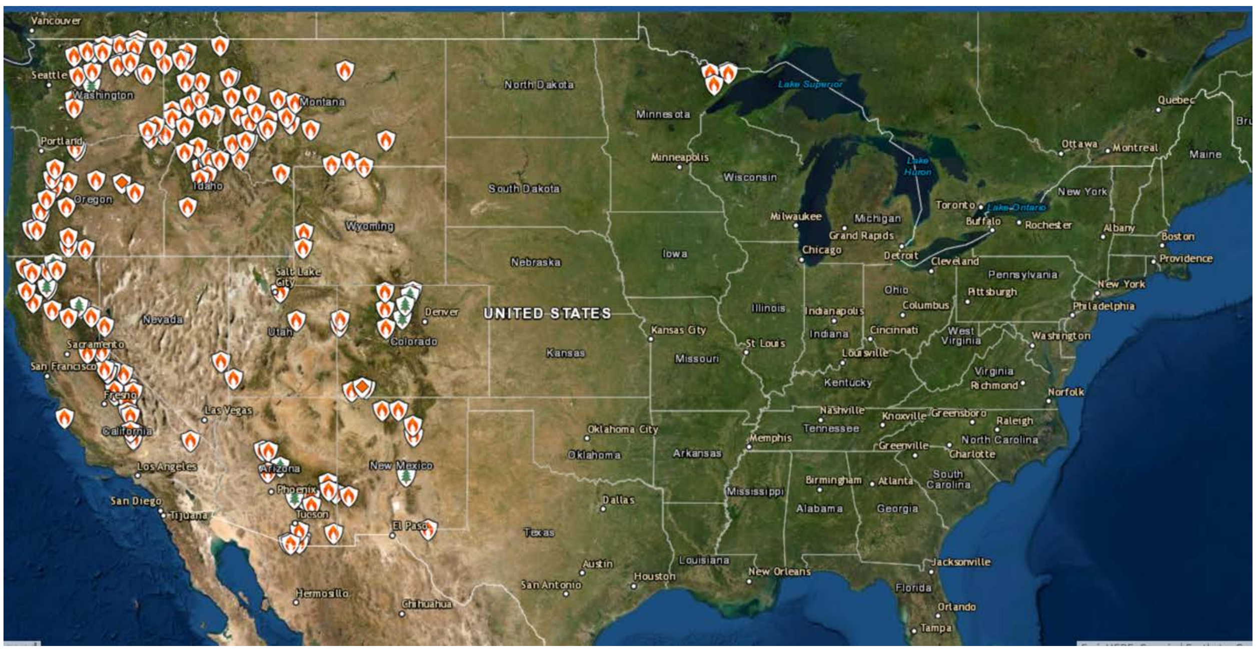


Figure 13: From https://inciweb.nwcg.gov/#. August 22, 2021.

---

[70] Philip et al, *Rapid attribution analysis of the extraordinary heatwave on the Pacific Coast of the US and Canada June 2021*, available at https://www.worldweatherattribution.org/western-north-american-extreme-heat-virtually-impossible-without-human-caused-climate-change/.

See also AR6 IPCC Physical Science Basis report, sections 11.8.3 and 12.4.3.2 noting that "the attribution of extreme weather events has emerged as a growing field of climate research with an increasing body of literature. It provides evidence that greenhouse gases and other external forces have affected individual extreme events by disentangling anthropogenic drivers from natural variability." The IPCC finds "medium confidence" that "weather conditions that promote wildfires have become more probable in southern Europe, northern Eurasia, the USA, and Australia over the last century."

[71] Stephen Leahy, *If the Hardiest Species Are Boiled Alive, What Happens to Humans?* The Atlantic. July 31, 2021.

[72] The Dixie Fire, InciWeb, at https://inciweb.nwcg.gov/incident/7690/.

[73] CalFire, Top 20 Largest California Wildfires, Aug. 20, 2021.

(B) Sea-level Rise

Fossil fuel emissions-driven sea-level rise clearly presents an "unreasonable" as well as an "imminent" risk of serious or widespread injury to health or the environment.[74]

As the planet warms, sea level rises due to two factors: (a) thermal expansion of seawater, and (b) melting of glaciers and ice sheets.

Thermal expansion is estimated to account for 50% of the observed sea level rise since 1971, with melting of glaciers and ice sheets contributing 22% and 20% respectively.[75] Like temperature, sea level can be measured with high accuracy. We have tidal gauge measurements dating back to 1880, and more accurate satellite measurements unaffected by changes in land elevations beginning in 1993. These indicate that there has been a rise in average sea level by a total of 15-25 cm (~6-10 in) during the period 1901-2018, as shown in Figure 14.

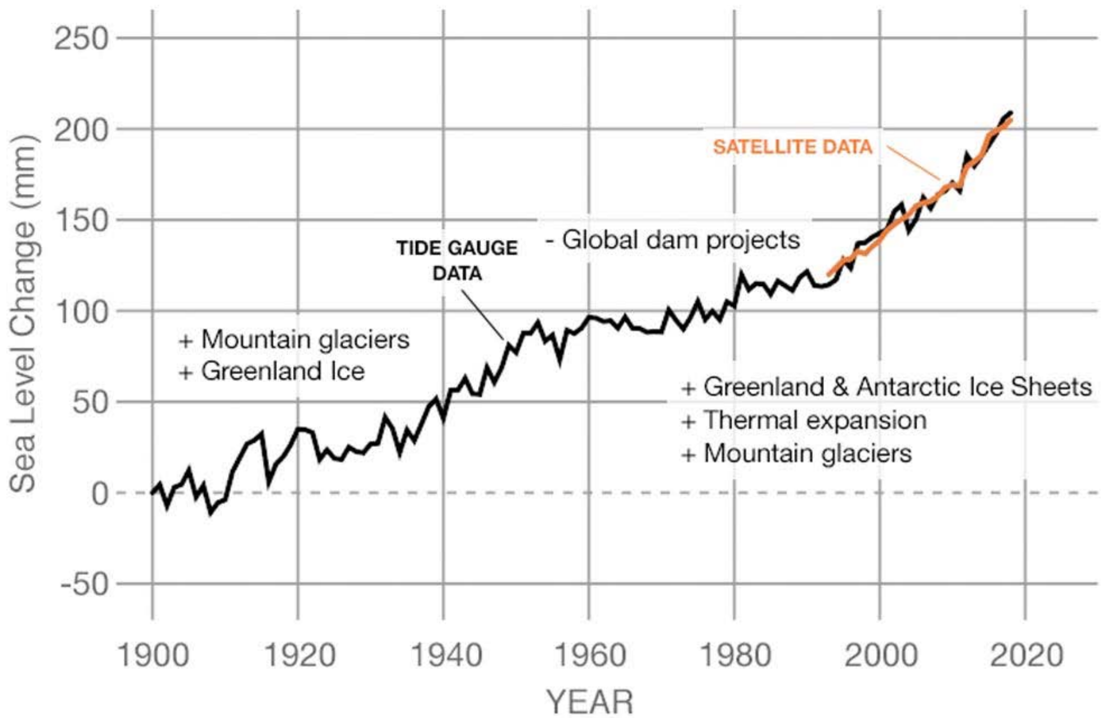


Fig. 14. Satellite observations of sea level rise from 1993 to 2021. Data Source: Frederikse et al. (2020).[76] From: https://climate.nasa.gov/vital-signs/sea-level/

The rate of sea level rise has been accelerating over at least the past century by about 0.1 mm/yr. The average rate of sea level rise increased from 1.3 mm/yr during the period 1901 to 1971 to 1.9 mm/yr during the period 1971-2006 and further increased to 3.7 mm/yr, during the period 2006-2018. In fact, the IPCC finds with high confidence that the global mean sea level

[74] Comparing 15 USC §2605(a) ("unreasonable risk of injury to health or the environment") with 15 USC §2606(f) ("imminent and unreasonable risk of serious or widespread injury to health or the environment").

[75] IPCC AR6 WGI, Climate Change 2021, The Physical Basis, p. SPM-6. Changes in land water storage account for 8%. *Id.*

[76] Frederikse *et al.*, The causes of sea-level rise since 1900, *Nature*, vol 584, pp. 393-397 (2020), at https://www.nature.com/articles/s41586-020-2591-3/.

has risen faster since 1900 than during any preceding century in the last 3000 years.[77] Even for IPCC's very low GHG emission scenario (SSP1-1.9), total sea level rise is predicted to reach 32 to 62 cm (12.6 to 24.4 in) by the end of this century. This 1-2 feet of sea level rise will be difficult enough for future generations to contend with, but even to keep sea level within that range requires drastic cuts in current GHG emissions. Other scenarios that include a range of likely future emissions if drastic cuts are not made predict sea level rises in the range of about 500 to 1,000 cm, or 1.6 to 3.5 ft.

While the IPCC assessment of sea-level rise is quite dire, Petitioners aver, nonetheless, that its reports underestimate the actual extent to which sea-level is likely to rise. A 2016 study by Petitioner Hansen and 18 other climate scientists, titled "Ice melt, Sea level rise and Superstorms" (hereafter, Ice Melt) warned, *inter alia*, that based on an analysis of paleoclimate evidence, ongoing observations, and modeling, continued high fossil fuel emissions may yield nonlinear ice mass loss sufficient to raise sea level several meters within 50-150 years.[78]

The major implications of the Ice Melt study include that (1) the (then) widely accepted target "of limiting global warming to 2°C . . . does not provide safety," (2) that "global surface air temperature, although an important diagnostic, is a flawed metric of planetary health," because faster ice melt has a cooling effect for a substantial period [so that] Earth's energy imbalance is a more fundamental climate diagnostic, and (3) the existence of amplifying feedbacks present a "real danger that we will hand young people and future generations a climate system that is practically out of their control."[79]

The described amplifying feedbacks include reduced Southern Ocean bottom water formation (and thus retention of subsurface heat), a slow-down and risk of shutdown of the Southern Ocean and Atlantic Meridional Overturning Circulations (SOMC and AMOC), increased temperature gradients and storminess in the North Atlantic region, as well as the potential for nonlinear disintegration of major ice sheets in West Antarctica and Greenland. Figure 15 depicts some of these feedbacks. In light of these additional "real dangers" the Ice Melt scientists concluded that "we have a global emergency [and that] fossil fuel CO_2 emissions should be reduced as rapidly as practical."[80] Petitioners here strongly concur with that conclusion.

---

[77] *Id.* at p. SPM-9.

[78] Hansen *et al.,* Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2°C global warming could be dangerous, Atmos. Chem. Phys., 16, 3761–3812 (2016) at www.atmos-chem-phys.net/16/3761/2016/. Hereinafter, "Ice Melt."

[79] *Id.*

[80] *Id.* at p. 3801.

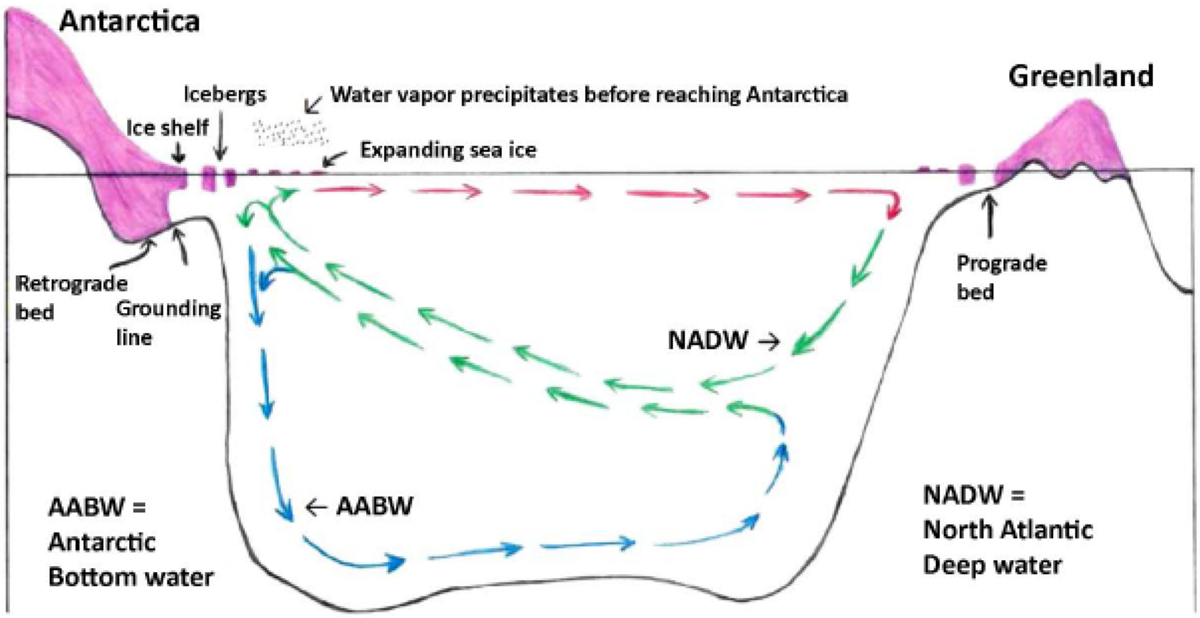


Fig. 15: Schematic of stratification and precipitation amplifying feedbacks. Increased freshwater flux reduces surface water density, reducing AABW formation, trapping NADW heat, and increasing ice shelf melt.

Present and imminent impacts from continued sea-level rise include the loss of habitable land and frequent flooding due to higher tides and bigger storm surges. River deltas in Africa and Asia, and low-lying small island nations such as Maldives, Tuvalu, Kirabati and Fiji, are immediately vulnerable to *any* additional sea level rise. The highest elevation in all of the Maldives – which consists of 26 atolls, supports a population of ~ 500,000 people, and has an average elevation of 1.8 m (6 ft) – is only 2.4 meters (7.9 ft). Thus, at current rates of sea level rise – even if rapid ice sheet disintegration is somehow staved off – the Maldives will be uninhabitable by 2100, as is true of many other island nations where tidal flooding is becoming more frequent.

Already five of the Solomon Islands, ranging in size from one to five hectares have been completely submerged due to sea level rise,[81] and king floods in the Marshall Islands capital Majuro that historically occurred every few decades are now occurring multiple times per decade. Worldwide, approximately 600 million people live directly on the coast, and 267 million people live on land less than 2 meters above sea level.[82] Further increases in sea level, especially when combined with increased storm intensity caused by global warming, will result in loss of habitable and agricultural land, forcing tens to hundreds of millions of people to migrate further inland and reducing food production.

US citizens and residents are also at great present and imminent risk due to sea level rise. As of 2014, 127 million people or 40% of the U.S. population lived in coastal counties, and effects of sea level rise are already being felt in many of these densely populated areas. Hurricane Katrina, one of the most damaging storms in U.S. history, caused $170 billion in

---

[81] Klein, Five Pacific islands vanish from sight as sea levels rise, *New Scientist*, 9 May 2016, available at https://www.newscientist.com/article/2087356-five-pacific-islands-vanish-from-sight-as-sea-levels-rise/.

[82] Hooijer and Vernimmen, Global LIDAR land elevation data reveal greatest sea-level rise vulnerability in the tropics, *Nature Communications*, vol. 12, p. 3592 (2021) at https://www.nature.com/articles/s41467-019-12808-z/.

damages, resulted in the displacement of hundreds of thousands of people, and killed more than 1,800. A 2013 study shows that the storm surge from Katrina would have been 15 to 60 percent lower for sea level conditions of 1900.[83] Similarly, the storm surge flooding of New York City and the New England coastline due to Superstorm Sandy in 2012 was amplified by the 12-inch rise in sea level, as measured by the tidal gauge at Battery Park, during the past century.[84]

A recent study estimates future flood losses stemming from already-realized sea level rise.[85] Miami ranks only slightly behind Guangzhou, China as the most vulnerable city worldwide in terms of risk of average annual loss of property from storm-related flooding, and New Orleans ranks just behind Guangzhou in terms of estimated annual loss as a percentage of GDP of that city. Three US cities – Miami, New York City and New Orleans – account for 31% of global aggregate losses from impacts on the 136 most vulnerable cities, due their high wealth and low protection level. With an assumption of 20 cm of additional sea level rise by 2050 and no additional adaptation, this study predicted aggregate losses due to flooding in excess of $1 trillion per year in the US. Although not meant to be predictive, the analysis illustrated the severe risk of continued sea-level rise to the United States.

The IPCC reports that if fossil fuel-driven warming is allowed to reach 2.0 ºC, then at least 10 million more people may be subjected to "sea-level rise greater than 0.66 feet (0.2 meters) [and will ensure] increased coastal flooding, beach erosion, salinization of water supplies" and other impacts on humans and ecological systems.

Petitioners here adopt the global emergency assertion of the *Ice Melt* authors in support of their request to EPA to restrict and remove continuing and legacy GHG emissions, and phase-out fossil fuels, under TSCA. In particular, the virtual certainty of accelerating sea level rise, if GHG emissions are not rapidly reduced, as described in the consensus IPCC report itself, fully establishes an actual (as well as imminent) and unreasonable risk of serious or widespread injury to health or the environment. The "real danger" of nonlinear ice sheet disintegration (with its correlated rapid sea level rise on the order of several meter) and likely increased superstorm activity supports the view that continued unabated fossil fuel emissions may prove calamitous – and thus an "existential" threat, to appropriate President Biden's term – a threshold well beyond that required to be established under TSCA.

---

[83] Irish et al., Simulations of Hurricane Katrina under sea level and climate conditions for 1900, *Climatic Change*, vol. 122, pp. 635-649 (2014), at https://doi.org/10.1007/s10584-013-1011-1/.

[84] Kahn, B. Superstorm Sandy and Sea Level rise, NOAA Climate.gov (2020), at https://www.climate.gov/news-features/features/superstorm-sandy-and-sea-level-rise/.

[85] Hallegatte et al., Future flood losses in major coastal cities, *Nature Climate Change*, vol. 3, pp. 802-806 (2013) at https://www.nature.com/articles/nclimate1979/.

(C) Extreme Weather

1. Predicted Changes in Frequencies of High Temperature, Precipitation and Drought

Increased temperature over land results in increased evaporation of water. In many regions this results in a reduction of soil moisture and eventually drought, while in other regions the increased water vapor in the atmosphere results in increased precipitation. According to the IPCC,[86] the increase in average global temperature of about 1.2°C that we are experiencing so far is already resulting in increased frequencies of extreme temperature events, heavy precipitation events, and agricultural and ecological droughts, as shown in Figure 16.

Hot temperature extremes that historically (1850-1900) occurred once every 10 years now occur 2.8 times more often. For warmings of 1.5°C, 2°C and 4°C, such events are predicted to occur 4.1 times, 5.6 times and 9.4 times more frequently; that is, a temperature event that occurred previously only once every ten years would occur almost every year on average if the planet were allowed to warm by 4°C. And those extreme temperature events would be even more severe. As well, ten-year extreme temperature events are now 1.2°C higher than in the last half of the 18th century, with temperature records continually being set at locations around the world. As seen in Figure 16, global warmings of 1.5°C, 2°C and 4°C are predicted to result in 10-year events that are 1.9°C, 2.6°C and 5.1°C higher than historical values.

The effects of global warming on 50-year events are greatly amplified over that of 10-year events. For example, in the case of a 2°C warming of the planet, a 50-year event is predicted to occur 13.9 times more frequently, meaning that humans and the livestock, crops and natural ecosystems we depend on will experience what was a 50-year event once every 3.6 years on average. For a catastrophic warming of 4°C, 50-year events would occur 39 times more often or almost every year.

As also summarized in Figure 16, increases in the frequencies of heavy precipitation and droughts are predicted to increase further with increased average global temperatures. Ten-year events for heavy precipitation have already shortened to 7.7 years and will further decrease to 6.7, 5.9 and 3.7 years for warmings of 1.5°C, 2°C and 4°C, respectively. Ten-year agricultural and ecological droughts are estimated to already be occurring once every 5.9 years and those periods are predicted to be reduced to 5, 4.2 and 2.4 years for 1.5°C, 2°C and 4°C warmings. In the same way that extreme temperature events will also be hotter, the historically 10-year events will be wetter for heavy precipitation events and drier for drought events.

[86] IPCC AR6 WGI, Climate Change 2021, The Physical Basis, pp. SPM-20-24.

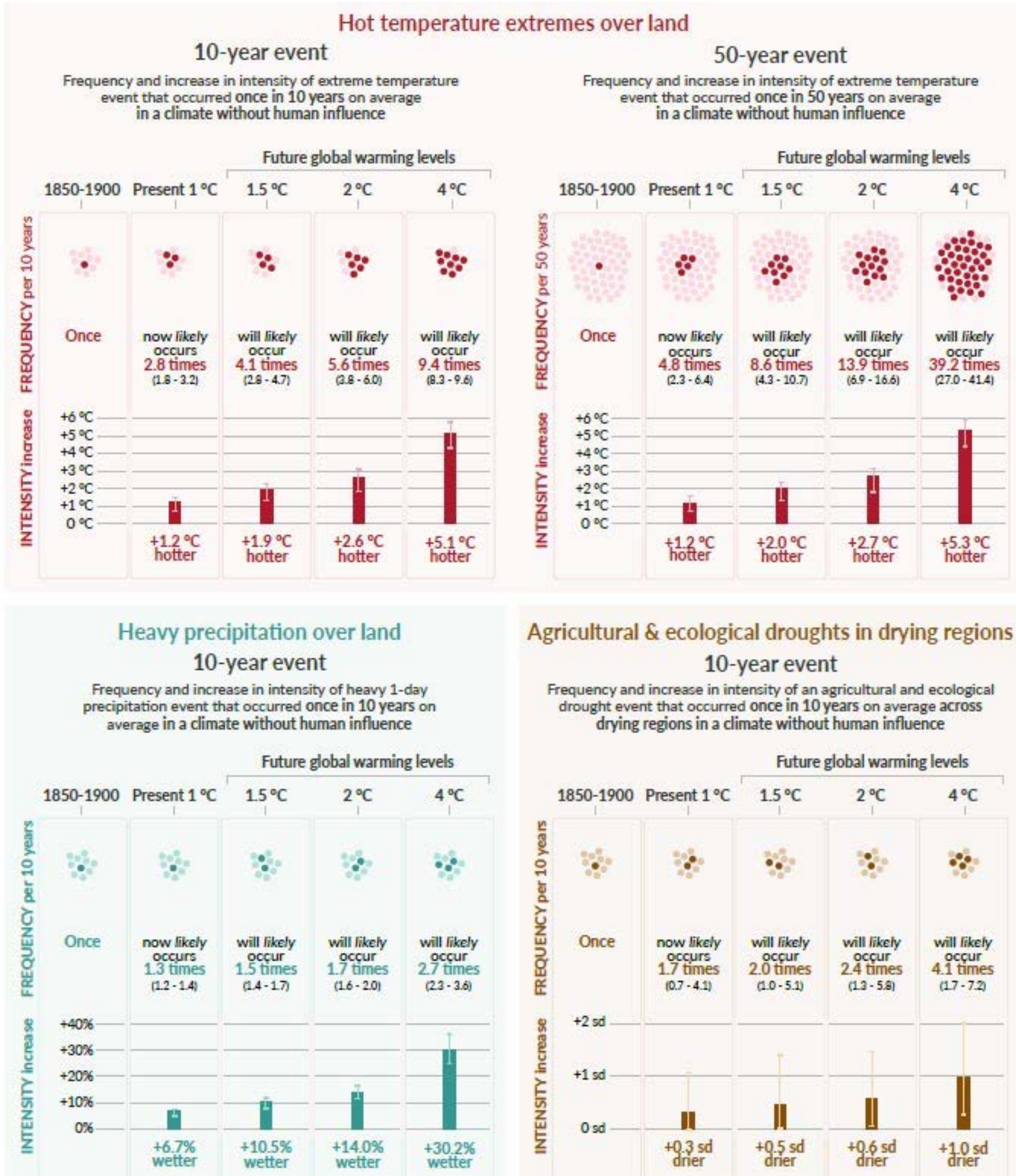


Figure 16. Projected changes in the intensity and frequency of hot temperature extremes over land, extreme precipitation over land, and agricultural and ecological droughts in drying regions. Figure SPM.6, p. SPM023 of the IPCC AR6 report, *Climate Change 2021, The Physical Science Basis*, 2021.

The 4°C scenario would be simply catastrophic in terms of high temperature extremes and heavy precipitation events that lead to flooding and droughts.

The 2015 Paris Agreement[87] committed signatory nations, including the US, to hold the increase in the global average temperature "to well below 2°C above pre-industrial levels" and to pursue efforts "to limit the temperature increase to 1.5°C above pre-industrial levels."

Clearly, 1.5ºC is highly preferable to 2ºC, but even 1.5ºC is unacceptable considering that a large fraction of the population would then experience extreme temperature events once every 2.5 years. Indeed, Petitioners aver that it is necessary not only to phase out fossil fuel emissions, but also to remove a large fraction of the excess greenhouse gases from the atmosphere in order to return the planet to a temperature sustainable for human life, agriculture and the many delicate ecosystems on which we depend.

2. Changes in Frequency and Severity of Tropical Storms

The heat content of air, land and oceans and its distribution around the planet drive the weather we experience. Uneven heating results in pressure differences that produce winds. Because of the Coriolis effect, winds near the surface of our rotating planet result in cyclones that, depending on intensity and spatial scale, become tropical storms, hurricanes/typhoons, waterspouts and tornadoes. Water vapor plays a key role in the formation and intensities of storms, providing a means for heat to be transported from the surface of the ocean to the atmosphere. Evaporation of water at the surface provides water vapor to the atmosphere with potential energy (latent heat) that can be released again as kinetic energy (sensible heat) as it rises, cools, and condenses back to liquid water. The fundamental physics that drives weather is well understood: greater energy in the land/water/air system results in larger pressure differentials, more water vapor in the atmosphere, an an intensification of weather processes.

Global climate models find that although about half of the equilibrium response to a climate forcing, such as a radiative forcing due to added greenhouse gases, occurs within a few years, the remaining response is "recalcitrant"[88] – requiring many decades or even centuries for the complete response. This is primarily due to the slow mixing of the oceans, which act analogous to a capacitor in an electrical circuit, storing the excess energy provided by Earth's energy imbalance. Although the oceans serve to reduce the immediate climate response to some degree, they also ensure that it will take decades to centuries for the climate system to return to its balanced state – even after much of the excess radiative forcing due to greenhouse gases is removed.

Because many of the climate consequences for the excess energy we have already added to the oceans lie in the future, and because of the difficulty in detecting the climate change signal above the natural noise of weather, we must rely on our predictive models – taking into account our best understanding of the geophysical processes that drive them. Current model studies predict that although tropical cyclones may be fewer in number they will have increased intensity, result in increased rainfall and produce stronger storm surges.[89] Such changes are

---

[87] As described by the United Nations, "[t]he Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at COP 21 in Paris, on 12 December 2015 and entered into force on 4 November 2016." https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

[88] Held, et al., Probing the fast and slow components of global warming by returning abruptly to preindustrial forcing, *Journal of Climate*, vol. 23, pp. 2418-2427 (2018), at https://journals.ametsoc.org/view/journals/clim/23/9/2009jcli3466.1.xml/.

caused primarily by rising sea temperatures, which result in higher water vapor content of the atmosphere. The condensation of lofted water vapor releases the latent heat that drives the winds of cyclones. The most recent U.S. National Climate Change Assessment concluded that "increases in greenhouse gases and decreases in air pollution have contributed to increases in Atlantic hurricane activity since 1970."[90] The amplification of cyclone strength from the decrease in certain air pollutants – in particular, SO_2, NO and NO_2 – reflects a partial unleashing of the full radiative forcing of greenhouse gases. Accordingly, as we reduce aerosol pollution to improve human health we also eliminate their cooling effect. This in turn allows the fuller warming effect of GHG emissions to be expressed. [91]

Although hurricane frequency may not have changed with statistical certainty, there is evidence that late-season Atlantic hurricanes are occurring more often. During the 140-year period of 1851-1990, only 30 hurricanes formed in the Atlantic on or after November 1, for a total of less than one late season hurricane every five years, and only four Category 3 or stronger late-season hurricanes occurred in those 140 years, with only three Caribbean hurricanes. However, during the 26-year period ending in 2017, there were 17 late-season hurricanes (only five expected based on historical data), with six in the Caribbean, four of which were Category 3 or above.[92]

The science of weather event attribution is rapidly advancing, and for two main reasons: "[1] the understanding of the climate and weather mechanisms that produce extreme events is improving, and [2] rapid progress is being made in the methods that are used for event attribution."[93] The IPCC now attributes at least the increases in precipitation from such storms to human activities with "high confidence." For example, there is high confidence that anthropogenic climate change contributed to extreme rainfall during hurricane Harvey and other intense tropical storms.[94]

Extreme weather events already cause enormous annual loss of life and property in the U.S., so that any significant potential amplification is of grave concern. During the decade 2010-2019, the U.S. sustained 258 weather and climate disasters where the overall damage costs reached or exceeded $1 billion, and the cumulative cost for those events exceeded $1.75 trillion.[95] These billion-dollar events included drought (26), flooding (32), freezes (9), severe

---

[89] Walsh et al., Tropical cyclones and climate change, *Tropical Cyclone Research and Review*, vol. 8, pp. 240-250, at https://www.sciencedirect.com/science/article/pii/S2225603220300047?via%3Dihub/.

[90] Fourth National Climate Assessment, Chapter 2: Our Changing Climate (2018), at https://nca2018.globalchange.gov/chapter/2/.

[91] Hansen and Sato, July Temperature Update: Faustian Payment Comes Due (13 August 2021) at http://www.columbia.edu/~mhs119/Temperature/Emails/July2021.pdf.

[92] Masters, November Atlantic hurricane outlook: The season is not over yet, *Weather Underground*, 1 November 2017, at https://www.wunderground.com/cat6/november-atlantic-hurricane-outlook-season-not-over-yet/.

[93] National Academies of Sciences Committee on Extreme Weather Events and Climate Change Attribution, *Attribution of Extreme Weather Events in the Context of Climate Change* (2016) at https://climatemodeling.science.energy.gov/system/files/private/meetings/attachments/Sobel_Extreme_Weather_Events.pdf

[94] IPCC AR6 WGI, Climate Change 2021, The Physical Basis, p. TS-74.

[95] Smith, 2010-2019: A landmark decade of U.S. billion-dollar weather and climate disasters, NOAA National Centers for Environmental Information, at https://www.climate.gov/news-features/blogs/beyond-data/2010-2019-landmark-decade-us-billion-dollar-weather-and-climate/.

storms (113), hurricanes (44), wildfires (17) and winter storms (17). It is especially noteworthy that the costs of inflation-adjusted billion-dollar disasters have increased steadily over the past four decades, averaging $13B, $27B, $51B and $80B per year during the decades of the 1980s, 1990s, 2000s and 2010s, respectively. Associated fatalities have increased as well, averaging 281, 217, 305 and 521 annually in each of those decades. The costs of severe weather events in terms of property and life clearly correlate strongly with the observation of increasing average global temperature. The observed trend over the past four decades agrees with the expectation that increasing the energy content of the land/ocean/atmosphere system will increase the frequency and intensity of severe weather events.

We note that the conclusions of the NAS and IPCC are based on climate modeling and observations of trends in severe weather in recent decades. They do not take into account the possibility of much more far-reaching consequences that may result from nonlinearities in the climate system, as has been proposed by Petitioner Hansen and colleagues (*Ice Melt*) based on paleoclimate studies coupled with climate system modeling discussed above in reference to increasing sea levels. With respect to the mechanism described above in Figure 12, freshwater released to the ocean by melting of West Antarctic and Greenland ice sheets results in a slowdown and possibly stopping of the thermohaline circulation in the vicinity of Antarctica due to the lower density of freshwater. This "stratification" process induces amplifying feedbacks that increase subsurface ocean warming and ice shelf melting. Another effect is expansion of sea ice off Antarctica as a result of the colder surface water, causing increased precipitation over the ocean and decreased precipitation over the ice sheet.

The transfer of ice and freshwater to the ocean could raise sea level by several meters. This mechanism could explain the 6-9 m sea level rise that occurred in the prior interglacial period. Near the end of that period (Eemian), 130,000-115,000 years ago, there is evidence of much larger global temperature gradients with resulting extreme storms while Earth was warmer by less than 1°C than it is today. The geologic evidence for the superstorms near the end of the Eemian period are reviewed in *Ice Melt* paper and include [1] megaboulders averaging 100 tons that were plucked from seaward middle Pleistocene outcrops and washed onto a younger Pleistocene landscape, [2] wave run-up deposits that reach heights of over 40 m along hundreds of kilometers of older built-up dune ridges in the Bahama Islands, and [3] chevron-shaped sand ridges standing ~5-15 m across several kilometers of broad, low-lying platforms or ramps throughout the Atlantic-facing, deep-water margins of the Bahamas.

A critical conclusion of the *Ice Melt* authors is that even a "… 2°C global warming above the preindustrial level could be dangerous." The study suggested that ice mass loss from the most vulnerable ice could rise exponentially rather than linearly in which case doubling times of 10, 20 or 40 years will yield multi-meter sea level rise in about 50, 100 or 200 years, respectively.

VI. Ocean-Based Risks – A Short Survey

<u>(A) Acidification</u>

There is clear consensus among leading national and international scientific bodies that anthropogenic CO_2 causes changes in ocean chemistry.

For one, the IPCC, comprehensively reviewing the evidence, determined in 2014 and in 2021 that human sources of CO_2 have caused a significant decline in surface ocean pH, with further increases in atmospheric CO_2 "virtually certain to further acidify the Ocean and change its carbonate chemistry."[96] *See* Figure 17 showing a slowing of acidification only under the most stringent of decarbonization scenarios considered recently by the IPCC.

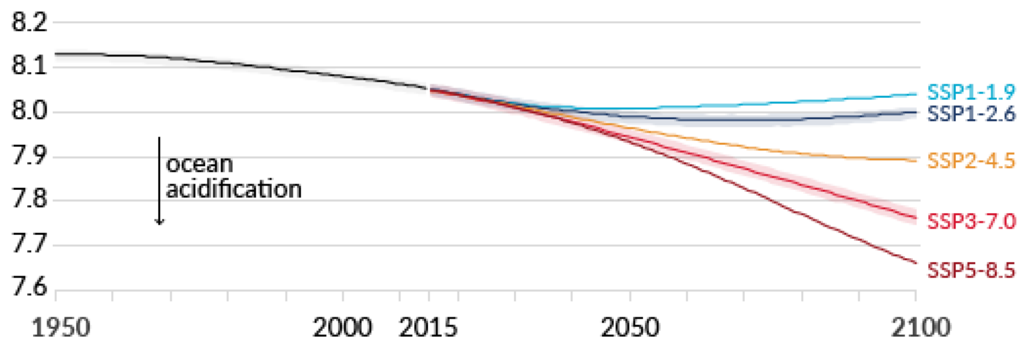


Fig. 17: Global ocean surface pH. Source: IPCC AR6 (2021) SPM-29.

The concern by the international scientific community is long-standing. More than a dozen years ago, for instance, 90 national academies of sciences, including that of the United States, warned that "[t]he average pH of oceanic surface waters [had] been lowered by 0.1 units since the pre-industrial period, representing a 30% increase in hydrogen ion activity," producing a situation in which carbonate ion concentrations – "needed by many marine organisms, such as corals and shellfish, to produce their skeletons, shells and other hard structures" – "are now lower than at any other time during the last 800,000 years."[97]

The Interacademy Panel concluded that CO_2 has increased ocean acidity with "potentially profound consequences for marine plants and animals" including severe threats to coral reefs, polar ecosystems, and a likely reduction in marine food supplies.[98] The National Research Council also acknowledges that "existing data support a growing consensus in the research community that most documented responses to acidification reflect impairment of physiological

[96] Hoegh-Guldberg, O., R. Cai, E.S. Poloczanska, P.G. Brewer, S. Sundby, K. Hilmi, V.J. Fabry, and S. Jung, 2014: The Ocean. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. at 1674. *See also*, Rhein, M. et al., 2013. Observations: Ocean. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, at what page? And IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis.

Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, SPM-6.

[97] Interacademy Panel, 2009. IAP Statement on Ocean Acidification at https://oceanfdn.org/sites/default/files/International%20Academy%20Panel%20Statement%20on%20Ocean%20Acidification.pdf.

[98] *Id.*

capacity or performance" for marine life with likely substantial socioeconomic impacts.[99] The U.S. National Climate Assessment concluded that ocean acidification will alter marine ecosystems in dramatic ways including threatening coral reef habitats, inhibiting the ability of marine organisms to form their shells or skeletons[100] and causing reduced growth and survival of shellfish in all regions.[101]

EPA itself has already concluded that greenhouse gases, including CO_2 and CH_4, endanger public health and the environment in part because of ocean acidification,[102] and that "ocean acidification presents a suite of environmental changes that would likely negatively affect ocean ecosystems, fisheries, and other marine resources." [103]

That fossil fuel company-traced emissions make a huge contribution to ocean acidification is made clear by recent research by Petitioner Heede and colleagues.[104] They found that nearly two-thirds of all industrial carbon dioxide and methane emissions between 1880 and 2010 can be traced to the products of 83 large producers[105] of coal, oil, and natural gas, and 7 cement manufacturers. Ekwurzel et al.[106] found that between 1880 and 2010, emissions traced to these 90 largest industrial carbon producers contributed ~57% of the rise in atmospheric CO_2, 42%–50% of the rise in global mean surface temperature, and approximately 26%–32% of the rise in global sea level. Similarly, because the global surface pH is a function of the atmospheric concentration of carbon dioxide,[107] researchers led by R. Licker,[108] using the Heede data, quantified the contribution of fossil fuel producers to global-scale ocean acidification and found that "emissions traced to the 88 largest industrial carbon producers from 1880–2015 and 1965–2015 have contributed ~55% and ~51%, respectively, of the historical 1880–2015 decline in surface ocean pH. The latter 1965–2015 period, we note, also captures the timeframe in which

---

[99] National Research Council, 2013. Review of the Federal Ocean Acidification Research and Monitoring Plan Committee on the Review of the National Ocean Acidification Research and Monitoring Plan ; Ocean Studies Board ; Division on Earth and Life Sciences ; National Research Council.

[100] https://nca2018.globalchange.gov/chapter/9/ Last accessed 2/12/21

[101] Doney, S. et al., 2014. Ch. 24: Oceans and Marine Resources. In Climate Change Impacts in the United States: The Third National Climate Assessment, pp.557–578.

[102] EPA, Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act 80 (Dec. 7, 2009).

[103] 75 Fed. Reg. 13538 (Mar. 22, 2010).

[104] Richard Heede et al., Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854–2010 Clim. Change.

[105] These producers include investor-owned, state-owned, and nationalized companies.

[106] Ekwurzel B, Boneham J, Dalton M W, Heede R, Mera R J, Allen M R and Frumhoff P C 2017 The rise in global atmospheric CO2, surface temperature, and sea level from emissions traced to major carbon producers Clim. Change 144 579–90.

[107] National Academies of Sciences, Engineering and Medicine 2017 Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide (Washington DC: The National Academies Press).

[108] R. Licker et al, Attributing ocean acidification to major carbon producers

2019 Environ. Res. Lett. **14** 124060. Available at https://iopscience.iop.org/article/10.1088/1748-9326/ab5abc.

the major fossil fuel companies became aware that continued emissions from the intended use of their products imposed significant climate risks on public health and the environment.[109]

Ocean acidification already constitutes an unreasonable, serious and widespread injury to the marine environment. The oceans have absorbed CO_2 emitted into the atmosphere from coal and gas-fueled power plants, industrial facilities, internal combustion engine vehicles, cement production, and stemming from land use changes. From 1850 to 2019, 2,400 gigatons of CO_2 were emitted by human activity.[110] Around 950 (and now, ~ 1000) gigatons remain in the atmosphere,[111] with approximately half of the balance taken up by the oceans and the rest by the land.[112] Indeed, each day about 22 million metric tons of CO_2 is taken up by the oceans.[113] This uptake of CO_2 is changing ocean chemistry, causing the oceans to become more acidic. As we have indicated, since the industrial revolution surface ocean pH has declined by 0.11 units on average, corresponding to a 30% increase in acidity.[114, 115, 116] If emissions continue unabated, ocean acidity will increase up to 170% from pre-industrial levels by the end of the century.[117]

Figure 18 illustrates how the pH in the ocean decreases with increasing atmospheric CO_2 concentration. The time series shows atmospheric CO_2 at Mauna Loa (ppmv) and surface ocean pH and pCO_2 (µatm) at Ocean Station Aloha in the subtropical North Pacific Ocean. The increase in oceanic CO_2 over the period of observations is consistent with the atmospheric increase of CO_2 within the statistical limits of the measurements.[118]

---

109 Benjamin Franta, *Early oil industry knowledge of CO_2 and global warming,* Nat. Clim. Change 8 1024 (2018) available at https://www.nature.com/articles/s41558-018-0349-9.

110 *See* https://www.theworldcounts.com/challenges/climate-change/global-warming/global-co2-emissions/story

111 Available at https://www.theworldcounts.com/challenges/climate-change/global-warming/global-co2-emissions/story (accessed 4/8/21).

112 Rhein, M. et al., 2013. Observations: Ocean. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

113 Feely, R.A. et al., 2008. Evidence for upwelling of corrosive "acidified" water onto the continental shelf. Science, 320 (5882), p.1490.

114 Orr, J. et al., 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature, 437 (7059), pp.681–686.

115 Caldeira, K. & Wickett, M.E., 2005. Ocean model predictions of chemistry changes from carbon dioxide emissions to the atmosphere and ocean. J. Geophys. Res., 110(C9), p.C09S04.

116 Because the pH scale is logarithmic a small decrease is a significant change in acidity; for example, a decrease of 0.1 pH is an approximate 30 percent increase in acidity. Can you refresh my mathematics knowledge of this?

117 IBGP et al., 2013. *Available* at http://www.igbp.net/publications/summariesforpolicymakers/summariesforpolicymakers/oceanacidificationsummaryforpolicymakers2013.5.30566fc6142425d6c9111f4.html.

118 Feely, R.A., Doney, S. & Cooley, S., 2009. Ocean acidification: Present conditions and future changes in a high CO_2 world. Oceanography, 22(4), pp.36–47.

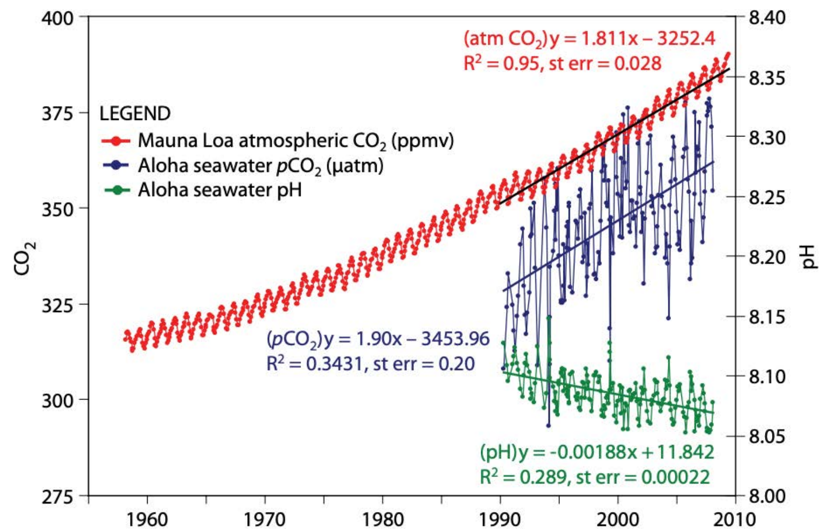


Fig. 18. Time series of atmospheric CO_2 at Mauna Loa (ppmv) and surface ocean pH and pCO_2 (µatm) at Ocean Station Aloha in the subtropical North Pacific Ocean (see inset map).[119]

Anthropogenic ocean acidification exceeds the level of natural variability up to 30 times in some regions.[120] The rate of change in ocean acidity is unprecedented in the past 300 million years, a period that includes four mass extinctions.[121, 122] The seawater chemistry change is an order of magnitude faster than what occurred 55 million years ago during Paleocene-Eocene Thermal (PET) Maximum, which is considered to be the closest analogue to the present. During the PET Maximum period, 96% of marine species went extinct.[123] Regrettably, the current changes in seawater chemistry are irreversible on human timescales.[124]

CO_2 pollution already is changing ocean chemistry and harming the marine environment. Unabated, there will be severe and detrimental impacts on marine ecosystems, the economy, and public health. On the other hand, fossil fuel emissions phaseout coupled with "[a]nthropogenic carbon dioxide removal (CDR) leading to global net negative emissions would lower the atmospheric CO_2 concentration and reverse surface ocean acidification."[125]

In light of their impact on ocean chemistry and associated impacts arising from such acidification, fossil fuel CO_2 emissions and excess atmospheric CO_2 from legacy emissions

---

[119] Feely, R.A., Doney, S. & Cooley, S., 2009. Ocean acidification: Present conditions and future changes in a high CO_2 world. Oceanography, 22(4), pp.36–47. The increase in oceanic CO_2 over the period of observations is consistent with the atmospheric increase within the statistical limits of the measurements.

[120] Friedrich, T., et al. "Detecting regional anthropogenic trends in ocean acidification against natural variability." Nature Climate Change 2.3 (2012): 167-171. https://www.nature.com/articles/nclimate1372

[121] Honisch, B. et al., 2012. The Geological Record of Ocean Acidification. Science, 335(6072), pp.1058–1063.

[122] Zeebe, R., 2012. History of Seawater Carbonate Chemistry , Atmospheric CO_2 , and Ocean Acidification. Annual Review of Earth and Planetary Sciences, (December 2011), pp.141– 165.

[123] Penn, Justin L., et al. "Temperature-dependent hypoxia explains biogeography and severity of end-Permian marine mass extinction." *Science* 362.6419 (2018).

[124] Royal Society, 2005. Ocean acidification due to increasing atmospheric carbon dioxide. *See also* IPCC AR 6 (2021) SPM-28 ("Changes are irreversible on centennial to millennial time scales in global ocean temperature (very high confidence), deep ocean acidification (very high confidence) and deoxygenation (medium confidence)."

[125] IPCC AR6 (2021), SPM-29. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf.

clearly constitute both an unreasonable risk of injury to the environment and health, and also an imminent and unreasonable risk of serious and widespread injury to health of the environment.

(B) Ocean Warming

As climate change warms the Earth, the oceans respond more slowly than land environments.[126] The US National Academy of Science,[127] the Royal Society,[128] 377 members of the National Academy of Sciences, including 30 Nobel laureates,[129] the InterAcademy Partnership,[130] and scientists from around the world have identified increased ocean warming as a threat to marine ecosystems.

As the EPA itself has observed:[131]

> Changes in sea surface temperature can alter marine ecosystems in several ways. For example, variations in ocean temperature can affect what species of plants, animals, and microbes are present in a location, alter migration and breeding patterns, threaten sensitive ocean life such as corals, and change the frequency and intensity of harmful algal blooms such as "red tide" and threaten the ocean's primary producers. Over the long term, increases in sea surface temperature could also reduce the circulation patterns that bring nutrients from the deep sea to surface waters. Changes in reef habitat and nutrient supply could dramatically alter ocean ecosystems and lead to declines in fish populations, which in turn could affect people who depend on fishing for food or jobs.

Perhaps the ocean organism most vulnerable to temperature change is coral. Evidence establishes that reefs will eject their symbiotic algae at even a slight persistent temperature rise. Such "bleaching" slows coral growth, makes them susceptible to disease, and can lead to large-scale reef die-off. EPA has found that coral reefs are "already disappearing due to climate change and other non-climate stressors. Temperature increases and ocean acidification are projected to further reduce coral cover in the future. Without global GHG mitigation, extensive loss of shallow corals is projected by 2050 for major U.S. reef locations."[132]

Other organisms affected by ocean temperature change include krill,[133] an extremely important link at the base of the food chain. Research has shown that krill reproduce in significantly smaller numbers when ocean temperatures rise. This can produce a cascade effect

---

[126] Sejas et al, Environmental Research Letters, Volume 9, Number 12, 2014

[127] Climate Change Evidence & Causes, http://dels.nas.edu/resources/static-assets/exec-office-other/climate-change-full.pdf

[128] *Id.*

[129] An Open Letter Regarding Climate Change From Concerned Members of the U.S. National Academy of Sciences, September, 20, 2016

[130] Cheng, Lijing, et al. "Improved estimates of ocean heat content from 1960 to 2015." Science Advances 3.3 (2017): e1601545.

[131] USEPA "Climate Change Indicators in the United States. Accessed 12/22/2020 https://www.epa.gov/climate-indicators/climate-change-indicators-sea-surface-temperature. Internal citations omitted.

[132] EPA, *Climate Action Benefits: Coral Reefs* (Jan. 19, 2017). EPA Archive Pages.

[133] Flores et al.: Krill and climate change, Mar Ecol Prog Ser 458: 1–19, 2012

by disrupting the life cycle of krill eaters, such as penguins and seals—which in turn causes food shortages for higher predators.

When water heats up, it expands. Thus, the most readily apparent consequence of higher sea temperatures is a rapid rise in sea level, as discussed earlier. Sea level rise causes inundation of coastal habitats for humans as well as plants and animals, shoreline erosion, and more powerful storm surges that can devastate low-lying areas.

As Petitioners also discussed above, we are already seeing the effects of higher ocean temperatures in the form of stronger and more frequent tropical storms and hurricanes/cyclones. Warmer surface water evaporates more, making it easier for small ocean storms to escalate into larger, more powerful systems.[134] [135] These stronger storms increase damage to human structures when they make landfall. They can also harm marine ecosystems like coral reefs and kelp forests.

Warmer sea temperatures are associated with the spread of invasive species and marine diseases. The evolution of a stable marine habitat is dependent upon myriad factors, including water temperature. If an ecosystem becomes warmer, it can create an opportunity where outside species or bacteria, once excluded, can newly thrive, leading to forced migration and even extinction of endemic and specifically-adapted species.

Changes in ocean temperatures and currents brought about by climate change will lead to alterations in climate patterns around the world. For example, warmer waters may promote the development of stronger storms in the tropics, which can cause property damage and loss of life. The impacts associated with sea level rise and stronger storms are especially relevant to coastal communities. Figure 19, from EPA's Climate Change Indicators project, shows the change in ocean heat content. The Agency pointedly noted that, "for reference an increase of 1 unit . . . (1×10^{22} joules) is equal to approximately 17 times the total amount of energy used by all the people on Earth in a year."[136]

[134] de Vries, Hylke, et al. "How Gulf-Stream SST-fronts influence Atlantic winter storms." *Climate Dynamics* 52.9 (2019): 5899-5909.

[135] Zhang, Li, et al. "Decadal coupling between storm tracks and sea surface temperature in the Southern Hemisphere midlatitudes." *Climate Dynamics* 56.3 (2021): 783-798.

[136] EPA, Climate Change Indicators, at https://www.epa.gov/climate-indicators/climate-change-indicators-ocean-heat.

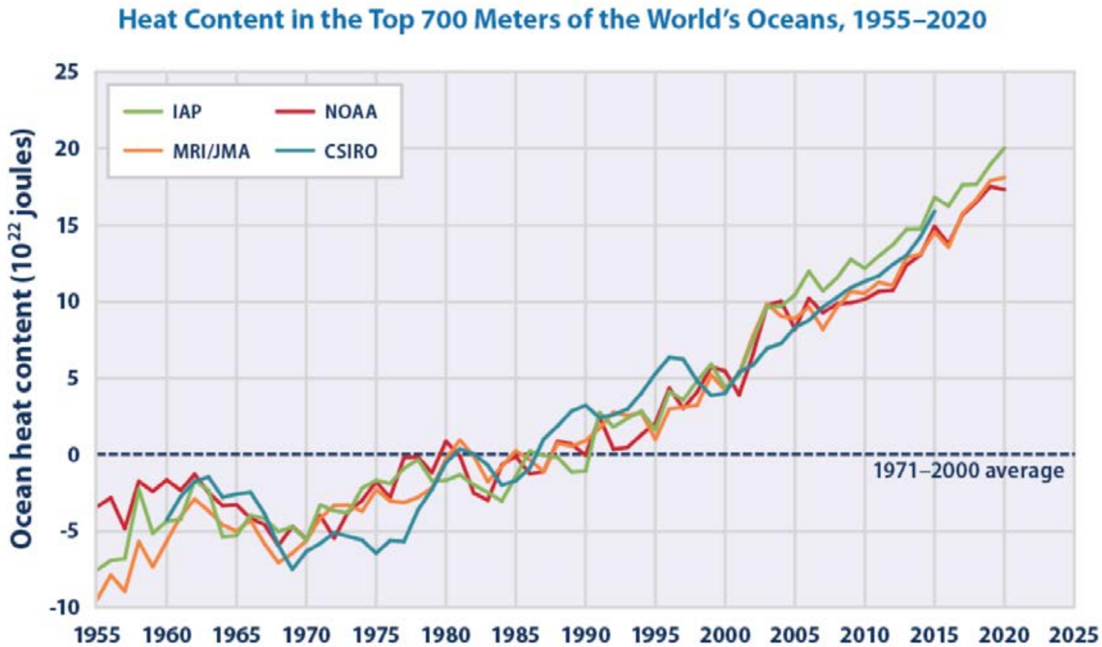


Fig. 19. Source: EPA based on data reported by the United States' National Oceanic and Atmospheric Administration et al.

In addition, recent research suggests that ocean warming is destabilizing ocean floor gas hydrates and inducing seafloor methane leakage.[137]

To reduce ocean temperatures, we must rapidly phase out fossil fuel GHG emissions and remove excess legacy GHGs. In light of their ocean warming impact and the train of impacts arising from such warming, additional fossil fuel emissions and legacy emissions impose both an unreasonable risk of injury to the environment and health as well as an imminent and unreasonable risk of serious or widespread injury to health or the environment.

(C) Ocean deoxygenation

Ocean warming also drives deoxygenation, through solubility and stratification effects. The effect is not merely to coastal waters: "Ocean warming and increased stratification of the upper ocean caused by global climate change will likely lead to declines in dissolved O_2 in the ocean interior, with implications for ocean productivity, nutrient cycling, carbon cycling, and marine habitat."[138]

Dissolved O_2 is essential for aerobic respiration, and low O_2 levels negatively affect the physiology of higher animals. This can lead to suboxic areas or even "dead zones" where many macrofauna are absent. Deoxygenation can also accelerate climate change, rendering it an amplifying climate feedback. Suboxic conditions can cause denitrification in the ocean, increasing production and release of nitrous oxide – a potent, long-lived GHG. In addition, the organic matter respiration that generates hypoxia (lowered-oxygen) also elevates CO_2, thus

[137] M. Ketzer et al., *Gas hydrate dissociation linked to contemporary ocean warming in the southern hemisphere*, Nature Communications (2020) at https://www.nature.com/articles/s41467-020-17289-z.

[138] Jewett, L., and A. Romanou, 2017: Ocean Acidification and Other Ocean Changes. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. Wuebbles, D. J., D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, and T. K. Maycock, Eds., U.S. Global Change Research Program, Washington, DC, USA, 364–392.

leading to coupled deoxygenation and ocean acidification in a future warmer, high-CO_2 world. The synergistic effects of these multiple stressors may amplify the negative physiological and microbial responses beyond the impacts anticipated for each perturbation considered in isolation.

Ocean models predict declines of 1 to 7% in the global ocean O_2 inventory over the next century, with declines continuing for a thousand years or more.[139] An important consequence may be an expansion in the area and volume of so-called "oxygen minimum zones," wherein O_2 levels are too low to support many macrofauna and profound changes in biogeochemical cycling occur.

Ocean deoxygenation is primarily the consequence of two generally reinforcing, but independent, ocean warming processes: (1) oxygen is less soluble as temperature increases and (2) warming waters, as well as decreased surface salinity from ice melt, enhance stratification and thus reduced mixing and transport. The combination reduces the supply of oxygen, and that loss of oxygen from the ocean will cause myriad harmful effects – including a reduction in the habitable range for higher organisms that require a certain minimum level of oxygen. Additional major biogeochemical shifts may be triggered as well.[140]

Significant deoxygenation has occurred over the past 50 years in the North Pacific and tropical oceans, and a convergence of evidence implies further significant changes. Changes in the North Pacific are tied to increased stratification in the subarctic region. O_2 declines are consistent with the predicted response to global warming in global ocean models, and the patterns of observed O_2 change can be reproduced with higher-resolution models driven by observed forcings. The relative rapidity of O_2 decreases in the subarctic Pacific and in coastal upwelling regions off the west coast of North America raises the specter of imminent impacts on marine habitat and fisheries.[141] There is potential for even larger O_2 declines in the future if levels of greenhouse gases in the atmosphere continue to increase.

Falkowski et al. analyzed relatively long-term databases of ocean conditions and found trends of deoxygenation in upwelling areas along continental margins and shoaling of the depths of critical oxygen concentrations. They concluded that even a moderately long-term decline in source-water oxygen and increasing nutrient concentrations will cause currently intermittent but extreme deoxygenation conditions to become more frequent, intense, and persistent, with a potentially profound impact on global fisheries.[142]

---

[139] Keeling, Ralph F., Arne Körtzinger, and Nicolas Gruber. "Ocean deoxygenation in a warming world." Marine Science 2 (2010).

[140] Harvey et al., *Meta-analysis reveals complex marine biological responses to the interactive effects of ocean acidification and warming*, Ecology and Evolution 2013; 3(4): 1016–1030

[141] Keeling et al., Ocean Deoxygenation in a Warming World Annu. Rev. Mar. Sci. 2010. 2:199–229

[142] Falkowski et al., *Eos*, Vol. 92, No. 46, 15 November 2011

Petitioners note, as well, that the number of hypoxic (deoxygenated) ocean ecosystems may be underestimated in modeling by an order of magnitude in the tropics,[143] in part because of the skewed distribution of research capacity with respect to tropical ecosystems.[144]

There is no doubt that deoxygenation is occurring and accelerating.[145] Worldwide shoaling of the upper oxygen minimum zone (OMZ) boundaries has been documented in the eastern boundaries of all major OMZs over the past several decades. In some cases, the lower OMZ boundaries have also shifted to greater depths, and minimum oxygen concentrations in the OMZ cores have also decreased – intensifying the OMZ.[146] Keeling et al.[147] provides tabulations of oxygen declines and volume changes in different OMZs. Whitney et al.[148] provides time-series data that reveal an extensive oxygen decline in the northeast Pacific and a significant expansion of oxygen minimum zones in the tropical and sub topical ocean over the past half century. Using historical data (1960-2015) Santos et al.[149] identifies declines in the thickness and oxygen content of OMZs in the eastern tropical South Atlantic (ETSA) and eastern tropical North Atlantic (ETNA) over a 55-year period.

Long et al.,[150] in a study utilizing the Community Earth System Model (CESM), found that by the 2030s, under RCP8.5 (carbon emission business as usual), widespread loss of oxygen in the thermal layer will be seen. At a global scale, anthropogenic climate change in RCP8.5 drives a sharp acceleration of oceanic deoxygenation in the first half of the 21st century.

Suboxia can control the loss of fixed nitrogen via denitrification and therefore influence the availability of nitrate, a limiting nutrient for ocean productivity.[151,152.] Oxygen levels also control ocean production of N_2O; production can increase under suboxic conditions as a product

143 Laffoley, Dan, and John M. Baxter. Ocean Deoxygenation: Everyone's Problem-Causes, Impacts, Consequences and Solutions. Gland, Switzerland: IUCN, 2019. Available at https://portals.iucn.org/library/sites/library/files/documents/2019-048-En.pdf.

144 Altieri, A.H., Harrison, S.B., Seemann, J., Collin, R., Diaz, R.J., & Knowlton, N. (2017). Tropical dead zones and mass mortalities on coral reefs. Proceedings of the National Academy of Sciences of the United States of America. https://www.pnas.org/content/114/14/3660.

145 IPCC Climate Change 2013: The Physical Science Basis (eds Stocker, T. et al.) (Cambridge Univ. Press, 2013).

146 Gilly et al., Oceanographic and Biological Effects of Shoaling of the Oxygen Minimum Zone, Annual Review of Marine Science, December 2011

147 Keeling et al. Ocean deoxygenation in a warming world.*Annu.Rev.Mar.Sci.* 2:199–229 (2010)

148 Whitney, F. A., Freeland, H. J. & Robert, M. *Prog. Oceanogr.* 75**,** 179–199 (2007).

149 Santos, Guilherme Cordova, et al. "Influence of Antarctic intermediate water on the deoxygenation of the Atlantic Ocean." *Dynamics of Atmospheres and Oceans* 76 (2016): 72-82.

150 Long, Matthew C., Curtis Deutsch, and Taka Ito. "Finding forced trends in oceanic oxygen." Global Biogeochemical Cycles 30.2 (2016): 381-397.

151 Codispoti LA, Brandes JA, Christensen JP, Devol AH, Naqvi SWA, et al. 2001. The oceanic fixed nitrogen and nitrous oxide budgets: Moving targets as we enter the anthropone? Sci. Marina 65:85–105 (revising "the prevailing oceanic N O 2 source term upwards by 2 Tg N yr-1 in our oceanic fixed N budget [] to account for the expan- sion of low oxygen conditions in coastal regions").

152 Gruber N. 2008. The marine nitrogen cycle: Overview of distributions and processes. In

Nitrogen in the marine environment, ed. DG Capone, DA Bronk, MR Mulholland, EJ Carpenter, pp. 1–50. Amsterdam: Elsevier. 2nd ed.

of denitrification.[153] Both of these effects – release of N_2O and limiting primary production (thus slowing the carbon pump) will amplify climate change. A reduction in the nutrient supply to the euphotic layer as a result of increased thermal stratification may also lead to a decreased efficiency of the biological pump in sequestering atmospheric CO_2. The concomitant loss of ocean buffering is another amplifying feedback.[154, 155]

On the other hand, fossil fuel phaseout and removal of excess legacy emissions, as Petitioners here propose, should reduce deoxygenation by more than half of what otherwise will occur from our current trajectory.[156]

In light of their impact on ocean oxygen levels and the train of impacts arising from such ocean deoxygenation, additional fossil fuel CO_2 emissions and legacy CO_2 must be deemed to impose both an unreasonable risk of injury to the environment and health, and also an imminent and unreasonable risk of serious or widespread injury to health or the environment.

(D) Widespread and Synergistic Ocean Risks

Although there is considerable uncertainty about the spatial and temporal details, climate change is clearly and fundamentally altering ocean ecosystems.[157] Further change will continue to impose enormous challenges and costs for societies worldwide, and adversely affect future generations.[158] The effects are widespread throughout the marine food web, impacting ocean biodiversity,[159] with severe effects on top predators,[160] mesopredators,[161] herbivores,[162] as well as

---

153 Codispoti LA, Brandes JA, Christensen JP, Devol AH, Naqvi SWA, et al. 2001. The oceanic fixed nitrogen and nitrous oxide budgets: Moving targets as we enter the anthropocene? Sci. Marina 65:85–105. https://www.academia.edu/47919156/The_oceanic_fixed_nitrogen_and_nitrous_oxide_budgets_Moving_targets_as_we_enter_the_anthropocene.

154 Cermeno et al., The role of nutricline depth in regulating the ocean carbon cycle, PNAS V105 no. 51, 2008.

155 Viviani, Donn A., Spatial Variability in near-surface plankton metabolic rates. Diss. UNIVERSITY OF HAWAI'I.

156 IOC –UNESCO and UNEP (2016). Open Ocean: Status and Trends, Summary for Policy Makers. United Nations Environment Programme (UNEP), Nairobi.

157 Du Pontavice, Hubert, et al. "Climate change undermines the global functioning of marine food webs." *Global change biology* 26.3 (2020): 1306-1318.

158 Ove et al. The Impact of Climate Change on the World's Marine Ecosystems, Science 18 Jun 2010: Vol. 328, Issue 5985, pp. 1523-1528

159 Hillebrand, Helmut, et al. "Climate change: Warming impacts on marine biodiversity." *Handbook on marine environment protection*. Springer, Cham, 2018. 353-373.

160 Rosa, Rui, and Brad A. Seibel. "Synergistic effects of climate-related variables suggest future physiological impairment in a top oceanic predator." Proceedings of the National Academy of Sciences 105.52 (2008): 20776-20780.

161 Flynn et al. Ocean acidification exerts negative effects during warming conditions in a developing Antarctic fish, Oxford Journals, Conservation Physiology Volume 3, Issue 1, 2015

162 Poore et al. Direct and indirect effects of ocean acidification and warming on a marine plant-herbivore interaction. Oecologia. 2013 Nov;173(3):1113-24

substantial impacts to the base of the chain[163] – that is, to primary producers that supply half of our oxygen[164] and serve as engines for our planet's biological carbon pump.

Ocean impacts include warming, decreased ocean productivity, altered food web dynamics, reduced abundance of habitat-forming species, shifting species distributions, and a greater incidence of disease. Recent research demonstrates that a combination of elevated temperature and acidification, both exacerbated by fossil fuel GHG emissions, particularly CO_2 and CH_4, has a synergistic effect on marine life[165] and the ocean.

1. Ocean Warming, Deoxygenation and Acidification's Synergistic Ecosystem Impacts

The full impact of elevated greenhouse gases on marine ecosystems is still being written, but there is high confidence that ecosystem impacts will be sharply negative – as has been established by recent meta-analysis into the multiplicative nature of ocean warming and acidification.[166] Demonstrated and anticipated impacts include loss of diversity,[167] loss of abundance of calcifying species, shifting prey and predator interactions, and loss of suitable habitat. As mentioned above, the synergistic impacts of ocean acidification and warming also stand to amplify climate change. Mesocosm studies found that ocean acidification may amplify global warming through decreasing biogenic production of the marine sulfur component dimethylsulfide, which can impact cloud albedo.[168] Similarly, ocean warming through a number of mechanisms (solubility and density) increases ocean stratification and deoxygenation, resulting in increased nitrous oxide formation and emissions.[169]

In 2011, Nicholas Gruber took a broad-level look at three stressors: ocean warming, acidification and deoxygenation, He found that each of them, unless strong climate mitigation measures are implemented, are bound to have profound effects on marine biogeochemistry and ecosystems, and that situation may be aggravated further if these three stressors act simultaneously.[170] Similarly, in 2010 Anlauf et al. looked at the joint effects of warming and acidification and found that although primary polyp growth was reduced only marginally by

---

[163] Bopp *et al.*, Biogeosciences, 10, 6225–6245, 2013

[164] Field et al, Primary Production of the Biosphere: Integrating Terrestrial and Oceanic Components SCIENCE VOL 281 10 JULY 1998

[165] Cattano, Carlo, et al. "Living in a high CO2 world: a global meta-analysis shows multiple trait-mediated fish responses to ocean acidification." *Ecological Monographs* 88.3 (2018): 320-335.

[166] Kroeker, Karisty J., et al. "Impacts of ocean acidification on marine organisms: quantifying sensitivities and interaction with warming." *Global change biology* 19.6 (2013): 1884-1896.)

[167] Colossi Brustolin, Marco, et al. "Future ocean climate homogenizes communities across habitats through diversity loss and rise of generalist species." *Global change biology* 25.10 (2019): 3539-3548.

[168] Six KD, Kloster S, Ilyina T, Archer SD, Zhang K, et al. 2013. Global warming amplified by reduced sulphur fluxes as a result of ocean acidification. Nature Climate Change.

[169] Keeling *et al.*, Annu. Rev. Mar. Sci. 2010. 2:199–2 29

[170] Gruber built upon the German Advisory Council on Global Change (WBGU)'s report entitled 'The future oceans: warming up, rising high, turning sour'; which summarized what was known at that time (2006) with regard to how the ocean might respond to global warming induced primarily by increases in greenhouse gases.

more acidic seawater, the *combined* effect of high temperature and lowered pH caused a reduction in growth of primary polyps by almost a third.[171]

The latest global coral reef assessment[172] estimated that "large scale coral bleaching events are the greatest disturbance to the world's coral reefs," and that a bleaching event in 1998 alone "killed 8% of the world's coral. Subsequent disturbance events, occurring between 2009 and 2018, killed 14% of the world's coral."[173] Other results suggest that up to 70% of the world's coral reefs may be lost within the next four decades if current trends in climate change and coastal human population growth persist.[174] Major threats to corals include warming sea-surface temperatures,[175] expanding seawater acidification[176] and deoxygenation[177] resulting from GHG emissions.

In 2013, Camilo Mora[178] found that "[o]cean warming and acidification… are causing a new set of conditions that are very close to the tolerance thresholds of corals, making them vulnerable to massive bleaching and mortality when long-term trends related to climate change are added to natural variability." The decay of coral reefs could potentially impair their ability to deliver goods and services such as fisheries and tourism, valued in 1997 at over US $375 billion annually.[179] Likewise, future changes in ocean temperature are expected to cause a redistribution in the global diversity of cetaceans,[180] which in turn could impact local economies that rely on tourism or the take of these species.

Anthony et al.[181] found that the combination of ocean warming and acidification from increasing levels of atmospheric CO_2 threaten coral reefs that are in many regions also subject to local-scale disturbances such as overfishing and conventional pollution.[182] Further, in 2014

---

[171] Anlauf, Holger, Luis D'Croz, and Aaron O'Dea. "A corrosive concoction: the combined effects of ocean warming and acidification on the early growth of a stony coral are multiplicative." Journal of Experimental Marine Biology and Ecology 397.1 (2011): 13-20.

[172] Global Coral Reef Monitoring Network (GCRMN), The Sixth Status of Corals of the World: 2020 Report (October 5, 2021) at https://gcrmn.net/2020-report/.

[173] *Id.* Executive Summary at 19.

[174] Wilkinson, C., 2004. Status of Coral Reefs of the World: 2004. Australian Institute of Marine Science, Townsville, Australia, p. 301.

[175] Hoegh-Guldberg, Ove, et al. "Coral reefs under rapid climate change and ocean acidification." science 318.5857 (2007): 1737-1742.

[176] *Id.*

[177] Alva-Basurto, Jorge Christian, and Jesús Ernesto Arias-González. "Modelling the effects of climate change on a Caribbean coral reef food web." Ecological Modelling 289 (2014): 1-14.

[178] Mora et al., Biotic and Human Vulnerability to Projected Changes in Ocean Biogeochemistry over the 21st Century PLOS Biology, October 2013, Volume 11, Issue 10

[179] Costanza R, d'Arge RC, de Groot R, Farber S, Grasso M, et al. (1997), The value of the world's ecosystem services and natural capital. Nature 387: 253– 261.

[180] Whitehead H, McGill B, Worm B (2008) Diversity of deep-water cetaceans in relation to temperature: implications for ocean warming. Ecology Letters 11: 1198–1207.

[181] Anthony et al. , Ocean acidification and warming will lower coral reef resilience, Global Change biology, Volume 17, Issue 5 May 2011 Pages 1798–1808

[182] *Id.*

Basurto et al.[183] looked at coral bleaching from warming temperatures, the potential decreases in dissolved oxygen concentration (deoxygenation) and pH (acidification) in the oceans. These employed several dynamic models constructed from an extensive database of 171 reef fish species (abundance and biomass) and benthic communities from 13 coral reefs along 400 km of the Mexican Caribbean coast. When all the three sources of stress were combined, their simulations "found a general decrease of biomass in fish, non-fish, and some commercially valuable fish and macroinvertebrate functional groups, suggesting that the combined effects can result in a potential loss of biodiversity and ecosystem services in coral reefs."

Using a probabilistic resilience model (and conservative assumptions) and building on the dynamics of a species pair of corals (Acropora) and fleshy macroalgae (Lobophora), researchers have determined that the effects of ocean acidification and warming on coral growth and mortality will impact coral reef resilience – that is, will lower the threshold at which other, normally occurring, stresses can drive the study community from predominantly coral-dominated to predominantly algal-dominated states, specifically by reducing coral growth (due to acidification) and survivorship (due to warming).[184] Figure 20 illustrates their projection of the bleaching risk over time for the Great Barrier Reef from ocean acidification and temperature.

The researchers concluded that a failure to rapidly stabilize and reduce the concentration of CO_2 in Earth's atmosphere is likely to lead to significant loss of key framework builders such as Acropora, irrespective of the effectiveness of local management.[185]

---

183 Alva-Basurto, Jorge Christian, and Jesús Ernesto Arias-González. "Modelling the effects of climate change on a Caribbean coral reef food web." Ecological Modelling 289 (2014): 1-14.

184 *Id.*

185 Similarly, Harvey et al., in a meta-analysis of 107 peer reviewed articles, containing 623 unique observations, found complex marine biological responses to the interactive effects of ocean acidification and warming. While biological responses varied across taxonomic groups, life-history stages, and trophic levels, combining stressors generally exhibited a stronger biological (either positive or negative) effect. Using a subset of orthogonal studies, they showed that four of five of the biological responses measured (calcification, photosynthesis, reproduction, and survival, but not growth) interacted synergistically, and negatively, when warming and acidification were combined. Harvey et al., *Meta-analysis reveals complex marine biological responses to the interactive effects of ocean acidification and warming*, Ecol Evol. 2013 Apr; 3(4): 1016–1030

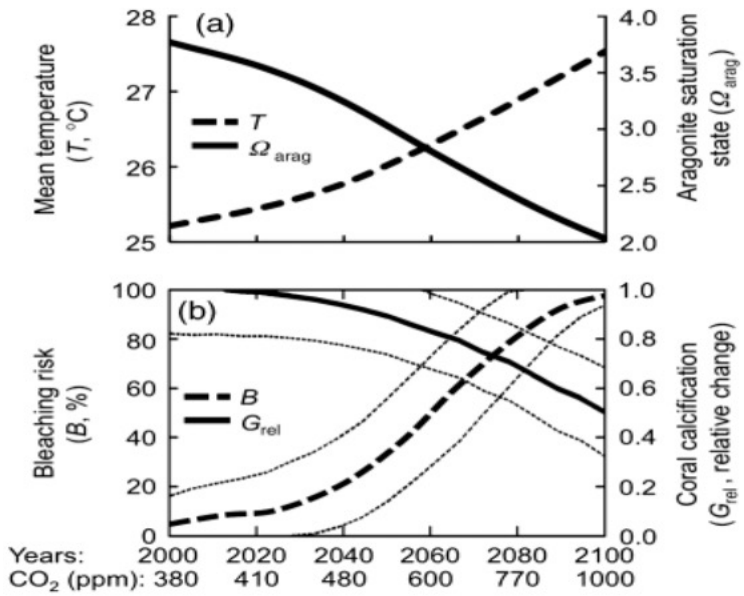


Figure 20[186] Projections of ocean warming and acidification and predicted responses by Acropora for the southern Great Barrier Reef, Australia.[187]

Nagelkerken et al.[188] performed a meta-analysis of 632 published experiments derived from multiple ecosystems and latitudes, that quantified the direction and magnitude of ecological change resulting from ocean acidification and warming. They looked at how these stressors (warming and acidification) affected the interactions between trophic levels and determined that there were important and deleterious mismatches between the trophic levels. As did Harvey, they found primary production by temperate noncalcifying plankton increases with elevated temperature and CO_2, (and tropical plankton decreases productivity because of acidification). Temperature increases consumption by and metabolic rates of herbivores as well, but this response didn't translate into greater secondary production, which instead decreases with acidification in calcifying and noncalcifying species.

This effect creates a mismatch with carnivores whose metabolic and foraging costs increase with temperature. Species diversity and abundances of tropical as well as temperate species decline with acidification, with shifts favoring novel community compositions dominated by noncalcifiers and microorganisms. Both warming and acidification instigate reduced calcification in tropical and temperate reef-building species. Acidification leads to a decline in dimethylsulfide production by ocean plankton which, as a climate gas, contributes to cloud formation and maintenance of the Earth's heat budget. Analysis of responses in short- and long-term experiments and studies at natural CO_2 levels reveal little evidence of acclimation to acidification or the temperature changes, except for microbes. This conceptualization of change

[186] Kenneth RN, et al. "Ocean acidification and warming will lower coral reef resilience." *Global Change Biology* 17.5

[187] (a) Mean sea surface temperatures (T) and aragonite saturation states (Oarag) for the A1FI carbon emission scenario for the southern Coral Sea as estimated by the UVicglobal carbon cycle model. (b) Projected bleaching risk (dashed lines) and projected relative change in coral calcification of Acropora intermedia for the 6-month period (October–March) that includes the Austral summer.

[188] Nagelkerken and Connell, Global alteration of ocean ecosystem functioning due to increasing human CO_2 emissions, PNAS vol. 112 no. 43, 2015.

across whole communities and their trophic linkages forecast a reduction in diversity and abundances of various key species that underpin current functioning of marine ecosystems.

Nagelkerken and Connel[189] observe that ocean acidification and warming are fundamentally changing the globe's largest ecosystem that sustains economic revenue and food for many countries. Their meta-analysis shows that many species and ocean habitats will change from their current states, warning that ocean acidification and warming "increase the potential for an overall simplification of ecosystem structure and function with reduced energy flow among trophic levels and little scope for species to acclimate. The future simplification of our oceans has profound consequences for our current way of life, particularly for coastal populations and those that rely on oceans for food and trade."

Nagelkerken et al.[190] recently simulated the effects of multiple stressors in a mesocosm study and found that the multiple stressors, acidification and warming had a catastrophic effect on the marine food web. The researchers filled 12 pools with 5700 gallons of seawater, put in sand, rocks and a medium for algae to grow, added invertebrates to graze on the algae and a predator fish – a complete food web. They found that CO_2 benefited growth, but that warming nonetheless not only wiped out that benefit but the invertebrate population collapsed. Warm water increased the metabolism of the predator fish, so they ate more, but while there was more algae growth the invertebrates did not grow enough under the new conditions. This mismatch between the availability of food and the need for food was predicted by the earlier meta-analysis.[191]

Pistevos et al.[192] also showed how warming and acidification harms the marine food web. Combining long term laboratory and mesocosm studies with sharks, they found detrimental effects on predators. Elevated CO_2 and acidification amounted to an "anagonistic effect," causing a mismatch by, e.g., higher metabolic demand and decreased ability to locate prey – all of which may have cascading top-down controls over food webs through altered predator-prey relationships.[193]

In 2016, Bednaršek et al.[194] summarized the threats that ocean acidification, warming, and deoxygenation pose to pteropod populations.[195] They suggested that pteropods were most

---

[189] *Id.*

[190] Nagelkerken., et al. "Boosted food web productivity through ocean acidification collapses under warming." Global Change Biology (2017). Available at https://www.researchgate.net/publication/316531707_Boosted_food_web_productivity_through_ocean_acidification_collapses_under_warming.

[191] Nagelkerken Global alteration of ocean ecosystem functioning due to increasing human CO2 emissions, PNAS vol. 112 no. 43, 2015

[192] Pistevos, Jennifer CA, et al. "Ocean acidification and global warming impair shark hunting behaviour and growth." Scientific reports 5 (2015): 16293.

[193] Similarly, *see* Goldenberg, Silvan U., et al. "Boosted food web productivity through ocean acidification collapses under warming." Global Change Biology (2017) and Kroeker et al, Impacts of ocean acidification on marine organisms: quantifying sensitivities and interaction with warming, Glob Chang Biol. 2013 Jun; 19(6): 1884–1896.

[194] Bednaršek, Nina, et al. "Pteropods on the edge: Cumulative effects of ocean acidification, warming, and deoxygenation." Progress in Oceanography 145 (2016): 1-24.

[195] "Pteropods are abundant aragonitic calcifiers, contributing up to 89% of total pelagic calcification. Because of their delicate shells, they are considered "canaries in the coalmine" to indicate impacts of ocean acidification." Peijnenburg

likely to become extinct in the polar oceans, where the entire water column could become undersaturated in aragonite (a naturally occurring crystal form of calcium carbonate ($CaCO_3$) *this century*. Pteropods play an extremely important role in many ocean ecosystems. In the Ross Sea, the pteropod *Limacina helicina* sometimes replaces krill as the dominant zooplankton species in the ecosystem. In many polar and subpolar regions, pteropods are an important food source for a wide range of species, including North Pacific salmon, mackerel, herring, cod, large whales, and other important species that provide food and livelihood. Overall, pteropods are responsible for an estimated 20%– 42% of total carbonate production in the ocean,[196] so the aragonite undersaturation risk to the marine carbon pump (the ocean's biologically-driven sequestration of carbon) is enormous.

The Southern Ocean (SO), covering about 34.8 million km^2, will be one of the first and most severely affected regions from ocean acidification (OA) due to naturally low levels of $CaCO_3$. It is estimated that under the current trajectory much of the SO will be unsaturated in aragonite within two or three decades,[197] and it is expected that the seawater of the entire Southern Ocean south of 60° S and a part of the subarctic Pacific will become unsaturated with aragonite by 2100.[198] A recent meta-analysis found that many primary calcifiers are extremely vulnerable to acidification and warming (Figure 18), and that their shells would be thermodynamically predisposed to dissolve rather than form. This could eventually collapse the marine food web and induce major alterations in the biogeochemical cycle of carbon.[199]

---

et al., The origin and diversification of pteropods precede past perturbations in the Earth's carbon cycle, PNAS, Sept. 24, 2020 at https://www.pnas.org/doi/10.1073/pnas.1920918117.

196 Bednaršek N., Možina J, Vogt M, O'Brien C, Tarling GA. 2012. The global distribution of pteropods and their contribution to carbonate and carbon biomass in the modern ocean. Earth Systems Science Data 4: 167–186.

197 Hossain, M. Belal, and Mahabubur Rahman. "Ocean Acidification: an impending disaster to benthic shelled invertebrates and ecosystem." *Journal of Noakhali Science and Technology University (JNSTU)* 1.1 (2017): 19-30.

198 Kuroyanagi, Azumi, et al. "Decrease in volume and density of foraminiferal shells with progressing ocean acidification." *Scientific reports* 11.1 (2021): 1-7.

199 Figuerola, Blanca, et al. "A review and meta-analysis of potential impacts of ocean acidification on marine calcifiers from the Southern Ocean." *Frontiers in Marine Science* 8 (2021): 24.

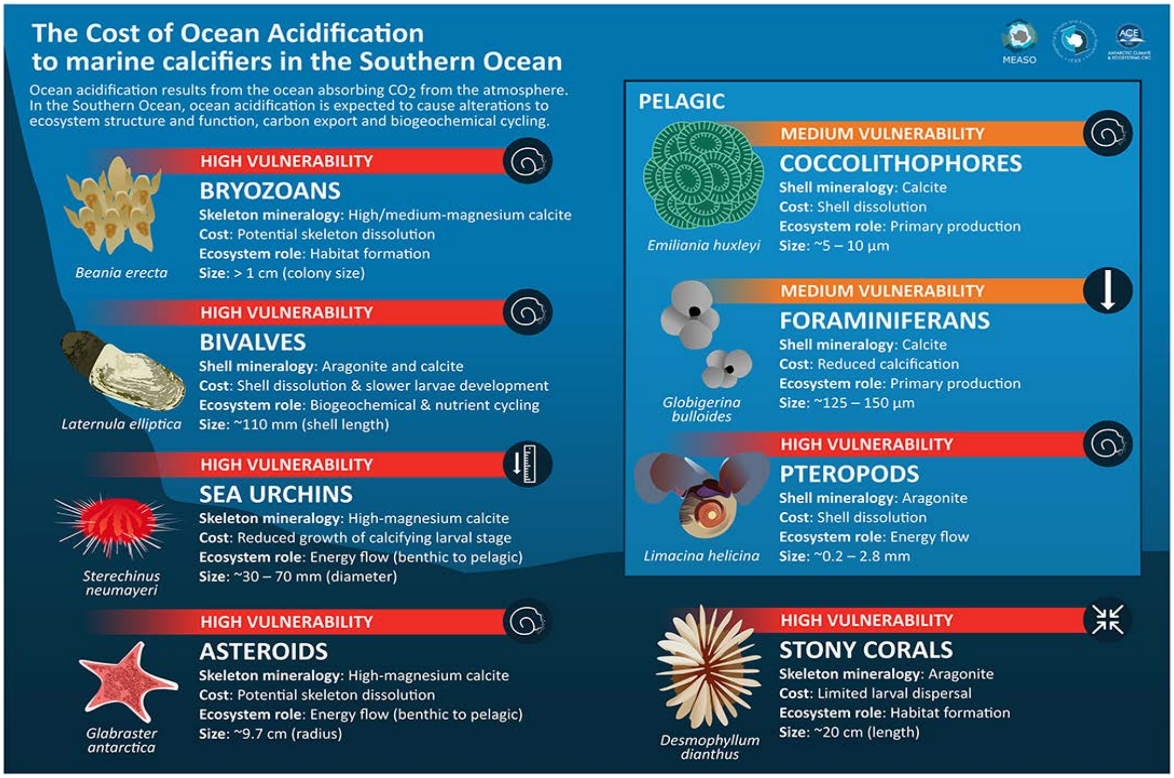


Figure 21: Vulnerability of Marine Calcifiers to Ocean Acidification[200]

2. Additional Ocean Impacts

Climate change is rendering certain ocean waters more conducive to waterborne pathogens. In particular, inland and coastal warming is accelerating the release of dissolved organic matter (DOM) through increases in precipitation, thawing of permafrost, and changes in vegetation. The selective absorption of ultraviolet radiation (UV) by DOM can decrease the valuable ecosystem service provided by sunlight inactivation of waterborne pathogens. Additional warming thus threatens increased exposure to infectious diseases in humans, through drinking water and other exposures, as well as to wildlife.[201]

200 *Id.*

201 Williamson, Craig E., et al. "Climate change-induced increases in precipitation are reducing the potential for solar ultraviolet radiation to inactivate pathogens in surface waters." *Scientific Reports* 7.1 (2017): 1-12.

VIII. Air Quality

In a later section, Petitioners touch on some of the direct health benefits deriving from a phaseout of fossil fuels. We summarize here, however, recent evidence of excess death that is a direct consequence of fossil fuel utilization.

In particular, in 2021, leading academic researchers established that the total global annual burden of premature deaths due to particulate pollution from fossil fuel combustion was ~10.2 million in 2012.[202] For persons over the age of 14, these included an estimated 483,000 premature deaths in North America, 187,000 deaths in South America, 1,447,000 deaths in Europe, 7,916,000 deaths in Asia, and 194,000 deaths in Africa.[203]

The same researchers also estimated "mortality due to lower respiratory infections (LRI) among children under the age of five in the Americas and Europe" and calculated that an estimated 876 such children in North America, 747 in South America, and 605 in Europe died from fossil fuel-induced LRI in 2012 alone.[204]

The researchers advised that their study "demonstrates that the fossil fuel component of PM2.5 contributes a large mortality burden. The steeper concentration-response function slope [that they found] at lower concentrations leads to larger estimates than previously found in Europe and North America, and the slower drop-off in slope at higher concentrations results in larger estimates in Asia. Fossil fuel combustion can be more readily controlled than other sources and precursors of PM2.5 such as dust or wildfire smoke, so this is a clear message to policymaker and stakeholders to further incentivize a shift to clean sources of energy."

---

[202] KarnVohra et al., Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: Results from GEOS-Chem, Environmental Research, Volume 195, April 2021, 110754, at https://www.sciencedirect.com/science/article/abs/pii/S0013935121000487#!.

[203] *Id.*

[204] *See also*, Fuller, Pollution and health: a progress update, The Lancet Planetary Health, May 17, 2022DOI:https://doi.org/10.1016/S2542-5196(22)00090-0 (finding that "pollution remains responsible for approximately 9 million deaths per year, corresponding to one in six deaths worldwide. . . [D]eaths from household air pollution and water pollution are offset by increased deaths attributable to ambient air pollution and toxic chemical pollution (ie, lead). Deaths from these modern pollution risk factors, which are the unintended consequence of industrialisation and urbanisation, have risen by 7% since 2015 and by over 66% since 2000. Despite ongoing efforts by UN agencies, committed groups, committed individuals, and some national governments (mostly in high-income countries), little real progress against pollution can be identified overall, particularly in the low-income and middle-income countries, where pollution is most severe. Urgent attention is needed to control pollution and prevent pollution-related disease, with an emphasis on air pollution and lead poisoning, and a stronger focus on hazardous chemical pollution. Pollution, climate change, and biodiversity loss are closely linked. Successful control of these conjoined threats requires a globally supported, formal science–policy interface to inform intervention, influence research, and guide funding. Pollution has typically been viewed as a local issue to be addressed through subnational and national regulation or, occasionally, using regional policy in higher-income countries. Now, however, it is increasingly clear that pollution is a planetary threat, and that its drivers, its dispersion, and its effects on health transcend local boundaries and demand a global response. Global action on all major modern pollutants is needed.").

XI. Risk Reduction Methods

There are several ways to mitigate risk from CO_2 and CH_4. EPA should use a suite of tools to lower atmospheric concentrations of CO_2 and CH_4, including by the timely phaseout of fossil fuels, removing and sequestering CO_2 (including compelling such sequestration, or payment to ensure sequestration, by responsible parties) along with other GHGs so as to mitigate and repair, to the degree possible, additional injury to health and the environment.

There is evidence that many industries could employ existing technology to achieve meaningful emissions reductions affordably. EPA's own data demonstrate that lower pollution rates are readily achievable for many industrial sources of CO_2 and CH_4. For example, the Agency has identified dozens of "control measures and energy efficiency options that are currently available for pulp and paper mill processes," ranging from technological upgrades to improved equipment maintenance.[205] Similarly, EPA has compiled more than a decade of reports on "cost-effective" control strategies and other approaches available to reduce cement plant CO_2 emissions, "includ[ing], for example, energy efficiency measures, reductions in cement clinker content, and raw materials substitution."[206] EPA also has a number of voluntary programs to reduce methane emissions. These could be made compulsory or incentivized.[207]

In 2017, the non-profit Project Drawdown[208] laid out a comprehensive plan to reverse global warming in thirty years using only solutions currently in place. The diverse group of international researchers,[209] modeled the 100 most substantive, existing solutions to address climate change. Their research shows a pathway,[210] using currently available technology, from 2020 to 2050 that reduces CO_2-eq emissions by 1050 GT.[211] Benefits and savings estimated from implementation of this strategy far outweigh costs. Project Drawdown has since developed two scenarios[212] to assess what global efforts to address climate change might look like. Both scenarios are plausible and economically realistic. Drawdown Scenario 1 is roughly in-line with 2˚C temperature rise by 2100, while Drawdown Scenario 2 is roughly in-line with 1.5˚C temperature rise at century's end. The first removes 998 Gigatons CO_2 Equivalent while the second removes 1,576 Gigatons CO_2 Equivalent.

The potential for so-called "natural climate solutions" (NCS) – reforestation, improved forest management, and improvement in agriculture and soils management – holds special attraction for their availability, in theory, not only to safely sequester a portion of excess

---

205 *See* EPA, Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from the Pulp and Paper Industry at 11 (2010).

206 EPA, National Emission Standards for Hazardous Air Pollutants From the Portland Cement Manufacturing Industry and Standards of Performance for Portland Cement Plants, 75 Fed. Reg. 54,970, 54,997 (Sep. 9, 2010).

207 https://www.epa.gov/natural-gas-star-program

208 Drawdown, Ed. Paul Hawken, Penquin Books, 2017

209 http://www.drawdown.org/advisors,

210 http://www.drawdown.org/solutions-summary-by-rank

211 The change in CO2-EQ, cost and benefits is the marginal difference between a reference case that assumes 2014 levels of adoption continue in proportion to the growth in global markets.

212 https://drawdown.org/solutions/table-of-solutions

atmospheric CO_2 but also for the co-benefits they promise – including with respect to ecosystem and hydrologic restoration. In 2017, an international team published a comprehensive review of the potential, nation by nation, for such natural atmospheric carbon removal.[213] Petitioners graphically depict the potential of the top 20 of them in Figure 19, below.

The potential varies widely depending on a nation's land area, present conditions of its forests, lands and soils, latitude, and other factors. A fossil-fuel company's payments to remove its share of legacy GHG emissions generated in or connected to its US operations in theory could pay for verified, effective natural climate solutions projects located outside the United States. But any associated credit generated towards such an emitter's carbon removal obligation would need to be adjusted for the level of permanency and risk inhering in such projects.

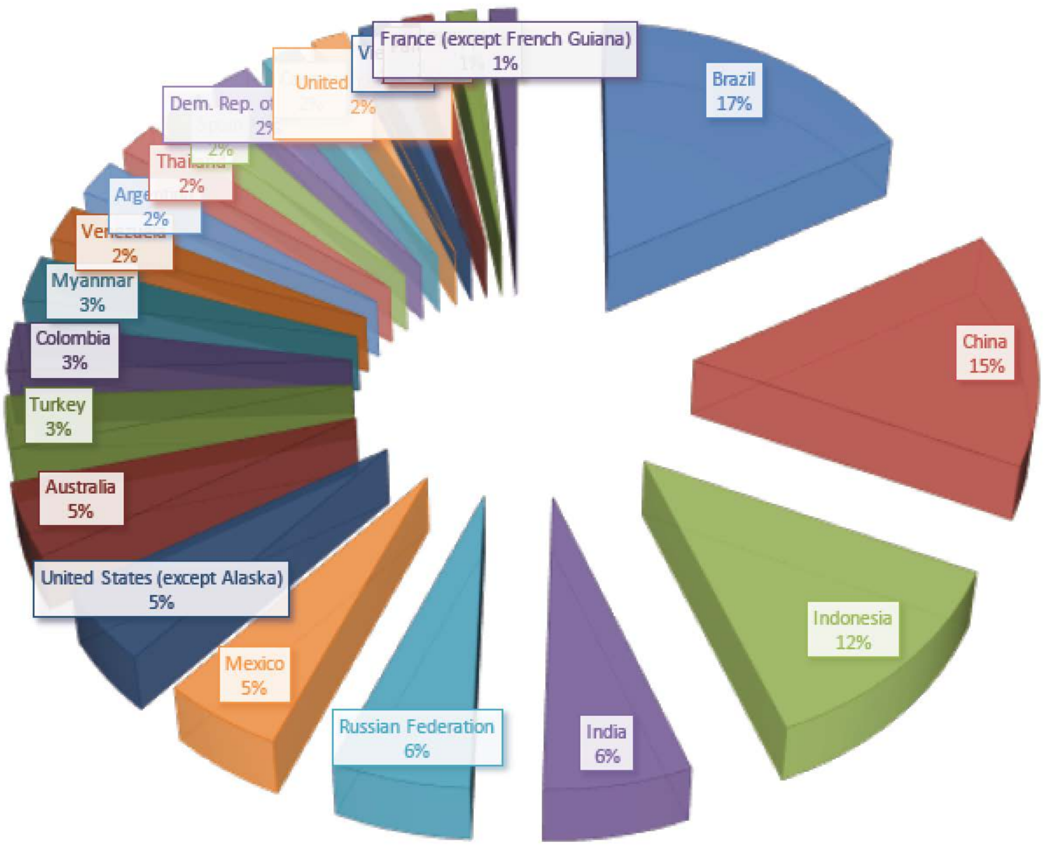


Fig. 22: Calculations and graphics by the Law Office of Daniel M Galpern.

[213] Griscom et al., *Natural Climate Solutions*, PSAS (2017) at www.pnas.org/content/114/44/11645.

A recent article in *Science Advances*[214] quantified the potential of natural climate solutions to increase carbon storage and avoid GHG emissions in the United States. They found a maximum potential of 1.2 (0.9 to 1.6) Gt CO_2 eq y^{-1}, the equivalent of 21% of current net annual emissions of the United States. At current carbon market prices (US $10 per Mg CO_2 eq), 0.3 Gt CO_2 eq y^{-1} could be achieved. NCS would also provide air and water filtration, flood control, soil health, wildlife habitat, and climate resilience benefits.

Although cost-effective strategies to reduce CO_2 and CH_4 emissions are available, existing controls have not reduced CO_2 and CH_4 emissions sufficiently to protect against environmental harm. For example, most natural gas power plants have *never* exceeded the agency's recently proposed emissions limit, thus indicating that existing and newly constructed facilities could easily satisfy a more stringent standard.[215] Because energy-related CO_2 and CH_4 pollution accounts for more than eighty percent of U.S. GHG production, readily achievable reductions in this sector would significantly benefit the environment.[216] Similarly, the pulp and paper industry ranks among the largest consumers of energy,[217] and emitted nearly 58 million metric tons of CO_2 equivalent gases in 2004.[218]

Moreover, market incentives and regulatory controls are effective in increasing the rate of innovation for technologies that can reduce CO_2 and CH_4 emissions. Federal programs aimed at consumers also can reduce CO_2 and CH_4 emissions. For example, EPA's Energy Star program has prevented 1.8 Gt of GHG emissions by providing information that helps customers select energy efficient devices. Sequestration of CO_2 in products, infrastructure, and waste management are among numerous methods that could be cost-effective to mitigate CO_2 and CH_4 pollution. Providing solar cooking ovens or stoves to replace coal burning ones in countries where this is a predominate cooking "appliance" would substantially reduce emissions. Reducing coal use and achieving the health, albedo and other benefits of reducing black carbon would also be useful.

If a chemical presenting an unreasonable risk to health and the environment has already been distributed, EPA may prescribe procedures by which relevant manufacturers and purchasers must replace or repurchase that chemical.[219] In addition, EPA is authorized to prohibit or otherwise restrict any continuing disposal of CO_2 and CH_4 by its manufacturer, processor or other person.[220] In the present situation, we urge the agency to exercise its authority to remediate existing harm by requiring that responsible parties either remove residual or legacy CO_2 and CH_4 emissions or pay into a carbon removal fund sufficient for that to be done.

---

[214] Fargione, Joseph E., et al. "Natural climate solutions for the United States." *Science Advances* 4.11 (2018): eaat1869.

[215] Ctr. for Biological Diversity, Comments on Standards of Performance for Greenhouse Gas Emissions from New Stationary Sources: Electric Utility Generating Units (Proposed Rule) Docket No. EPA-HQ-OAR-2013-0495 at 1314 (May 9, 2014).

[216] U.S. Dept. of State, U.S. Climate Action Report at 16 (2010).

[217] *See* U.S. Energy Information Administration, First Use of Energy for All Purposes (Fuel and Nonfuel), 2010 (Mar. 2013), http://www.eia.gov/consumption/manufacturing/data/2010/#r1.

[218] EPA, Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from the Pulp and Paper Industry at 7 (2010).

[219] 15 U.S.C. § 2605(a)(7)(C).

[220] 15 U.S.C. § 2605(a)(6)(A).

There are numerous approaches to sequestering CO_2 and CH_4. Effective land use and agricultural practices can significantly reduce CO_2 and CH_4 emissions and sequester CO_2, as mentioned above with respect to our discussion of natural climate solutions to sequester CO_2.

As for methane, near-source destruction methods may be employed to destroy fugitive methane from the fossil fuel industry, such as aggregating and destroying fugitive emissions from coal mines.[221] Methods of destroying less concentrated methane are also being researched and developed. Promising methane removal methods that, at least in "[d]esk and laboratory studies," appear to mimic natural removal processes, may prove to be viable – for example, iron salt aerosols employed to enhance natural sinks and remove CH_4 as well as CO_2.[222] If trials and subsequent assessments of methane removal prove its feasibility,[223] then EPA could require oil, gas, and coal producers to pay for their utilization to remove excess atmospheric methane, as well as its CO_2 remainder.

Methods of removing ambient CO_2 also are being researched and developed, including with the Agency's support. Petitioners deem it critical that the Agency evaluate progress in this area continuously to discern the efficiency and effectiveness of methods. Particularly in light of the long atmospheric residence time of CO_2, as discussed *supra*, [224] the full potential "to remove CO_2 from the atmosphere and durably store it in reservoirs" must be pursued in order to "compensate for residual emissions [and] if implemented at a scale where anthropogenic removals exceed anthropogenic emissions, to lower surface temperature."[225]

However, while "[t]he cooling (or avoided warming) due to CDR might be proportional to the cumulative amount of CO_2 removed from the atmosphere by CDR,"[226] CO_2 emissions and removal efforts are not perfectly symmetric. This is so, according to the IPCC, because "the fraction of CO_2 remaining in the atmosphere after an emission is larger than the fraction of CO_2 remaining out of the atmosphere after a removal."[227] This implies that, all other things being equal, it is preferable to avoid an emission than to remove it later. For this and other reasons, Petitioners strongly endorse a recent admonition from the Department of Energy's Office of Fossil Energy and Carbon Management, namely that "it is imperative that Carbon Capture and Storage and Carbon Dioxide Removal technologies are not used as mechanisms to continue

---

221 https://verra.org/methodology/vm0014-interception-and-destruction-of-fugitive-methane-from-coal-bed-methane-cbm-seeps-v1-0/

222 Ming, Tingzhen, et al. "A nature-based negative emissions technology able to remove atmospheric methane and other greenhouse gases." *Atmospheric Pollution Research* (2021).

223 In its recently-released AR6 Working Group I report, the IPCC stated, "Methane removal is, however, still in its infancy and the available literature is insufficient for an assessment." We note, however, that "the cut-off date for scientific literature to be included in the contribution to the Sixth Assessment Report (AR6) of Working Group I" was January 31, 2021. *See* https://www.ipcc.ch/2020/05/29/ipcc-extends-working-group-i-literature-cut-off-date-postpones-final-lead-author-meeting/. At minimum, a number of leading scientists have since that time attempted to forge a research agenda aimed at systematically assessing the potential for promising atmospheric methane removal. *See* Jackson RB et al. 2021 Atmospheric methane removal: a research agenda. Phil. Trans. R. Soc. A 379: 20200454 (May 20, 2021) available at https://doi.org/10.1098/rsta.2020.0454.

224 *Op-cit* nte 68.

225 IPCC AR6, SPM-39.

226 *Id.*

227 *Id.* at §5.6.2.1.4.

burning fossil fuels, but instead as tools in an overall strategy to achieve deep decarbonization."[228]

The IPCC recently reviewed the effects of specific CDR methods on biogeochemical cycles and climate.[229] The methods include "afforestation, soil carbon sequestration, bioenergy with carbon capture and storage, wetland restoration, ocean fertilization, ocean alkalinization, enhanced terrestrial weathering and direct air capture and storage."[230] In its March 2022 report on Mitigation of Climate Change, the IPCC's Working Group III evaluated and discussed the potential of different CDR options in terms of the amount of CO_2 removed per year from the atmosphere, costs, risks and impacts, tradeoffs, and potential role in various mitigation pathways. Petitioners here reprint that report's Table TS.7, in which the IPCC neatly summarizes its most current assessment of CDR methods.[231]

Table TS.7: Summary of status, costs, potentials, risk and impacts, co-benefits, trade-offs and spill over effects and the role in mitigation pathways for CDR methods {12.3.2, 7.4} TRL = Technology Readiness Level

CDR option	Status (TRL)	Cost (USD tCO_2^{-1})	Mitigation Potential ($GtCO_2\ yr^{-1}$)	Risk and Impacts	Co-benefits	Trade-offs and spill over effects	Role in mitigation pathways	Section
Afforestation/Reforestation	(8-9)	0-240	0.5-10	Reversal of carbon removal through wildfire, disease, pests may occur. Reduced catchment water yield and lower groundwater level if species and biome are inappropriate.	Enhanced employment and local livelihoods, improved biodiversity, improved renewable wood products provision, soil carbon and nutrient cycling. Possibly less pressure on primary forest.	Inappropriate deployment at large scale can lead to competition for land with biodiversity conservation and food production.	Substantial contribution in IAMs and also in bottom-up sectoral studies.	{7.4}
Soil Carbon Sequestration in croplands and grasslands	(8-9)	45-100	0.6-9.3	Risk of increased nitrous oxide emissions due to higher levels of organic nitrogen in the soil; risk of reversal of carbon sequestration.	Improved soil quality, resilience and agricultural productivity.	Attempts to increase carbon sequestration potential at the expense of production. Net addition per hectare is very small; hard to monitor.	In development – not yet in global mitigation pathways simulated by IAMs in bottom-up studies: with medium contribution.	{7.4}
Peatland and coastal wetland restoration	(8-9)	Insufficient data	0.5-2.1	Reversal of carbon removal in drought or future disturbance. Risk of increased CH_4 emissions.	Enhanced employment and local livelihoods, increased productivity of fisheries, improved biodiversity, soil carbon and nutrient cycling.	Competition for land for food production on some peatlands used for food production.	Not in IAMs but some bottom-up studies with medium contribution.	{7.4}
Agroforestry	(8-9)	Insufficient data	0.3-9.4	Risk that some land area lost from food production; requires very high skills.	Enhanced employment and local livelihoods, variety of products improved soil quality, more resilient systems.	Some trade off with agricultural crop production, but enhanced biodiversity, and resilience of system.	No data from IAMs, but in bottom-up sectoral studies with medium contribution.	{7.4}
Improved Forest management	(8-9)	Insufficient data	0.1-2.1	If improved management is understood as merely intensification involving increased fertiliser use and introduced species, then it could reduce biodiversity and increase eutrophication.	In case of sustainable forest management, it leads to enhanced employment and local livelihoods, enhanced biodiversity, improved productivity.	If it involves increased fertiliser use and introduced species it could reduce biodiversity and increase eutrophication and upstream GHG emissions.	No data from IAMs, but in bottom-up sectoral studies with medium contribution.	{7.4}
Biochar	(6-7)	10-345	0.3-6.6	Particulate and GHG emissions from production; biodiversity and carbon stock loss from unsustainable biomass harvest.	Increased crop yields and reduced non-CO_2 emissions from soil; and resilience to drought.	Environmental impacts associated particulate matter; competition for biomass resource.	In development – not yet in global mitigation pathways simulated by IAMs.	{7.4}
DACCS	6	100-300 (84–386)	5-40	Increased energy and water use.	Water produced (solid sorbent DAC designs only).	Potentially increased emissions from water supply and energy generation.	In a few IAMs; DACCS complements other CDR methods.	{12.3}
BECCS	(5-6)	15-400	0.5-11	Inappropriate deployment at very large- scale leads to additional land and water use to grow biomass feedstock. Biodiversity and carbon stock loss if from unsustainable biomass harvest.	Reduction of air pollutants; fuel security, optimal use of residues, additional income, health benefits and if implemented well can enhance biodiversity.	Competition for land with biodiversity conservation and food production.	Substantial contribution in IAMs and bottom -up sectoral studies. Note-mitigation through avoided GHG emissions resulting from the bioenergy use is of the same magnitude as	{7.4}

[228] Office of Fossil Energy and Carbon Management, *DOE's Office of Fossil Energy and Carbon Management Makes Historic Shift to Center Work on Climate Change* (Dec. 6, 2021) available at https://www.energy.gov/fecm/articles/does-office-fossil-energy-and-carbon-management-makes-historic-shift-center-work

[229] IPCC AR6 WGI Report: Physical Science Basis, at §5.6.2.2.

[230] *Id.* at §4.6.3.2 and §5.6.2.2.

[231] As the diagonal watermark denotes, this displayed table and other sections of the IPCC WGIII report (outside of its Summary for Policymakers) have been accepted for publication but, at this writing, May 26, 2022, remain "subject to final edits."

CDR option	Status (TRL)	Cost (USD tCO_2^{-1})	Mitigation Potential ($GtCO_2$ yr^{-1})	Risk and Impacts	Co-benefits	Trade-offs and spill over effects	Role in mitigation pathways	Section
							the mitigation from CDR (TS.5.6).	
Enhanced weathering	3-4	50-200 (24-578)	2-4 (<1-95)	Mining impacts; air quality impacts of rock dust when spreading on soil.	Enhanced plant growth, reduced erosion, enhanced soil carbon, reduced pH, soil water retention.	Potentially increased emissions from water supply and energy generation.	In a few IAMs; EW complements other CDR methods.	{12.3}
"Blue carbon" in coastal wetlands	2-3	Insufficient data	<1	If degraded or lost, coastal blue carbon ecosystems are expected to release most of their carbon back to the atmosphere; potential for sediment contaminants, toxicity, bioaccumulation and biomagnification in organisms; issues related to altering degradability of coastal plants; use of subtidal areas for tidal wetland carbon removal; effect of shoreline modifications on sediment redeposition and natural marsh accretion; abusive use of coastal blue carbon as means to reclaim land for purposes that degrade capacity for carbon removal.	Provide many non-climatic benefits and can contribute to ecosystem-based adaptation, coastal protection, increased biodiversity, reduced upper ocean acidification; could potentially benefit human nutrition or produce fertiliser for terrestrial agriculture, anti-methanogenic feed additive, or as an industrial or materials feedstock.		Not incorporated in IAMs, but in some bottom-up studies: small contribution.	{7.4, 12.3.1}
Ocean fertilisation	1-2	50-500	1-3	Nutrient redistribution, restructuring of the ecosystem, enhanced oxygen consumption and acidification in deeper waters, potential for decadal-to-millennial-scale return to the atmosphere of nearly all the extra carbon removed, risks of unintended side effects.	Increased productivity and fisheries, reduced upper ocean acidification.	Subsurface ocean acidification, deoxygenation; altered meridional supply of macro-nutrients as they are utilised in the iron-fertilised region and become unavailable for transport to, and utilisation in other regions, fundamental alteration of food webs, biodiversity.	No data.	{12.3.1}
Ocean alkalinity enhancement	1-2	40–260	1–100	Increased seawater pH and saturation states and may impact marine biota. Possible release of nutritive or toxic elements and compounds. Mining impacts.	Limiting ocean acidification.	Potentially increased emissions of CO_2 and dust from mining, transport and deployment operations.	No data.	{12.3.1}

Range based on authors' estimates (as assessed from literature) are shown, with full literature ranges shown in brackets

Petitioners suggest that in addition to any missing and necessary information concerning the science of ocean warming, deoxygenation and acidification, the Agency must work together with the Department of Energy and others to undertake any required additional testing of emissions reduction and sequestration processes and technologies. If information on the efficacy of removal and sequestration technologies is inadequate, Petitioners recommend that the Agency utilize its authorities under TSCA §4, 15 USC §2603. The Agency has in the past required TSCA test rules for many chemicals already released and in the environment in high volumes (such as dyes, plasticizers, flame retardants) to determine if treatment/mitigation methods (for example aerobic digestion) are sufficient to reduce the risk to human health and the environment to a reasonable level. [232] Treatment/mitigation methods to control CO_2 and CH_4 after release are analogous to those test rules. Any such Agency assessment should evaluate the efficiency and cost of sequestration technology and methods to treat/mitigate released CO_2 and CH_4. Costs for any such testing (and for remedies under §§ 2605 or 2608) should be apportioned among CO_2 and CH_4 emission contributors according to the cumulative CO_2 emission inventory information the Agency has collected. This could be structured in a manner similar to the sponsorship format used in TSCA's High Production Volume (HPV) Program (a more complex format than for GHGs, the Program covered thousands of chemicals and thousands of tests from both foreign and domestic sources).

Since any carbon emissions that result from sequestration actions must be subtracted to calculate net carbon sequestration, the Agency should in particular examine options that rely (completely or substantially) on non-fossil fuel energy, such as biosequestration relying on solar, wind, geothermal and nuclear power.

In the view of Petitioners, CDR methods that offer substantial ecological or agricultural co-benefits merit the Agency's special attention. By increasing their process area, volume, or efficiency, naturally occurring processes may sequester gigatons of carbon. For example, grass pastures can build soil carbon slowly through microbial processes. Legume-based pastures that

[232] See, for example: Certain Polybrominated Diphenylethers; Federal Register / Vol. 77, No. 63 / Monday, April 2, 2012 / Proposed Rules

fix nitrogen and drive higher biomass production of associated grasses may ensure a more rapid carbon accretion.[233] Marginal lands may be managed to trap a ton of carbon per hectare a year with proper management.[234] Enhanced soil carbon is beneficial not only for its increased productivity, but also because it enables greater infiltration and retention of rainfall, and this compensates for expected increases in temperature and more uncertain rainfall. In the oceans, microalgae can be fertilized to sequester carbon, and then removed/ harvested for products. For example, the nutritional value of micro algae,[235] and its potential as a biodiesel source,[236] have been extensively researched. Petitioners suggest that ancillary benefits like these should be accounted for in assessing net sequestration benefits, as is required to provide a complete analysis by OMB and Agency economic and regulatory guidelines.

Recently, the World Bank investigated the capacity of different agricultural land use management practices to sequester carbon. Biomass, especially in soils, sequesters atmospheric carbon, and this role as a carbon sink and carbon store can be strategically optimized through proven farming techniques and methods that simultaneously reduce emissions. These technical elements of climate-smart agriculture are well understood, and in addition to their technical feasibility they can be highly productive and profitable. In its report, the World Bank authors estimated there to be an enormous capacity of agriculture to sequester carbon and in turn provide markets to repurchase legacy carbon, yielding negative emissions options. Looking at different scenarios that are based on different levels of international integration and ecological concern, the employment of land use and management techniques in Asia, Africa and Latin America could sequester between 12 and 18 Gt of carbon, with net positive welfare benefits of between 1.4 and 1.6 trillion dollars by 2030.[237] Lal et al.[238] in particular have estimated that soil carbon has the potential to offset fossil-fuel emissions by 0.4 to 1.2 Gt C/ year, or 5 to 15% of the global emissions. Soil organic carbon is an extremely valuable natural resource and has many ancillary benefits including food security and watershed protection. These benefits should be considered in any carbon management regulatory option that includes trading soil C. This is another option for legacy carbon emission buy-back.

---

[233] Dalal, RC, Strong, WM, Weston, EJ, Cooper, JE, Lehane, KJ, King, AJ, Chicken, CJ (1995). Australian Journal of Experimental Agriculture, **35**

[234] Project Drawdown estimates Carbon sequestration rates of 1.3 tons per hectare per year, based on meta-analysis of 31 data points from four sources.

[235] FAO Fisheries Technical Paper 361

[236] NREL/TP-580-24190

[237] Carbon Sequestration in Agricultural Soils, The World Bank, REPORT NO. 67395-GLB, 2012

[238] Lal, Rattan. "Soil carbon sequestration impacts on global climate change and food security." science 304.5677 (2004): 1623-1627.

More aggressively, it has been proposed that lignin rich crops, which sequester carbon refractorially, might be used directly as a soil amendment to enrich and provide carbon to desertified or otherwise depleted lands, enabling the growth of more lignin crops to produce additional fertile soils, geometrically amplifying the sequestration.[239] Climate change may worsen desertification because of temporal changes in radiation, wind, temperature, rainfall and other parameters driven by the increased energy in the atmosphere,[240] making soil management all that more important.

Globally, human land use has resulted in an estimated 74 Mha of salinized agricultural land[241] – 43 Mha is irrigated land and 31 Mha is secondary salinization of nonirrigated land. There are ecosystem and economic benefits, in addition to carbon sequestration, to reclaiming desertified or salinized land, and studies have identified suitable tree species for reclamation of saline farmland,[242] and the use of salinized lands for fuel-wood production.[243] Of potential halophytic shrubs, saltbush (*Atriplex* spp.) has been the most extensively examined due to its salt tolerance and its nutritional potential as an alternative fodder for livestock.[244]

Studies have shown that another economically beneficial use for tree litter and other forestry and agricultural high lignin sources (>15%) would be for erosion control necessitated by the expected increase in rainfall in many areas from the rising temperatures.[245]

Sustainable biochar has both an energy and a sequestration component, so that it can be used to produce fuels while the char itself can be used to increase soil fertility, thus enabling greater sequestration of carbon. Researchers estimate that up to 12% of anthropogenic emissions could be offset by biochar application to soils.[246]

Reforestation and reducing deforestation can also play enormous roles. Reforestation to combat desertification is underway, e.g., in Mongolia by the Mongolian and South Korean governments.[247, 248] estimated that by halting deforestation, allowing forests to regrow, and leaving mature forests undisturbed, tropical forests alone could capture 25–35% of anthropogenic carbon emissions. Of course, the sequestration potential of forestration "varies depending on the scenario-assumptions of available land and of background climate. . . Afforestation of native grasslands, savannas, and open-canopy woodlands leads to the undesireable loss of unique natural ecosysems with risk biodiversity, carbon storage and other

239 Viviani, Bioenergy and Biobased Products, DOE National Bioenergy Center Strategic Partnerships Workshop, April 11-12, 2001, at 150-168. https://www.nrel.gov/docs/gen/fy01/30304.pdf

240 World Meterological Organization, Climate_Change Desertification, 2007.

241 Dregne, Harold E., and Nan-Ting Chou. "Global desertification dimensions and costs." Degradation and restoration of arid lands (1992): 73-92.

242 Marcar et al., 1995; Benyon et al., 1999; Niknam & McComb, 2000.

243 E.g. El-Lakany, 1986.

244 Norman et al., 2004.

245 Trees, Crops, and Soil Fertility: Concepts and Research Methods edited by G. Schroth, Fergus L. Sinclair

246 Nature Communications 1: 56 doi:10.1038/ncomms1053

247 Min-Kyung Kang et al, Jour. Korean For. Soc. Vol. 99 No. 5, pp 655-663 (2010)

248 Rosa C. Goodman and Martin Herold. 2014. "Why Maintaining Tropical Forests Is Essential and Urgent for a Stable Climate." CGD Working Paper 385. Washington, DC: Center for Global Development.

ecosystem services." Further, account needs to be taken of feedbacks which are "highly region dependent. For instance, afforestation at high latitudes would decrease albedo and increase local warming. . . ."[249][250]

X. Need for Regulations for GHG Emission Reductions and Sequestration

Given the magnitude of the climate change problem, the mitigation prescription must also be adequate to the purpose. In the absence of human activities, nature maintains carbon dioxide atmospheric concentrations within a narrow band by balancing emissions with sequestration. Nature efficiently removes atmospheric carbon by transforming it into biomass and minerals, or "storing" it in the oceans (the source of the ocean acidification problem). Unlike the natural cycle, which is in dynamic equilibrium, the anthropogenic carbon cycle is unbalanced.

The economics of the anthropogenic carbon cycle still do not take into account the externalities of climate change or ocean warming and acidification; accordingly, the economic carbon cycle is skewed towards emissions and away from removal and secure sequestration. While the amount of the imbalance is relatively small when compared to the annual amount of carbon nature moves into and out of the atmosphere, it is consistently biased in one direction and over the years has almost doubled the baseline atmospheric carbon.

We thus confront a two-fold market failure[251] as the environmental cost of emissions are not included in the price of fossil fuel energy and the environmental benefits of removal and sequestration of CO_2 (or oxidation of methane) similarly are not valued by the market. OMB's "best practices" [252] for preparing the economic analysis of a significant regulatory action, called for by Executive Order 12866,[253] include determining whether there exists a market failure that is likely to be significant. Fossil fuel GHG emissions-imposed global warming and associated atmospheric, land and oceans impacts clearly meet OMB's definition of an externality.[254] "Once a significant market failure has been identified, the analysis should show how adequately the regulatory alternatives to be considered address the specified market failure."[255] Of course, these are best practices for regulatory agencies, not Petitioners, and Petitioner here recommend that the Agency include all reasonable options in its cost analysis to comply with the OMB best practices.

The Council of Economic Advisers have pointed out that "the emission of greenhouse gases such as carbon dioxide (CO_2) harms others in a way that is not reflected in the price of carbon-based energy, i.e., CO_2 emissions create a negative externality. Because the price of carbon-based energy does not reflect the full cost or economic damages, market forces result in a level of CO_2 emissions that is far too high. Public policies are thus needed to reduce CO_2 emissions and thereby limit the damage to economies and the natural world from further climate

[249] IPCC AR6, WGI, §5.6.2.2.1.

[250] Petitioners add here that the selection of appropriate regulatory emission and sequestration remedies is a policy judgement for the Agency but, as noted *supra*, where promising options require further testing those could be required under TSCA §4.

[251] The Cost of Delaying Action to Stem Climate Change, US Council of Economic Advisors, EOP, 2014

[252] OMB: https://www.whitehouse.gov/omb/inforeg_riaguide last accessed 8/17/16

[253] Executive Order 12866, "Regulatory Planning and Review"

[254] OMB: https://www.whitehouse.gov/omb/inforeg_riaguide last accessed 8/17/16

[255] *Id.*

change."[256] Some of these harms have been identified herein, including severe heat, wildfire, extreme weather, degraded air quality, ocean warming, deoxygenation, and acidification. TSCA provides a vehicle for implementing the public policy called for by the Council necessary to rectify the market failure.

The largest benefits and perhaps the most powerful argument for action may be the possibility of catastrophic effects from continued emissions. These include the possibility of amplified climate change stemming from feedback physical and chemical processes. Most of these positive feedbacks are anticipated from the simple physics of the situation, including loss of arctic ice-albedo[257, 258] (more summer ice melt means warmer water, warmer water means less winter ice formation, gradually decreasing each year's arctic ice coverage) and the release of soil carbon as frozen soil warms.[259] These effects are occurring now, and there are many others,[260] including potential collapse of the marine food web; impacts to cloud albedo[261]; alterations in ocean circulation[262]; rapid sea-level rise driven by West Antarctic Ice Sheet collapse or other sources; shifts in weather patterns like the Indian Summer Monsoon or the West African Monsoon[263]; ecological regime shifts in the Amazon or the Sahel; and the potential for massive release of carbon from seafloor methane hydrates.[264] Modeling studies have revealed the potential for an atmospheric super rotation threshold that rapidly increases climate sensitivity by changing planetary cloudiness[265] or an abrupt decline in the volume of snow on the Tibetan Plateau.[266] Some of these potential tipping elements may be realized by 2100 or earlier under current trajectories, others are likely not to materialize this century. In any case, both near and long-term tipping points need to be included so that significant costs and benefits of regulatory alternatives may be considered by decision makers.

---

[256] The Cost of Delaying Action to Stem Climate Change, CEA, July 2014.

[257] Pistone et al http://www.pnas.org/content/111/9/3322.short

[258] Vihma, T. Surv Geophys (2014) 35: 1175. https://doi.org/10.1007/s10712-014-9284-0

[259] Shuur et al, The effect of permafrost thaw on old carbon release and net carbon exchange from tundra, Nature 459, 556-559 (28 May 2009).

[260] Price, James. "Climate Tipping Points." (2012).

[261]Six K.D., Kloster S., Ilyina T., Archer S.D., Zhang.K, Maier-Reimer,E., Global warming amplified by reduced sulphur fluxes as a result of ocean acidification. Nature Climate Change

[262]Rahmstorf, S., Box, J., Feulner, G., Mann, M., Robinson, A., Rutherford, S., Schaffernicht, E. (2015): Evidence for an exceptional 20th-Century slowdown in Atlantic Ocean overturning. Nature Climate Change (online)

[263] Nordhaus, William D., and Joseph Boyer. "Warming the world." (2000).

[264] Schellnhuber, Hans Joachim. "Tipping elements in the Earth System." Proceedings of the National Academy of Sciences 106.49 (2009): 20561-20563.

[265] Caballero, Rodrigo, and Matthew Huber. "Spontaneous transition to superrotation in warm climates simulated by CAM3." Geophysical Research Letters 37.11 (2010).

[266] Drijfhout, Sybren, et al. "Catalogue of abrupt shifts in Intergovernmental Panel on Climate Change climate models." Proceedings of the National Academy of Sciences 112.43 (2015): E5777-E5786.

As Petitioners discussed *supra*, Executive Order 12866[267] clearly requires accounting of low probability, high impact events in EPA's risk and benefit analysis. There is research[268] that indicates that probabilities, at least for extreme weather events, are consistently undervalued. Such mistakes must be avoided by the Agency in its evaluation of a rule that aims to ensure that fossil fuel and other GHG emissions, both new and legacy, are phased out and removed so as to eliminate their present and anticipated injury to public health and the environment.

XI. Risk Reduction Costs and Benefits

As discussed earlier, while the Agency's §21 guidance[269] stated that petitioners are *encouraged* to provide cost and benefit information, the plain language of TSCA section 2605 (b) (4) (A), as amended in 2016 – and thus, *after* the denial of Petitioner Viviani's 2015 petition -- now makes it clear that it is the Administrator's responsibility to conduct the risk evaluation to determine if a risk is unreasonable without consideration of cost and other nonrisk factors. That is:

> *The Administrator shall conduct risk evaluations pursuant to this paragraph to determine whether a chemical substance presents an unreasonable risk of injury to health or the environment, without consideration of costs or other nonrisk factors, including an unreasonable risk to a potentially exposed or susceptible subpopulation identified as relevant to the risk evaluation by the Administrator, under the conditions of use.*

As noted, *supra*, resolving the myriad widespread and severe threats to health and the environment arising from fossil fuel GHG emissions, in particular but not limited to CO_2 and CH_4 – including Earth's energy imbalance, global warming, increasing drought, wildfire, and extreme weather, ecosystem degradation, species loss,[270] ice melt and sea level rise, ocean acidification, ocean warming, ocean detoxification, and the threat to the food web – **all** require a phaseout of those emissions and removal of a significant share of their atmospheric excess.[271]

---

[267] https://www.whitehouse.gov/sites/default/files/omb/inforeg/eo12866/eo12866_10041993.pdf

[268] Mann, Michael E., Elisabeth A. Lloyd, and Naomi Oreskes. "Assessing climate change impacts on extreme weather events: the case for an alternative (Bayesian) approach." Climatic Change (2017): 1-12.

[269] FR Doc. 85-26938.

[270] A far more substantial review is warranted of the threat to land-based ecosystems and species from business-as-usual GHG pollution than is provided herein. Accordingly, Petitioners intend to supplement by way of letter upon EPA's opening of a docket governing the subject matter of this Petition. For now, we cite the recent IPCC AR6 WG3 technical report that stated, in relevant part, that, "[c]limate change has altered marine, terrestrial and freshwater ecosystems all around the world (very high confidence). Effects have been experienced earlier, are more widespread and with further reaching consequences than anticipated (medium confidence). Biological responses including changes in physiology, growth, abundances, geographic placement and shifting seasonal timing are often not sufficient to cope with recent climate change (very high confidence). Climate change has caused local species losses, increases in disease (high confidence), mass mortality events of plants and animals (very high confidence), resulting in the first climate driven extinctions (medium confidence), ecosystem restructuring, increases in areas burned by wildfire (high confidence), and declines in key ecosystem services (high confidence)." *See* also, IUCN Issue Brief, Species and Climate Change ("Species are already being impacted by anthropogenic climate change, and its rapid onset is limiting the ability of many species to adapt to their environments. Climate change currently affects at least 10,967 species on the IUCN Red List of Threatened Species™, increasing the likelihood of their extinction.").

[271] IBGP, IOC & SCOR, 2013. Ocean Acidification Summary for Policymakers – Third Symposium on the Ocean in a High- CO_2 World.

The information provided herein suffices for the Agency to determine that the present surfeit of these chemicals presents an imminent, widespread, severe and unreasonable risk of injury to health or the environment, so that EPA should initiate a civil action against fossil fuel companies to phase out production, release and the continuing disposal of these substances.

Further, Petitioners assert that the present concentrations of atmospheric CO_2 and CH_4 and ocean CO_2, combined with the certainty of worse to come absent emissions phaseout and removal, amply meets the TSCA unreasonable risk standard. Moreover, there is strong evidence that the benefits of strong action to reduce CO_2 and CH_4 concentrations outweigh the costs,[272, 273] i.e., the benefits based on the risk avoided and economic payback derived from increased reliance on clean energy and removal of excess atmospheric concentrations of CO_2 and CH_4 are calculated in the trillions of dollars. Global, country, and industry-wide analyses estimate a positive balance of benefit over cost for various mitigation options the Agency could select, and numerous analyses show that even with uneven initial participation by some countries, the goal of keeping or returning warming to below 1.5ºC still may be attained. These facts alone, given the enormity of the existential risk from global warming and ocean impacts, and the dire consequences of not acting quickly, require the Agency to initiate rule making under TSCA.

Petitioners herein present data on (a) the socio-economic costs of CO_2 and CH_4 pollution, (b) the feasibility of controls on CO_2 and CH_4, and (c) the social cost of carbon including the costs of delaying action to reduce and mitigate CO_2 and CH_4 pollution. Ultimately it is the responsibility of the Agency to gather all the necessary information, develop robust options and decide how to proceed, in order to comply with the intent of Congress, i.e., that the Administrator shall carry out this chapter in a reasonable and prudent manner, considering the environmental, economic, and social impact of any action the Administrator takes or proposes.[274]

(a) Socioeconomic Costs, and Benefits

The release of CO_2 and CH_4 into the environment is already imposing substantial social and economic impacts, and these will become ever more damaging upon additional loading of the atmosphere with these dangerous gases. Primary economic concerns include the lost functionality of coastal cities and regions, agricultural degradation and collapse, lost worker productivity, loss of life from migration-related civil unrest and war, and loss of fisheries and increased food insecurity.

1. US economic risks from unabated climate change

Volume II of the Fourth National Climate Assessment (NCA4) (2018) focuses on "the human welfare, societal, and environmental elements of climate change and variability for 10 regions and 18 national topics, with particular attention paid to observed and projected risks, impacts, consideration of risk reduction, and implications under different mitigation pathways."[275] The Environmental Protection Agency is one of 13 federal agencies comprising

---

[272] https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(18)30029-9/fulltext

[273] https://www.tandfonline.com/doi/full/10.1080/14693062.2020.1724070

[274] TSCA §2601. Findings, policy, and intent.

[275] *See* https://nca2018.globalchange.gov/chapter/front-matter-about/

"the Subcommittee on Global Change Research of the Committee on Environment within the National Science and Technology Council,"[276] that helped to provide "several rounds of technical and policy review" of that volume.[277] In the light of its high-quality, we directly incorporate and cite relevant portions of that volume's summary chapter (Chapter 1) in the duration of this sub-section, while omitting internal references for ease of reading.[278]

> Without more significant global greenhouse gas mitigation and regional adaptation efforts, climate change is expected to cause substantial losses to infrastructure and property and impede the rate of economic growth over this century. Regional economies and industries that depend on natural resources and favorable climate conditions, such as agriculture, tourism, and fisheries, are increasingly vulnerable to impacts driven by climate change. Reliable and affordable energy supplies, which underpin virtually every sector of the economy, are increasingly at risk from climate change and weather extremes. The impacts of climate change beyond our borders are expected to increasingly affect our trade and economy, including import and export prices and U.S. businesses with overseas operation and supply chains*)*. Some aspects of our economy may see slight improvements in a modestly warmer world. However, the continued warming that is projected to occur without significant reductions in global greenhouse gas emissions is expected to cause substantial net damage to the U.S. economy, especially in the absence of increased adaptation efforts. The potential for losses in some sectors could reach hundreds of billions of dollars per year by the end of this century.
>
> Existing water, transportation, and energy infrastructure already face challenges from heavy rainfall, inland and coastal flooding, landslides, drought, wildfire, heat waves, and other weather and climate. Many extreme weather and climate-related events are expected to become more frequent and more intense in a warmer world, creating greater risks of infrastructure disruption and failure that can cascade across economic sectors. For example, more frequent and severe heat waves and other extreme events in many parts of the United States are expected to increase stresses on the energy system, amplifying the risk of more frequent and longer-lasting power outages and fuel shortages that could affect other critical sectors and systems, such as access to medical. Current infrastructure is typically designed for historical climate conditions and development patterns—for instance, coastal land use—generally do not account for a changing climate, resulting in increasing vulnerability to future risks from weather extremes and climate. Infrastructure age and deterioration make failure or interrupted service from extreme weather even more likely. Climate change is expected to increase the costs of maintaining, repairing, and replacing infrastructure, with differences across regions.
>
> Recent extreme events demonstrate the vulnerabilities of interconnected economic sectors to increasing risks from climate change. In 2017, Hurricane Harvey dumped an unprecedented amount of rainfall over the greater Houston area, some of which

---

[276] https://www.globalchange.gov/agencies

[277] https://nca2018.globalchange.gov/chapter/front-matter-about/

[278] Petitioners direct the reader to https://nca2018.globalchange.gov/chapter/1/ for such further detail.

has been attributed to human-induced climate change. Resulting power outages had cascading effects on critical infrastructure facilities such as hospitals and water and wastewater treatment plants. Reduced oil production and refining capacity in the Gulf of Mexico caused price spikes regionally and nationally from actual and anticipated gasoline shortages. In the U.S. Caribbean, Hurricanes Irma and Maria caused catastrophic damage to infrastructure, including the complete failure of Puerto Rico's power grid and the loss of power throughout the U.S. Virgin Islands, as well as extensive damage to the region's agricultural industry. The death toll in Puerto Rico grew in the three months following Maria's landfall on the island due in part to the lack of electricity and potable water as well as access to medical facilities and medical care.

Climate-related risks to infrastructure, property, and the economy vary across regions. Along the U.S. coastline, public infrastructure and $1 trillion in national wealth held in coastal real estate are threatened by rising sea levels, higher storm surges, and the ongoing increase in high tide flooding. Coastal infrastructure provides critical lifelines to the rest of the country, including energy supplies and access to goods and services from overseas trade; increased damage to coastal facilities is expected to result in cascading costs and national impacts. High tide flooding is projected to become more disruptive and costlier as its frequency, depth, and inland extent grow in the coming decades. Without significant adaptation measures, many coastal cities in the Southeast are expected to experience daily high tide flooding by the end of the century. Higher sea levels will also cause storm surge from tropical storms to travel farther inland than in the past, impacting more coastal properties and infrastructure. Oil, natural gas, and electrical infrastructure located along the coasts of the Atlantic Ocean and Gulf of Mexico are at increased risk of damage from rising sea levels and stronger hurricanes; regional disruptions are expected to have national implications. Hawai'i and the U.S.-Affiliated Pacific Islands and the U.S. Caribbean also face high risks to critical infrastructure from coastal flooding, erosion, and storm surge.

In the western United States, increasing wildfire is damaging ranches and rangelands as well as property in cities near the wildland–urban interface. Drier conditions are projected to increase the risk of wildfires and damage to property and infrastructure, including energy production and generation assets and the power grid. In Alaska, thawing of permafrost is responsible for severe damage to roads, buildings, and pipelines that will be costly to replace, especially in remote parts of Alaska. Alaska oil and gas operations are vulnerable to thawing permafrost, sea level rise, and increased coastal exposure due to declining sea ice; however, a longer ice-free season may enhance offshore energy operations and transport. These impacts are expected to grow with continued warming.

U.S. agriculture and the communities it supports are threatened by increases in temperatures, drought, heavy precipitation events, and wildfire on rangelands. Yields of major U.S. crops (such as corn, soybeans, wheat, rice, sorghum, and cotton) are expected to decline over this century as a consequence of increases in temperatures and possibly changes in water availability and disease and pest outbreaks. Increases in growing season temperatures in the Midwest are projected to be the largest contributing factor to declines in U.S. agricultural. Climate change is also expected to lead to large-scale shifts in the availability and prices of many agricultural products across the world, with corresponding impacts on U.S. agricultural producers and the U.S. economy.

Extreme heat poses a significant risk to human health and labor productivity in the agricultural, construction, and other outdoor sectors. Under a higher scenario (RCP8.5), almost two billion labor hours are projected to be lost annually by 2090 from the impacts of temperature extremes, costing an estimated $160 billion in lost wages. States within the Southeast and Southern Great Plains regions are projected to experience some of the greatest impacts.

2. A closer look at ocean-based economic risks from unabated climate change

a. Sea-level rise economic risks

According to a recent Center on Public Integrity study – one that employed highly conservative assumptions – the United States faces more than $400 billion in costs over the next 20 years to defend coastal communities from unavoidable sea-level rise – requiring the construction of more than 50,000 miles of coastal barriers in 22 states.[279] More than 130 counties face at least $1 billion in costs, and 14 states will see expenses of $10 billion or greater between now and 2040. These costs reflect the bare minimum coastal defenses that communities need to build to hold back rising seas and prevent chronic flooding and inundation over the next 20 years. Unless action begins now to hold temperature rise to 1.5 ºC, costs for adaptation and public health impacts,[280] including increases in water-borne diseases[281] and other morbidities,[282] will greatly increase.

A 2018 analysis[283] using a multi-model approach estimated the different impacts in terms of sea level rise for a temperature increase of 1.5 ºC and 2.0 ºC by 2100. Authors found a difference of 11 cm global sea level rise in 2100 between the two temperatures and estimated potential additional losses of $1.4 trillion per year (0.25% of global GDP) if no additional adaptation is assumed from the modelled adaptation in the base year. The study used the NOAA-funded, Coupled Model Intercomparison Project (CMIP5).[284] This coupled model combines data from three types of models – Atmosphere–Ocean, General Circulation, and Earth System – and simulated both long and short-term data sets.

If the current emissions trajectory isn't changed, the human impact and the costs will become far more extreme. The UK National Oceanographic Centre found flooding from rising

---

[279] Center for Climate Integrity, High Tide Tax: The Price to Protect Coastal Communities from Rising Seas (2019) at https://www.climatecosts2040.org/files/ClimateCosts2040_Report.pdf.

[280] Allen, Thomas R., et al. "Linking water infrastructure, public health, and sea level rise: integrated assessment of flood resilience in coastal cities." *Public Works Management & Policy* 24.1 (2019): 110-139.

[281] Dvorak, Ana C., et al. "Possible impacts of sea level rise on disease transmission and potential adaptation strategies, a review." *Journal of environmental management* 217 (2018): 951-968.

[282] Vineis, Paolo, Queenie Chan, and Aneire Khan. "Climate change impacts on water salinity and health." *Journal of Epidemiology and Global Health* 1.1 (2011): 5-10.

[283] Jevrejeva, Svetlana, et al. "Flood damage costs under the sea level rise with warming of 1.5 C and 2 C." *Environmental Research Letters* 13.7 (2018): 074014.

[284] Taylor, Karl E., Ronald J. Stouffer, and Gerald A. Meehl. "An overview of CMIP5 and the experiment design." *Bulletin of the American meteorological Society* 93.4 (2012): 485-498

sea levels could cost more than $14 trillion worldwide *annually* by 2100, if global warming reaches 2 ºC above pre-industrial levels.[285]

A higher-end projection of 184 cm and a 95% quantile of 292 cm by 2100[286] was estimated by Le Bars et al, using a probabilistic process-based method. Uncertainties in the projections increase when including the temperature dependence of Antarctic mass loss and the uncertainty in the Coupled Model Intercomparison Project Phase 5 (CMIP5) model ensemble.

The costs required to respond to sea level rise are high and rising sharply. Sugiyama et al.[287] looked at four kinds of cost: protection cost; dryland/capital loss; wetland loss; and wetland gain. They found that, under an assumption of linear sea level rise, net wetland loss (wetland loss offset by gain) dominated costs, estimating that the cost of sea level rise[288] was $1,182B for global cost and loss.[289] As well, using purchasing power parity (PPP), they estimate $1,991B for global cost and loss (and $317B for the US).

A 2018 study[290] estimated global and coastal sea level projections with warming of 1.5 °C and 2 °C by 2100 and compared the costs associated with RCP8.5 business as usual temperature rise. They projected global sea-flood costs of $10.2 trillion per year (1.8% of GDP) without additional adaptation for sea level projections with warming of 1.5 °C by 2100. With adaptation they estimated costs could decrease to $1.1 trillion per year (0.2% GDP) for the same 1.5 °C scenario in 2100. If warming is not mitigated and follows the RCP8.5 scenario, global mean sea level could rise to 86 cm (median) or even 180 cm (95th percentile) by 2100. This could result in annual sea-flood costs of US$ 14 trillion per year and US$ 27 trillion per year, respectively, if no further adaptation were undertaken.[291]

Meeting the Paris Accord limits[292] could restrict sea level rise to about half of what it would be under the IPCC business as usual projections (RCP8.5). This would provide for a significant difference in risk, as "[t]he median global mean sea-level rise by 2100 is projected as 35 cm for RCP2.6 and 74 cm for RCP8.5"; and "under constant protection 0.2–2.9% of the global population is expected to be flooded annually in the year 2100 under RCP2.6 and 0.5–4.6% under RCP8.5."[293] Starting in about 20 years, the damage patterns from sea level rise-

---

285 Zhongming, Zhu, et al. "Rising sea levels could cost the world $14 trillion a year by 2100." UK NOC (2018).

286 Le Bars, Dewi, Sybren Drijfhout, and Hylke de Vries. "A high-end sea level rise probabilistic projection including rapid Antarctic ice sheet mass loss." *Environmental Research Letters* 12.4 (2017): 044013.

287 Sugiyama, Masahiro, Robert J. Nicholls, and Athanasios Vafeidis. Estimating the economic cost of sea-level rise. MIT Joint Program on the Science and Policy of Global Change, 2008.

288 All in 1995 dollars.

289 "Cost and loss" refers to protection cost, capital loss and wetland loss (net wetlands loss being the largest contributor).

290 Jevrejeva, Svetlana, et al. "Flood damage costs under the sea level rise with warming of 1.5 C and 2 C." *Environmental Research Letters* 13.7 (2018): 074014

291 The latter would equate to 2.7% of global GDP.

292 This is ~ RCP2.6, which is includes atmospheric CO_2 eq peaking at 490ppm and then declining.

293 Hinkel, Jochen, et al. "Coastal flood damage and adaptation costs under 21st century sea-level rise." *Proceedings of the National Academy of Sciences* 111.9 (2014): 3292-3297. In the constant protection strategy, dikes are maintained at their height, but not raised, so flood risk increases with time as relative sea level rises. In the enhanced protection strategy, dikes are raised following both relative sea-level rise and socioeconomic development (i.e., dikes are raised as the demand for safety increases with growing affluence and increasing population density) Dike costs comprise annual investment cost (for building and upgrading dikes) and the cost of maintaining the additional dike

induced flooding under different emissions scenarios begins to diverge sharply, so that the higher fossil fuel GHG emissions will impose trillions of additional costs on impacted communities.

The IPCC also found a doubling of sea level rise from RCP2.6 to RCP8.5.[294] In its Special Report on the impacts of global warming of 1.5°C , the IPCC projected that risks to global aggregated economic growth due to climate change impacts "would be lower at 1.5°C than at 2°C ," particularly "in the tropics and Southern Hemisphere subtropics."[295] The IPCC estimated that future rise in global mean sea level (GMSL) caused by thermal expansion, melting of glaciers and ice sheets and land water storage changes, will rise between 0.43 m (0.29–0.59 m, *likely* range; RCP2.6) and 0.84 m (0.61–1.10 m, *likely* range; RCP8.5) by 2100 relative to 1986–2005. Beyond 2100, sea level will continue to rise for centuries due to continuing deep ocean heat uptake and mass loss of the GIS and AIS and will remain elevated for thousands of years (*high confidence*). Under RCP8.5, estimates for 2100 are higher and the uncertainty range larger than in AR5. Antarctica could contribute up to 28 cm of SLR (RCP8.5, upper end of *likely* range) by the end of the century.[296] Keeping temperature rise to 1.5°C (versus 2°C) will reduce GMSL by about 100 cm.[297] Following the current business as usual, Zillow data indicates almost 1.9 million homes (or roughly 2 percent of all U.S. homes) – worth a combined $882 billion – are at risk of being underwater by 2100.[298]

b. Acidification-based economic risks

According to the Secretariat of the U.N. Convention on Biological Diversity, ocean acidification and warming will induce a loss of more than $1 trillion *annually* in marine food resources by disrupting marine communities, promoting harmful algal blooms and the spread of some diseases, and increasing contaminants in fish and shellfish[299]

The United Nations Environment Programme has also reported that ocean acidification's impact on marine organisms is a threat to food security,[300] posing a threat to fisheries resources and the billions of people that rely on a marine-based diet.[301] Seafood consumption has been

---

stock built since the base year of 1995. In 2100, these costs range from US$ 12–31 billion under RCP2.6 to US$ 27–71 billion under RCP8.5.

294 2013: Sea Level Change. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

295 IPCC Special Report on 1.5°C , SPM-B.5.5. Similarly, *see* Kopp, Robert E., et al. "Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites." Earth's Future 2.8 (2014): 383-406.

296 *See also*, Church, J.A., Clark, P.U., Cazenave, A., Gregory, J.M., Jevrejeva, S., Levermann, A., Merrifield, M.A., Milne, G.A., Nerem, R.S., Nunn, P.D. and Payne, A.J., 2013. Sea level change. PM Cambridge University Press.

297 IPCC special report on the impacts of global warming of 1.5°C

298 Rao, K., 2017. Climate Change and Housing: Will a Rising Tide Sink All Homes? https://www.zillow.com/research/climate-change-underwater-homes-12890/.

299 Tirado, M.C. et al., 2010. Climate change and food safety: A review. Food Research International, 43(7), pp.1745–1765.

300 UNEP, 2010. The Emissions Gap Report: Are the Copenhagen Accord pledges sufficient to limit global warming to 2°C or 1.5°C ?

301 United Nations Environment Programme, 2010. Environmental consequences of ocean acidification: A threat to food security.

shown to prevent hundreds of thousands of premature deaths, as well as significantly reducing infant morbidity, so that a decline of seafood availability will increase deaths. Additionally, entire populations, including subsistence fishing populations and poor communities that depend on seafood, will suffer from the loss of this critical food source. For example, 95% of Alaskan households do some sort of subsistence fishing, and 17% of the state's population, 120,000 people, depend on subsistence fishing.[302] Many subsistence fishers also have cultural ties that are threatened by ocean acidification. Accordingly, CO_2 and CH_4 implicate severe social and environmental justice concerns.[303]

Not only will ocean acidification affect global food webs and ecosystems, it also will have a direct effect on the global economy. The U.S. economy is highly dependent on the health of the ocean. In 2009, the ocean economy contributed over US$ 223 billion annually to the U.S. gross domestic product and provided more than 2.6 million jobs.[304] In Washington State alone, the seafood industry generates $1.7 billion for gross state product and employs 42,000 people.[305] Already, shellfish hatchery failures in Washington have caused an economic stir and caused some hatcheries to relocate. Alaska's commercial fishing industry is valued at over $4 billion a year and supports 90,000 jobs; recreational fishing and fishing tourism add even more value.[306]

Tropical coral reefs provide ecosystem services, such as habitat and nursery functions for commercial and recreational fisheries and coastal protection. As reefs decline in warming and increasingly acidified waters, there will be an ecological shift to a new ecosystem state dominated by less commercially valuable species. Brander et al.[307] estimated the annual economic damage of ocean acidification-induced coral reef loss will escalate rapidly over time, reaching $870 billion by 2100. In an updated review, Brander et al.[308] estimated the annual anticipated loss of ecosystem services from coral loss to be $1 trillion. Shoreline protection afforded by coral reefs and the services they provide by preventing loss of life, property damage and erosion are also reduced by legacy and continuing CO_2 and CH_4 emissions.

---

[302] Mathis, J.T. et al., 2014. Ocean acidification risk assessment for Alaska's fishery sector. Progress in Oceanography.

[303] Convention on Biological Diversity, 2014. An Updated Synthesis of the Impacts of Ocean Acidification on Marine Biodiversity.

[304] NOAA, http://oceanservice.noaa.gov/facts/oceaneconomy.html. *See also*, Cooley, Sarah R., and Scott C. Doney. "Anticipating ocean acidification's economic consequences for commercial fisheries." Environmental Research Letters 4.2 (2009): 024007.

[305] Washington State Blue Ribbon Panel, 2012. Ocean Acidification : From Knowledge to Action, Washington State's Strategic Response.

[306] Mathis, J. T., et al. "Ocean acidification risk assessment for Alaska's fishery sector." Progress in Oceanography 136 (2015): 71-91. Alaska is ranked among the most vulnerable areas to acidification.

[307] Brander, Luke M., et al. "The economic impact of ocean acidification on coral reefs." Climate Change Economics 3.01 (2012): 1250002.

[308] Brander, Luke M., et al. "The economic impacts of ocean acidification." Handbook on the Economics of Ecosystem Services and Biodiversity (2014): 78-92. *See also*, Lane, Diana, et al. "Climate change impacts on freshwater fish, coral reefs, and related ecosystem services in the United States." Climatic Change 131.1 (2015): 143-157 (modeling three major U.S. locations for shallow water reefs – South Florida, Puerto Rico, and Hawai'i – to project future reef cover and associated economic values to inform a GHG emissions mitigation scenario compared to a business as usual to estimate, for example, that reducing emissions would result in an "avoided loss" in Hawai'i of approximately $10.6 billion in recreational use).

Acidification impacts are so fundamental to the overall structure and function of marine ecosystems that any significant changes could have far-reaching consequences for the oceans of the future and the hundreds of millions of people that depend on its food and other resources for their livelihoods.[309] There is also a significant cost to delaying action. According to a recent report by the Council of Economic Advisers, delaying the implementation of policies to mitigate climate change could significantly increase economic damages, in addition to worsening environmental harm.[310]

While there are still large unknowns on the biological consequences of ocean acidification, the science we have is clear: from shellfish to corals, and from pteropods to fish, our marine resources are threatened by the acidification of our ocean waters, and these risks are amplified by synergistic effects from warming and deoxygenating oceans.[311]

A recent study estimated that the damage our oceans will face from emissions-related problems will amount to $428 billion a year by 2050 and nearly $2 trillion per year by the century's end.[312]

As was also mentioned *supra*, a recent study[313] of emissions traced to just 88 investor- and state-owned fossil fuel producers establishes their responsibility for half of the historical (1880–2015) decline in surface ocean pH. The research is critical to an assignment of associated damages and the cost of removing excess atmospheric CO_2 and CH_4.

3. A closer look at economic risks of climate extremes

As referenced earlier, some model estimates do not take full account of low probability or difficult-to-quantify effects that amplify and accelerate warming, such as unstable methane deposit releases from permafrost and the sea floor,[314] impacts to cloud albedo,[315] the observed effects on the ocean carbon pump, or the very likely and perhaps inevitable (absent swift action) collapse of major ice sheets.[316] Petitioners do not accept that all of these are low probability

---

309 Doney, S.C. et al., 2009. Ocean acidification: the other CO2 problem. Annual Review of Marine Science, 1, pp.169–192.

310 Executive Office of the President of the United States, The Cost of Delaying Action to Stem Climate Change at 1 (July 2014).

311 *See also*, Hoagland P, Scatasta S. 2006. The economic effects of harmful algal blooms. In E Graneli and J Turner, eds., Ecology of Harmful Algae. Ecology Studies Series. Chap. 29 (discussing toxicity of harmful algal bloom increases under conditions of ocean acidification, which not only poison marine mammals but also cause paralytic shellfish poisoning in people. Scientists hypothesize that some of the increases in red tides off the coast of Southern California may be related to ocean acidification, though this has yet to be confirmed).

312 Noone, K., Sumaila, R. & Diaz, R., 2012. *Valuing the Ocean*: Draft Executive Summary, Stockholm Environment Institute.

313 Licker, Rachel, et al. "Attributing ocean acidification to major carbon producers." *Environmental Research Letters* 14.12 (2019).

314 Schaefer, K., T. Zhang, L. Bruhwiler, and A. P. Barrett (2011), Amount and timing of permafrost carbon release in response to climate warming, Tellus Series B: Chem. Phys. Met., DOI: 10.1111/j.1600-0889.2011.00527.x.; oven teal, Analysis of Permafrost Thermal Dynamics and Response to Climate Change in the CMIP5 Earth System Models, JOURNAL OF CLIMATE 2013

315Six K.D., Kloster S., Ilyina T., Archer S.D., Zhang.K, Maier-Reimer,E., Global warming amplified by reduced sulphur fluxes as a result of ocean acidification. Nature Climate Change

316 Pycroft, Jonathan, Lucia Vergano, and Chris Hope. "The economic impact of extreme sea-level rise: Ice sheet vulnerability and the social cost of carbon dioxide." Global environmental change 24 (2014): 99-107. *See also* discussion, *op c*it, of *Ice Melt* study by Petitioner Hansen et al.

events in the case of continued high emissions. But even for those that may be denominated as relatively low probability, because of their fateful consequences they must be accounted for by EPA either as a deterministic estimate or, as suggested by Weitzman,[317] as a probability density function. Otherwise, the Agency's rulemaking will not be based on a true representation of all critical potential costs and benefits.

Pycroft *et al*.[318] looked at the importance for the social cost of carbon to incorporate the possibility of extreme sea-level rise. They incorporated three types of "fat tails" associated with the effect of elevated temperature on sea level rise allowing for, and representing in the damage function, the possibility that the physical consequences of greenhouse gases and/or the consequent economic damages might be very high. They found that incorporating the possible collapse of ice sheets "by adding thin, medium or fat tails to the climate sensitivity and damage exponents" raises the mean value for the social cost of carbon dioxide. When tails for the two parameters are normally distributed, the mean value of the social cost of carbon dioxide rises to \$135/t CO_2 (33% above the standard model), when using lognormal distributions the mean value is \$147/t CO_2 (44% above), and when using Pareto distributions the mean is \$218/tCO_2 109% above).

The effects on the social cost of carbon dioxide range show a consistent asymmetry. As expected, the 5th and 50th percentile values do not change significantly, while a more substantial increase is registered for the 95th and 99th percentiles. The 95th percentile for the social cost of carbon dioxide is \$489/ tCO_2 with the tails normally distributed and \$839/t CO_2 with the Pareto distribution (112% and 263% above the standard values). It should be noted here that EPA often has credited 95th[319] or higher percentile[320] impacts in one or more aspects of each risk assessment, e.g., for exposure or effect. But none of such previous uses of the 95th or higher percentile presented an equivalently devastating magnitude or potential risk as is presented by the over-concentration of CO_2 and CH_4 – including, e.g., from the potential of ice sheet collapse.

Executive Order 12866[321] clearly requires accounting of low probability high impact events in EPA's risk and benefit analysis. As was observed by a group convened by OMB to describe "best practices" for preparing the economic analysis of any significant regulatory action pursuant to E.O 12866, "risk assessments should be conducted in a way that permits their use in a more general benefit-cost framework," so that they characterize, in part, "the probabilities of

---

317 Weitzman, Martin L. "On modeling and interpreting the economics of catastrophic climate change." The Review of Economics and Statistics 91.1 (2009): 1-19.

318 *Id.*

319 e.g., the U.S. Ambient Water Quality Criteria for Protection of Aquatic Life are based on Species Sensitivity Distributions (SSDs), with the criteria set at the fifth percentile, they can be interpreted as protecting at least 95% of the species in a community.

320 We note, for instance, that EPA uses the 99.9 percentile for exposure in regulating pesticide food tolerance, when determining the threshold of concern for pesticide consumption. A lower percentile may be used if the risk assessment contains a number of "conservative" assumptions that might result in overestimates of risk at the 99.9th percentile. However, as noted in this petition, because many potential climate amplifying effects are ignored, the warming, acidification and other deleterious effect estimates cannot be characterized as at all conservative.

321 *See* https://www.reginfo.gov/public/jsp/Utilities/EO_12866.pdf.

occurrence of outcomes of interest" and provide "a valuation of the levels and changes in risk experienced by affected populations as a result of the regulation."[322]

Petitioners note that, according to the U.S. Global Change Research Program, in the period January 1980 through December 2020, the U.S. experienced 290 weather and climate disasters with damage costs reaching or exceeding $1 billion[323] for each individual event. The cumulative costs for these 290 events exceed $1.9 trillion. Figure 20 depicts these events; the trend is clear enough.

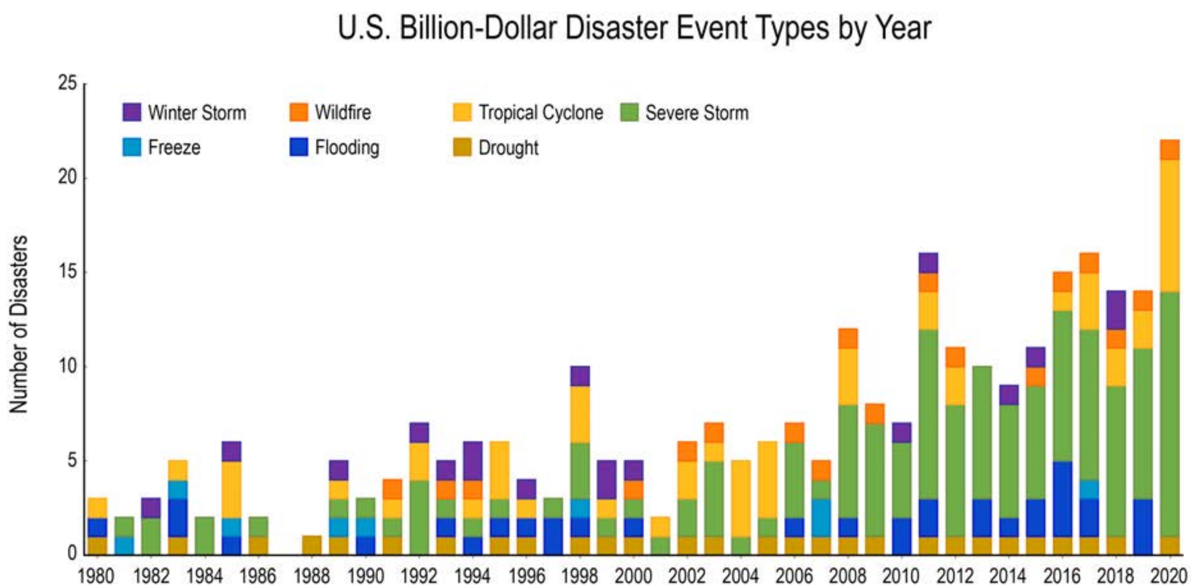


Fig. 23: Billion-dollar disaster events. Research and graphic from the U.S. Global Change Research Program

4. Accounting for climate action co-benefits

Local air quality co-benefits[324] amplify the beneficial impact of climate action, including by reducing premature deaths from air pollution. Vandyke et al,[325] showed that the transformation of the energy system implied by the emission reduction pledges of the Paris Agreement on climate change substantially reduces local air pollution across the globe. The Nationally Determined Contributions (NDCs), if achieved, could avoid between 71 and 99 thousand premature deaths annually in 2030 compared to a reference case, depending on the stringency of direct air pollution controls. The same study determined that if NDCs were strengthened so that they were actually consistent with Paris Agreement requirements (itself a wholly-inadequate target in light of the impacts of that level of warming on human and natural systems) then substantially more premature deaths from air pollution would be avoided –between

322 Economic Analysis of Federal Regulations Under Executive Order 12866, OMB, 1996, available at https://georgewbush-whitehouse.archives.gov/omb/inforeg/riaguide.html#iii.

323 https://www.globalchange.gov/browse/indicators/billion-dollar-disasters

324 Aldy, Joseph E., et al. Co-Benefits and Regulatory Impact Analysis: Theory and Evidence from Federal Air Quality Regulations. No. w27603. National Bureau of Economic Research, 2020.

325 Vandyck, Toon, et al. "Air quality co-benefits for human health and agriculture counterbalance costs to meet Paris Agreement pledges." *Nature communications* 9.1 (2018): 1-11.

178–346 thousand annually in 2030, and up to 0.7–1.5 million in the year 2050. Air quality co-benefits on morbidity, mortality, and agriculture could globally offset the costs of climate policy.

McCollum et al.,[326] using a single integrated assessment model, assessed just the benefits from energy security improvement, climate change mitigation, and the reduction of air pollution and its human health impacts accrued by keeping warming under 2°C . They found that total cost savings were between 0.1 % and 0.7 % of globally-aggregated GDP in 2030. While the steps taken in their analysis add to energy system expenditures, the analysis showed that these costs will be substantially compensated for by the corresponding reductions of air pollution control and energy security expenditures.

Petitioners are aware that while the impact of non-fossil fuel energy is complicated for pollutants such as NO_x and SO_2 that are already subject to emissions cap and trade programs, there are many pollutants other than CO_2 that pose serious adverse health and environmental impacts, including fine particulate matter, volatile organic compounds, and trace heavy metals *not* currently subject to emissions trading requirements. Emissions of these pollutants will be reduced when fossil fuel generation is reduced, and the health and environmental benefit from reduction of these pollutants need to be accounted for as benefits, to the extent each regulatory option considered includes them.

In particular, exposure to ambient fine particulate matter (PM) air pollution from fossil fuels is a major risk for premature death. Warmer temperatures speed up these reactions. When we breathe, particulate matter is pulled into our nose and lungs. Its presence in our bodies triggers inflammation. Many diseases and conditions are linked to inflammation – and by extension therefore are linked to polluted air. Particulate matter comes in many sizes – with the largest particles not making it much past our noses – because of a primary filtration process that takes place. With smaller particles it's a different story. The smaller the particle, the better it is at escaping our body's defenses. Ultrafine particulate matter is especially dangerous because it can cross directly from lung tissue into the bloodstream where it is then carried throughout the body, as illustrated in Figure 21. Research, already confirmed in nonhuman primates, suggests that in humans ultra-fine particulate matter also crosses the nasal mucosa to pass directly into the brain – transported via nerve endings.[327] These smaller particles, e.g., PM1 and PM0.1, present a greater risk because they penetrate further into the body. PM 0.1 indeed presents the most grievous risk as it readily crosses the alveoli into the blood stream, and then cross the blood brain barrier—inducing inflammation in the brain as well as other organs.

---

[326] McCollum et al, Climatic Change (2013) 119:479–494.

[327] Obederdöster, G., Elder, A., & Rinderknecht, A. (2009). Nanoparticles and the brain: Cause for concern? *Journal of Nanoscience and Nanotechnology, 9*, 4996–5007. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3804071/pdf/nihms-507989.pdf

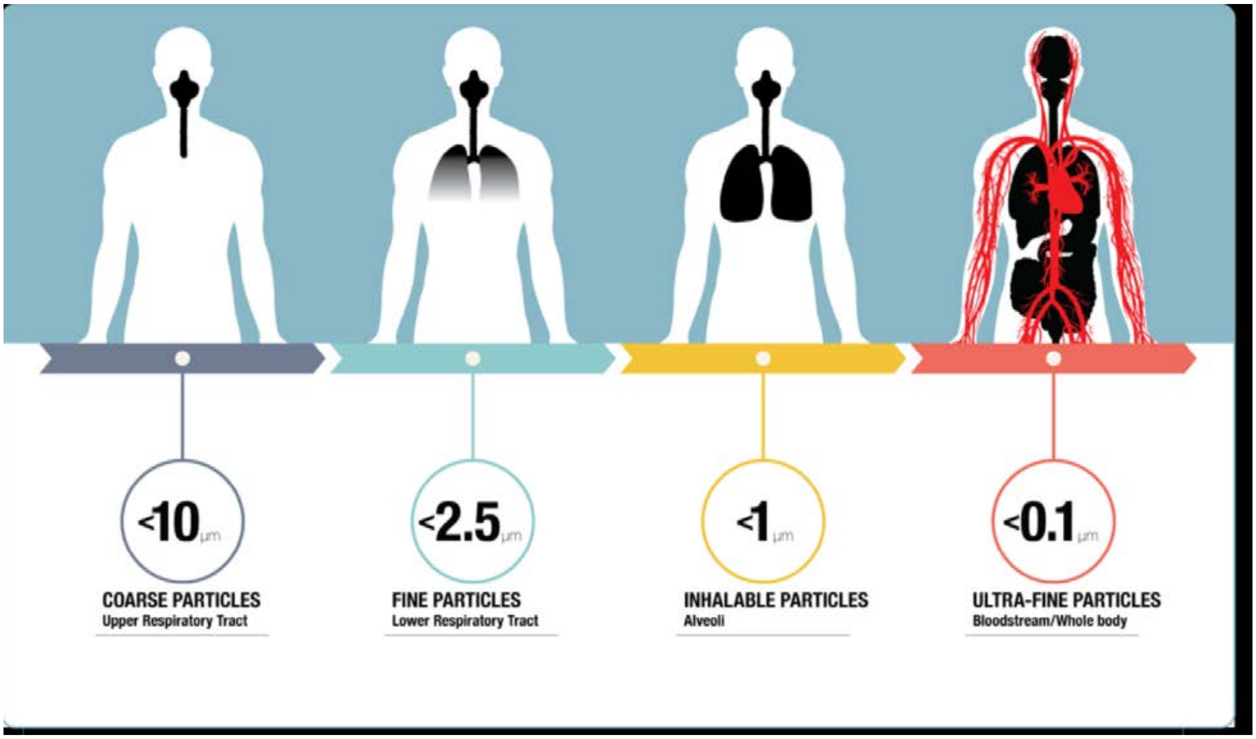


Figure 24: Transport of particulate matter in the body by size

Evidence is mounting that inflammation of brain tissue from air pollution is linked to dementia, including Alzheimer's type; to being a comorbidity factor in the development and exacerbation of symptoms of Parkinson's disease, and to amyotrophic lateral sclerosis (ALS).[328] Even intermittent exposure to exhaust PM air pollution cause both a decline in neurogenesis in some areas of the brain and an increase in other parts, and is accompanied by inflammation.[329] Reducing fossil fuel combustion will decrease this risk.[330]

Evidence supports a link between the role of neuro-inflammation in classic psychiatric illness and major depressive disorders, bipolar disorder, schizophrenia, and obsessive-compulsive disorders (Souhel, Pearlman, Alper, Najjar, & Devinsky, 2013[331]). Air pollution is

---

328 Calderón-Garcidueñas, L., & Villareal-Ríos, R. (2017). Living close to heavy traffic roads, air pollution, and dementia. *The Lancet, 389*, 675–677; Chen, C.-Y., Hung, H.-J., Chang, K.-H., Chung, Y. H., Muo, C.-H., Tsai, C.-H., et al. (2017). Long-term exposure to air pollution and the incidence of Parkinson's disease: A nested case-control study. *PLoS One, 12*(8), e0182834; Seelen, M., Toro Campos, R. A., Veldink, J. H., Visser, A. E., Hoek, G., Brunekreef, B., van der Kooi, A. J., de Visser, M., Raaphorst, J., van den Berg, L. H., & Vermeulen, R. C. (2017). Long-term air pollution exposure and amyotrophic lateral sclerosis in Netherlands: A population-based case-control study. *Environmental Health Perspectives, 125*, 097023.

329 Rivas-Arancibia, Selva, et al. "Oxidative stress caused by ozone exposure induces loss of brain repair in the hippocampus of adult rats." *Toxicological Sciences* 113.1 (2010): 187-197.

330 *See* World Health Organization, COP26 Special Report on Climate Change and Health

The Health Argument for Climate Action, October 2021 at https://www.who.int/publications/i/item/cop26-special-report.

331 Souhel, N., Pearlman, D., Alper, K., Najjar, A., & Devinsky, O. (2013). Neuroinflammation and psychiatric illness. *Journal of Neuroinflammation, 10*, 43.

also associated with increased psychosis in adolescents.[332] Even *low levels of pollution*—primarily from traffic—are associated with an increased risk of mental illness in children.[333] The American Psychological Association reported that children exposed to particulate matter were more likely to have "brain and damaged tissue in the prefrontal cortex," as well as lower test scores with respect to "memory, cognition and intelligence."[334] Researchers have also established a statistically-significant association between emergency room visits for anxiety—including panic attacks and threats to commit suicide—and air pollution.[335]

Petitioners anticipate that the incidence of these diseases and impacts will rise; they already bring an economic burden in the hundreds of billions of dollars. The cost in human suffering alone amplifies the case that continued use of fossil fuels threatens public health.[336, 337, 338]

While particulate matter is formed by a range of anthropogenic activities, fossil fuel combustion is the primary source. *See* Figure 22.[339] Wildfire smoke and dust, the major natural sources, are also increased by global warming. Accordingly, addressing warming by phasing out fossil fuels, reducing other GHG sources, and removing excess atmospheric CO_2 and methane—with the attendant resulting temperature moderation – accordingly will reduce the sources of fine and superfine PM in the troposphere.

Using data from the Global Burden of Disease project and actuarial standard life table methods, Apte et al[340] estimated global and national decrements in life expectancy that can be attributed to ambient PM2.5 for 185 countries. In 2016, PM2.5 exposure reduced average global life expectancy at birth by ∼1 year with reductions of ∼1.2−1.9 years in polluted countries of Asia and Africa. While more polluted countries would have greater increases in life expectancy from reduced air pollution and reduced particulate matter, countries at all levels of economic

332 Newbury, J. B., Arseneault, L., Beevers, S., et al. (2019). Association of air pollution exposure with psychotic experiences during adolescence. *JAMA Psychiatry, 76*, 614–623.

333 Oudin, A., Bråbäck, L., Åström, D. O., Strömgren, M., & Forsberg, B. (2016). Association between neighbourhood air pollution concentrations and dispensed medication for psychiatric disorders in a large longitudinal cohort of Swedish children and adolescents. *BMJ Open 6*:e010004.

334 Weir, K. (2012). Smog in our brains: Researchers are identifying startling connections between air pollution and decreased cognition and well-being. *American Psychological Association, 43*, 32. https://www.apa.org/monitor/2012/07-08/smog

335 Szyszkowicz, M., Willey, J. B., Grafstein, E., Rowe, B., & Colman, I. (2010). Air pollution and emergency department visits for suicide attempts in Vancouver, Canada. *Environmental Health Insights, 4*, 79–86.

336 Gladman, M., & Zinman, L. (2015). *The economic impact of amyotrophic lateral sclerosis: A systematic review*. National Center for Biotechnology Information, U.S. National Library of Medicine.

337 Kirson, N., Desai, U., Ristovska, L., Cummings, A. K., Birnbaum, H., Ye, W., et al. (2016). Assessing the economic burden of Alzheimer's disease patients first diagnosed by specialists. *BMC Geriatrics, 16*, 138.

338 Kowal, S.L., Dall, T. M., Chakrabarti, R., Storm, M.V., & Jain, A. (2013). *The current and projected economic burden of Parkinson's disease in the United States*. Movement Disorders Society. US National Library of Medicine National Institutes of Health.

339 Karagulian, Federico, et al. "Contributions to cities' ambient particulate matter (PM): A systematic review of local source contributions at global level." *Atmospheric environment* 120 (2015): 475-483.

340 Joshua S. Apte, Michael Brauer, Aaron J. Cohen, Majid Ezzati, and C. Arden Pope, *Environmental Science & Technology Letters* **2018** *5* (9), 546-551

development could experience gains in life expectancy on par with reducing other well recognized threats to public health.

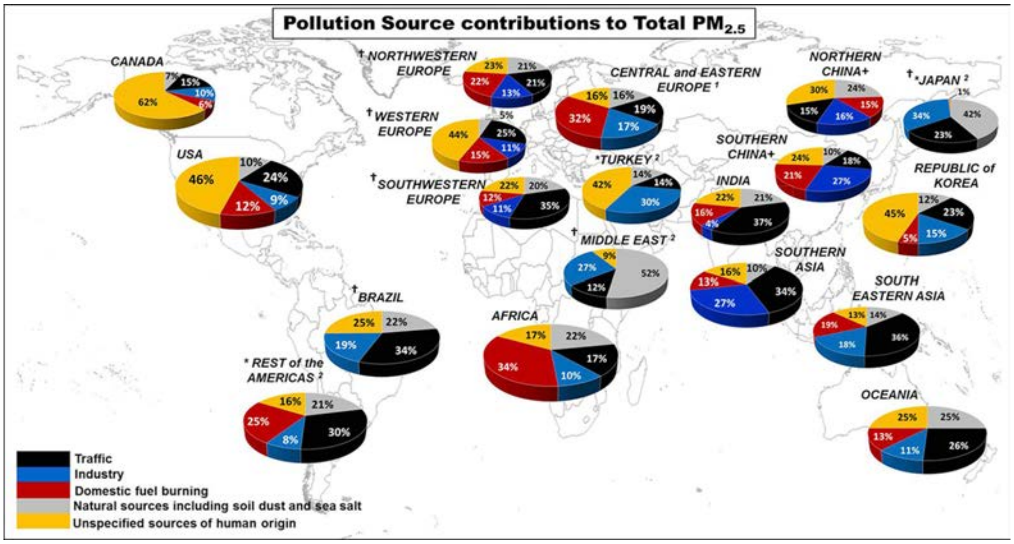


Figure 25: PM2.5 Sources by area[341]

Yang et al.[342] used the Environmental Benefits Mapping and Analysis Program to estimate the health and economic impacts of projected changes in O_3 and PM2.5 in the U.S. in a future (2046–2055) decade relative to the current (2001–2010) decade under the Representative Concentration Pathway (RCP) 4.5 and 8.5 climate scenarios. This petition asks that carbon emissions be held significantly under what these pathways estimate. The instant petition asks for CO_2 to be stabilized by 2100 at a little more than half of the RCP 4.5 and a quarter or the RCP 8.5 scenarios. Accordingly, the estimate by the aforementioned authors greatly underestimates the actual benefits in mortality and morbidity.

Even so, the benefits calculated for the US are highly significant. Comparing the decades 2001-10 with 2045-55 for the US, they estimated over 38,000 deaths avoided in the decades 2046-55 and $55,354 million in additional costs due to projected higher O_3 under RCP8.5 relative to RCP4.5. (Again, the benefits anticipated under the instant petition would be much larger.)

A recent *Lancet* study[343] used an additive model to examine the relationship between long-term exposure to the combustion products fine particulate matter <$PM_{2.}$, and tropospheric ozone, and hospital admissions among Medicare patients (2000-2016). The study looked at cardiovascular and respiratory outcomes (myocardial infarction, ischemic stroke, atrial fibrillation and flutter, and pneumonia). They found that "[l]ong-term exposure to air pollutants poses a significant risk to cardiovascular and respiratory health among the elderly population in

341 Karagulian, Federico, et al. "Contributions to cities' ambient particulate matter (PM): A systematic review of local source contributions at global level." *Atmospheric environment* 120 (2015): 475-483.

342 Yang, Peilin, et al. "Health impacts and cost-benefit analyses of surface O3 and PM2. 5 over the US under future climate and emission scenarios." *Environmental research* 178 (2019): 108687.

343 Danesh Yazdi, Mahdieh, et al. "Long-Term Association of Air Pollution and Hospital Admissions Among Medicare Participants Using a Doubly Robust Additive Model." *Circulation* 143.16 (2021): 1584-1596.

the United States, with the greatest increase in the association per unit of exposure occurring at lower concentrations." In particular, they found that each 1 μg/m^3 increase in annual $PM_{2.5}$ increased absolute annual risk of death by 0.073% (95% CI 0.071–0.076) and each 1 ppb increase in summer O_3 concentrations increased the annual risk of death by 0.081% (0.080–0.083). These translated to approximately 11,540 attributable deaths (95% CI 11,087–11,992) for $PM_{2.5}$, and 15,115 attributable deaths (14,896–15,333) for O_3 per year for each unit increase in pollution concentrations. The effects were higher in certain subgroups, including individuals living in areas of low socioeconomic status. These considerations are relevant here, since TSCA directs EPA to identify and protect "potentially exposed or susceptible sub-populations,"[344] which would include individuals living in areas of low socioeconomic status.

Lelieveld et al[345] estimated that globally, fossil-fuel-related emissions account for about 65% of the excess mortality imposed by air pollution. They relied upon Atmospheric Chemistry – Climate (EMAC)[346] model to estimate the climate and health outcomes attributable to fossil fuel use, indicating the potential benefits of a phaseout and estimated 3.61 (2.96–4.21) million deaths per year could be avoided worldwide by reducing and, for some uses, eliminating combustion of fossil fuels. This could be up to 5.55 (4.52–6.52) million per year by additionally controlling non fossil anthropogenic sources.

Peters et al.[347] found, in a systematic review of literature,[348] that greater exposure to airborne pollutants, particularly PM, is associated with increased risk of dementia. Because many of the studies used quantiles and/or different statistical methods, no meta-analysis was done.

TSCA provides regulatory and incentivized pathways to reduce particulate matter and ozone. Making combustion less competitive through fees targeting market failures, or emission limits, would ensure a market for non- and less polluting alternatives and encourage their development. Germany, e.g., has increased its green energy profile from less than 3%[349] to about

---

[344] The term "potentially exposed or susceptible subpopulation" means a group of individuals within the general population identified by the Administrator who, due to either greater susceptibility or greater exposure, may be at greater risk than the general population of adverse health effects from exposure to a chemical substance or mixture, such as infants, children, pregnant women, low-wage workers, the elderly, or persons with pre-existing respiratory disease.

[345] Lelieveld, J., et al. "Effects of fossil fuel and total anthropogenic emission removal on public health and climate." *Proceedings of the National Academy of Sciences* 116.15 (2019): 7192-7197. The authors attempted to take into account the global temperature and potential hydrologic impacts from removing fossil fuel aerosol pollution. They suggest that such aerosol pollution, if removed, could help restore rainfall patterns (ameliorating long-term drought) in Asia, the Sahel, and elsewhere, but at the cost of "liberating," that is, unlocking considerable additional warming. The study authors recommend, therefore, that "to reverse the major impacts on public health, regional climate, water supply, and food production," a phaseout of other anthropogenic emissions sources of CH4 and black carbon should be pursued in conjunction with a phaseout of fossil fuels.

[346] EMAC comprehensively simulates atmospheric chemical and meteorological processes and interactions with the oceans and the biosphere.

[347] Peters, Ruth, et al. "Air pollution and dementia: a systematic review." *Journal of Alzheimer's Disease* 70.s1 (2019): S145-S163.

[348] Medline, Embase, and PsychINFO® were searched from their inception to September 2018, for publications reporting on longitudinal studies of exposure to air pollution and incident dementia or cognitive decline in adults

[349] Wüstenhagen, Rolf, and Michael Bilharz. "Green energy market development in Germany: effective public policy and emerging customer demand." *Energy policy* 34.13 (2006): 1681-1696.

46% in 2020,[350] using a combination of subsidies, incentives and encouragement of consumer demand.[351]

TSCA §§ 2605 and 2606 can be used to reduce the emission of CO_2, through limits and fees, and thereby also limit the formation of much particulate matter. There is considerable literature on the ability of both Market Pull policies or Technology Push policies to increase the rate of innovation.[352] While not all of these sequestration technologies/methods are available at the current time to provide significant mitigation, they could be in the near future given proper market incentives and rules. In any case, the Agency has a successful history of setting regulatory "reach" targets (e.g., CAFE standards).

Under TSCA §2608, the Administrator would also be encouraged to fully use CAA authority to lower CAFE standards, while under section TSCA §§ 2611, 2612 and 2614, EPA can seize and/or impose fees on imports and exports that in their manufacture fail to meet the requirements of section 2605.

XII. In Conclusion

The evidence adduced in this Part amply establishes that the manufacture, distribution, use and disposal of the subject chemical substances and mixtures present an unreasonable risk to both health and the environment.

The Agency should act without delay to grant the petition. It should then proceed to render the TSCA determination and commence rulemaking to fashion and impose a set of requirements pursuant to TSCA §6, 15 USC §2605. The aim must be to place our nation on a secure path to achieve net-zero emissions, or better, well prior to 2050.

Securing that path is necessary not merely to honor our recent international commitments, but to reclaim a leadership position among nations with respect to the crisis.

Petitioners have demonstrated herein, including in Part I, that existing law suffices to commence a full decarbonization program in the United States. Indeed, TSCA provides both on-point and ample authority to the President and the Agency.

Petitioners and their Counsel stand ready to respond to any requests for clarification by the Agency and others on the President's climate team. There can be no doubt: we face an existential threat, as the President has observed. And so, there is work to be done to contain that threat, and thus to secure a viable future for our children and future generations. Together, in reason, based on the relevant evidence, and with all deliberate speed, we can work to avert added injury by protecting and restoring a functioning, habitable climate system.

---

[350] BMW1, 8th Monitoring Report on the Energy Transition (2021)

[351] Sunstein, Cass R., and Lucia A. Reisch. "Automatically green: Behavioral economics and environmental protection." *Harv. Envtl. L. Rev.* 38 (2014): 127. *See also*, Fischedick, Manfred. "German energy transition: targets, current status, chances and challenges of an ambitious pathway." (2019).

[352] "Impact of Renewable Energy Policy and Use on Innovation, A Literature Review," Felix Groba and Barbara Breitschopf 2013, Deutsches Institut für Wirtschaftsforschung.