

## **Exhibit A**

### **Declaration of Dr. James E. Hansen in Support of Plaintiffs' Complaint for Declaratory and Injunctive Relief**

In the matter  
*Kelsey Cascadia Rose Juliana, Xiuhtezcatl Tonatiuh M. et al. v.  
United States, Barack Obama et al.* (D. Or. Aug. 12, 2015)

**I, DR. JAMES E. HANSEN, hereby declare as follows:**

1. I make and offer this declaration in my capacity as guardian for Plaintiffs Sophie K. and Future Generations, and as an expert in the field of climate science.

2. I am Sophie's grandfather.

3. I am also a US citizen, an Adjunct Professor at Columbia University's Earth Institute, and Director of the Climate Science, Awareness and Solutions program at the Earth Institute, Columbia University. I am also the immediate past Director of the NASA Goddard Institute for Space Studies and a member of the United States National Academy of Sciences.

I have testified before the United States Senate and House of Representatives on many occasions, and in court on several occasions, in support of efforts to reduce reliance on carbon-intensive energy from fossil fuels and rapidly transition to carbon-free energy.

4. My training is in physics and astronomy, with early research on the clouds of Venus. Since the late 1970s, I have focused my research on Earth's climate, especially human-made climate change. Most recently, I have dedicated significant effort towards outlining the actions that must be undertaken by communities, states, the U.S. Government, and others, in order to preserve a viable climate system for young people, future generations, and other life on Earth. For the Court's more complete reference, I have attached my full CV as **Exhibit 1** to this declaration.

5. In my opinion, this lawsuit is made necessary by the at-best schizophrenic, if not suicidal, nature of U.S. climate and energy policy.

6. On the one hand, our federal government has recognized a fundamental duty to protect the public resources of our nation; to safeguard our lives and property; to secure the blessings of liberty; to ensure equal protection under the law for "ourselves and our posterity";

and, pursuant to the United Nations Framework Convention on Climate Change (UNFCCC), to “protect the climate system for present and future generations.”

7. On the other hand, the federal government continues to permit and otherwise support industry’s efforts to exploit fully our reserves of gas, coal, and oil, even in the face of increasing overwhelming evidence that our continued fossil fuel dependency is driving the atmospheric concentration of carbon dioxide (CO<sub>2</sub>) far beyond that in human experience, and constitutes one of the greatest threats to our nation, human civilization and nature alike.

8. These antinomies cannot be explained away as the product of ignorance. Our government has known for decades that the continued burning of coal, oil and natural gas causes global warming and risks dangerous and uncontrollable destabilization of the planet’s climate system on which our nation and future generations depend.

9. Moreover, the government has, during this last half decade, promoted the exploitation and consumption of fossil fuels in myriad ways. They include: permitting of fossil fuel development projects within the U.S.; financing of overseas fossil fuel development projects through the Export Import Bank and World Bank; issuance of leases and permits for oil, gas and coal extraction and development on contiguous federal and OCS lands; and subsidies through tax credits, deductions, preferences, percentage depletion, expensing, favorable loans and guarantees, accelerated amortization, below fair-market-value lease and royalty requirements, and other favorable tax treatment for fossil fuel development. This listing is partial.

10. It is now clear, as the relevant scientific community has established for some time, that continued high CO<sub>2</sub> emissions from fossil fuel burning will further disrupt Earth’s climate system, and that, in turn, will impose profound and mounting risks of ecological, economic and social collapse. In my view, our government’s actions and inactions that cause or contribute to

those emissions violate the fundamental rights of Sophie, other Youth, and future generations. Those violated rights include the right to life, the right to liberty, the right to property, the right to equal protection under the law, the right to government protection of public trust resources, and the right to retain a fighting chance to preserve a habitable climate system.

11. Here, then, I will address the fundamental context in which those fundamental rights violations arise. That context includes Earth's present and growing energy imbalance and the still real, but highly time-limited, opportunity to rapidly phase-down CO<sub>2</sub> emissions, restore energy balance, and stabilize the climate system.

12. The Court will find a more detailed treatment of these points, with supporting explanatory material and data, in two recent papers of which I am the lead author.

13. The first, Assessing “Dangerous Climate Change”: Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature, was published in late 2013, in conjunction with 17 colleagues. In that study we established that continued fossil fuel burning up to even 2°C above the preindustrial level<sup>1</sup> likely would cause large climate change with disastrous and irreversible consequences, so that actions to rapidly phase out CO<sub>2</sub> emissions are urgently needed to reduce the atmospheric CO<sub>2</sub> concentration to no more than 350ppm and restore Earth's energy balance. I have attached *Dangerous Climate Change* hereto as **Exhibit 2**,<sup>2</sup> and I hereby incorporate by reference, into this declaration, its analyses and conclusions.

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<sup>1</sup> We are already 0.9°C above the preindustrial temperature. Indeed, in 2015 global temperature is reaching a level ~1°C above the preindustrial level, but the high 2015 level is partly a temporary effect of a strong El Nino, a natural oscillation of tropical Pacific Ocean temperature.

<sup>2</sup> Published by PLOS One (Dec. 3, 2013) and available at: <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0081648>

14. The second, Ice Melt, Sea Level Rise and Superstorms: Evidence from Paleoclimate Data, Climate Modeling, and Modern Observations that 2°C Global Warming is Highly Dangerous, was published this month in conjunction with 16 colleagues. In it we conclude that, if CO<sub>2</sub> emissions are allowed such that energy is continuously pumped at a high rate into the ocean, then multi-meter sea level rise will become practically unavoidable, with consequences that may threaten the very fabric of civilization. I have attached *Ice Melt, Sea Level Rise and Superstorms* hereto as **Exhibit 3**,<sup>3</sup> and hereby incorporate by reference into this declaration its analyses and conclusions.

### **I. PRESENT AND LOOMING CLIMATE CRISES, AND A PATH TO STABILITY**

15. As indicated above, our late-2013 study provides a detailed treatment of our present predicament and the route that must be taken to sufficiently reduce atmospheric CO<sub>2</sub> to preserve a habitable climate system. See **Exhibit 2**. Our most recent work, establishing that nonlinear melting of Earth's major ice sheets is likely within a century, among other things, if fossil fuel emissions continue unabated, adds an additional element of immediacy to what, for too long, has been treated in practical terms as, at best, a distant but growing complication. See **Exhibit 3**.

16. I outline and summarize these matters here, before proceeding to a further explanation of them.

17. **First**: Human burning of fossil fuels has disrupted Earth's energy balance. In response, the planet is heating up – with no end in sight, unless we alter our present path. Atmospheric CO<sub>2</sub> concentration, for example, is now at its highest level in 3 million years, and

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<sup>3</sup> See also: <http://www.atmos-chem-phys-discuss.net/15/20059/2015/acpd-15-20059-2015.pdf>

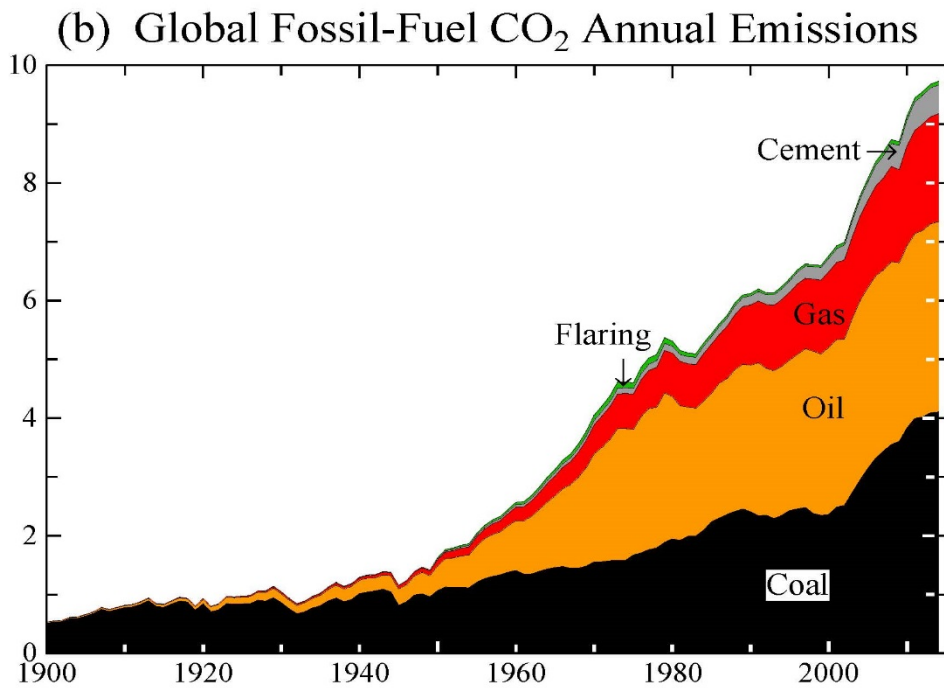
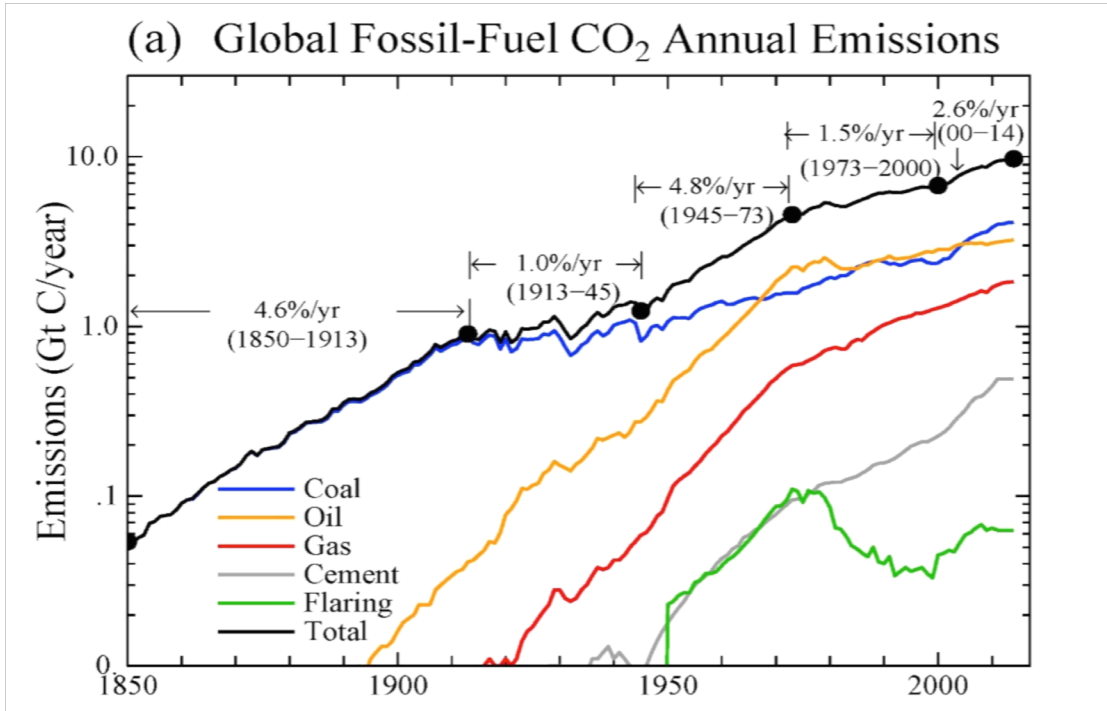
global surface temperatures now have reached the prior maximum of the Holocene era, the period of relatively moderate climate that, over the last 10,000 years, enabled civilization to develop.

18. **Second:** We are observing impacts of the relatively small amount of warming that has already occurred, and these constitute harbingers of far more dangerous change to come. We can discuss the observable consequences, and their implications, but the key point is that, if unabated, continued carbon emissions will initiate dynamic climate change and effects that spin out of human control, as the planet's energy imbalance triggers amplifying feedbacks and the climate and biological systems pass critical tipping points. Sea-level rise provides a key metric here.

19. **Third:** There is still time and opportunity to preserve a habitable climate system -- if we pursue a rational course. I will outline the glide path that we think remains feasible, though further delay in taking effective action will consign that effort to failure. Objectively, then, the situation is urgent and what governments and other decision-makers do, or do not do, today to reduce carbon pollution matters immensely.

## **II. OUR PLANET IS NOW OUT OF ENERGY BALANCE**

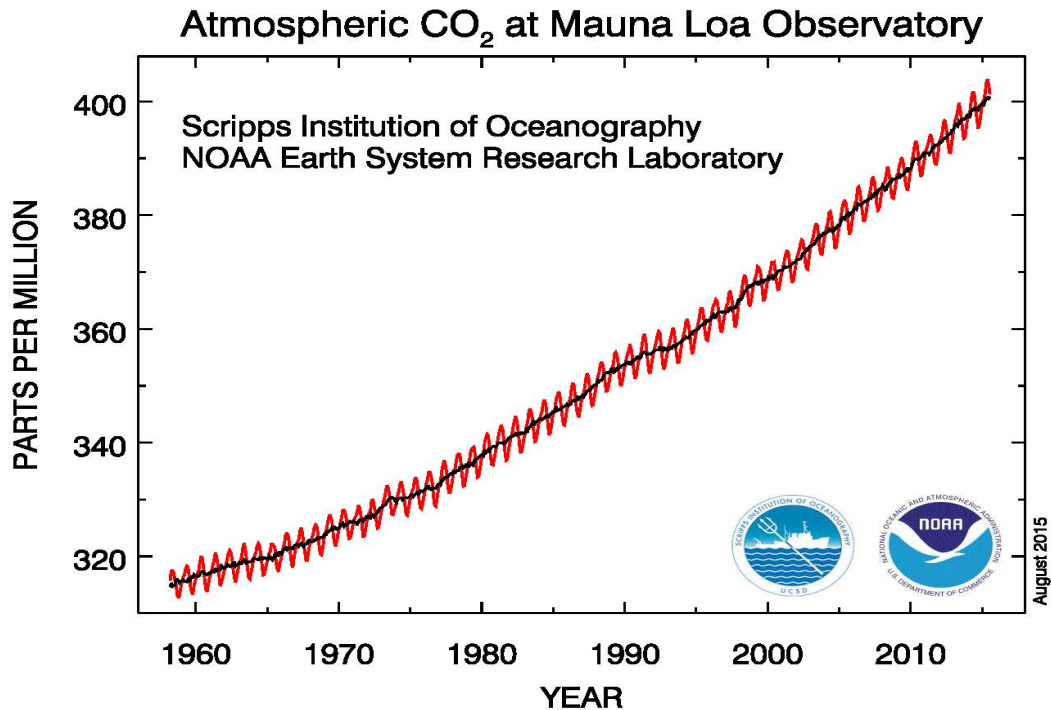
20. In Chart 1, we show global fossil fuel CO<sub>2</sub> emissions on an annual basis from the burning of coal, oil, and natural gas, and from cement production and flaring, along with the total emissions from these major sources. Although it is more than twenty years since 170 nations agreed to limit fossil fuel emissions in order to avoid dangerous human-made climate change, the stark reality – as illustrated here – is that global emissions have accelerated. Specifically, the growth rate of fossil fuel emissions increased from 1.5%/year during 1973–2000 to 2.6%/year in 2000–2014 (Chart 1(a)), due in the main to increased utilization of coal, oil, gas and cement (Chart 1(b)).



**Chart 1: CO<sub>2</sub> Annual Emissions From Fossil Fuel Use And Cement Manufacture**

Source: *Dangerous Climate Change* (**Exhibit 2** to this Declaration, at Fig. 1), updated through 2014 from <http://www.columbia.edu/~mhs119/CO2Emissions/>.

21. Our increased emissions are reflected, at least in part, in the rising concentration of atmospheric CO<sub>2</sub>, as is illustrated in Chart 2<sup>4</sup> that is based on readings taken at the Mauna Loa, Hawaii, observatory. The CO<sub>2</sub> atmospheric level is now approximately 400 ppm, over 40 percent more than the preindustrial level.



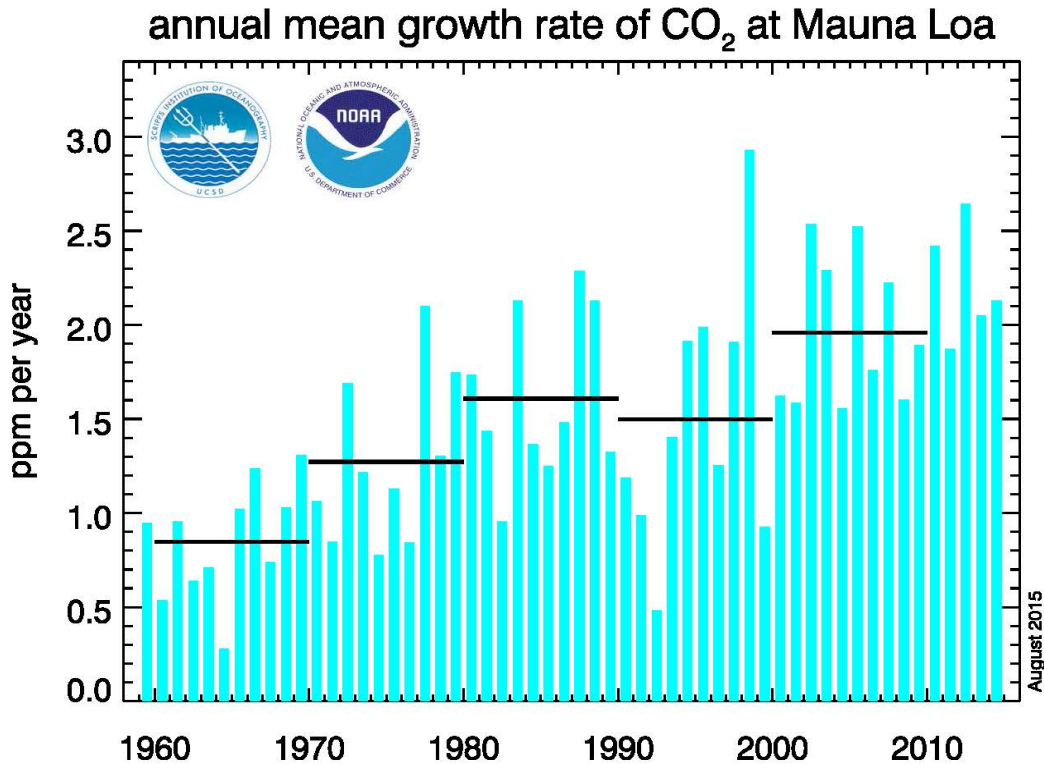
**Chart 2: From Noaa's Earth System Research Laboratory**  
at [http://www.esrl.noaa.gov/gmd/ccgg/trends/#mlo\\_full](http://www.esrl.noaa.gov/gmd/ccgg/trends/#mlo_full).

22. Moreover, the *increase* in the atmospheric CO<sub>2</sub> concentration is itself speeding up, as is illustrated in Chart 3.<sup>5</sup> The annual mean rate of CO<sub>2</sub> growth more than doubled from 0.85ppm in the 1960-70 period to 2.0ppm in 2000-2010.

<sup>4</sup> From [http://www.esrl.noaa.gov/gmd/ccgg/trends/#mlo\\_growth](http://www.esrl.noaa.gov/gmd/ccgg/trends/#mlo_growth)

<sup>5</sup> *Id.*





**Chart 3: From NOAA's Earth System Research Laboratory**  
at [http://www.esrl.noaa.gov/gmd/ccgg/trends/#mlo\\_growth](http://www.esrl.noaa.gov/gmd/ccgg/trends/#mlo_growth).

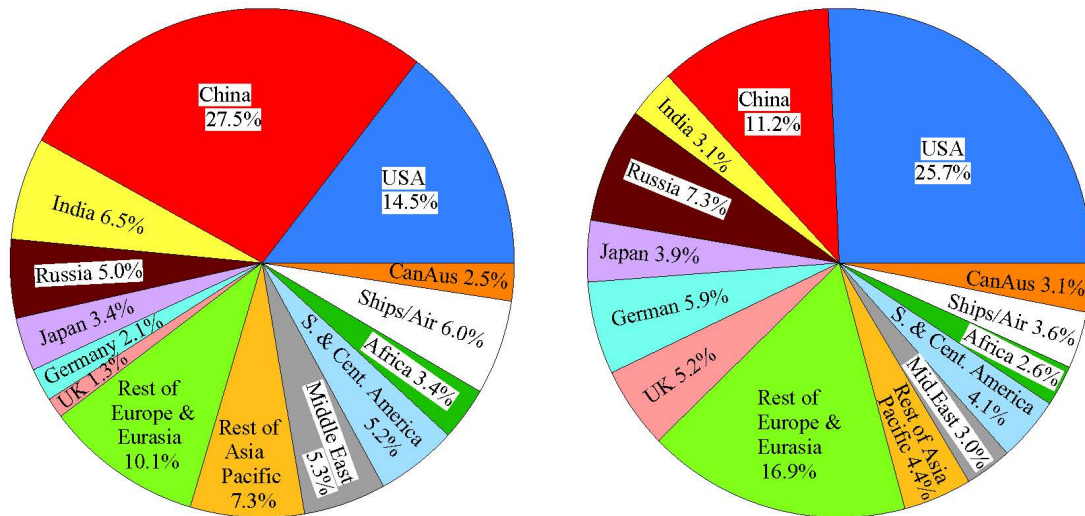
23. This increased concentration of CO<sub>2</sub> and other GHGs in the atmosphere operates to reduce Earth's heat radiation to space, thus causing an energy imbalance – less energy going out than coming in. This imbalance causes Earth to heat-up until it again radiates as much energy to space as it absorbs from the sun.

24. In point of fact, warming of Earth caused by the increasingly thick CO<sub>2</sub> “blanket” persisted even during the recent five-year solar minimum from 2005-2010. Had changes in insolation been the dominant forcing, the planet would have had a negative energy balance in that period, when solar irradiance was at its lowest level in the period of accurate data, i.e., since the 1970s. Instead, even though much of the greenhouse gas forcing had been expended in causing observed 0.9°C global warming to date, the residual positive forcing from CO<sub>2</sub> emissions

overwhelmed the negative solar. This illustrates, unequivocally, that it is human activity, and not the sun, that is the dominant driver of recent climate change.

25. In terms of responsibility for our present predicament, I will note that it is true, as we can illustrate with the aid of Chart 4 (a) (left side), that in recent years, CO<sub>2</sub> emissions from China have exceeded those from the U.S.

(a) 2013 Annual Emissions (9.9 GtC/yr) (b) 1751–2013 Cumulative Emis. (394 GtC)

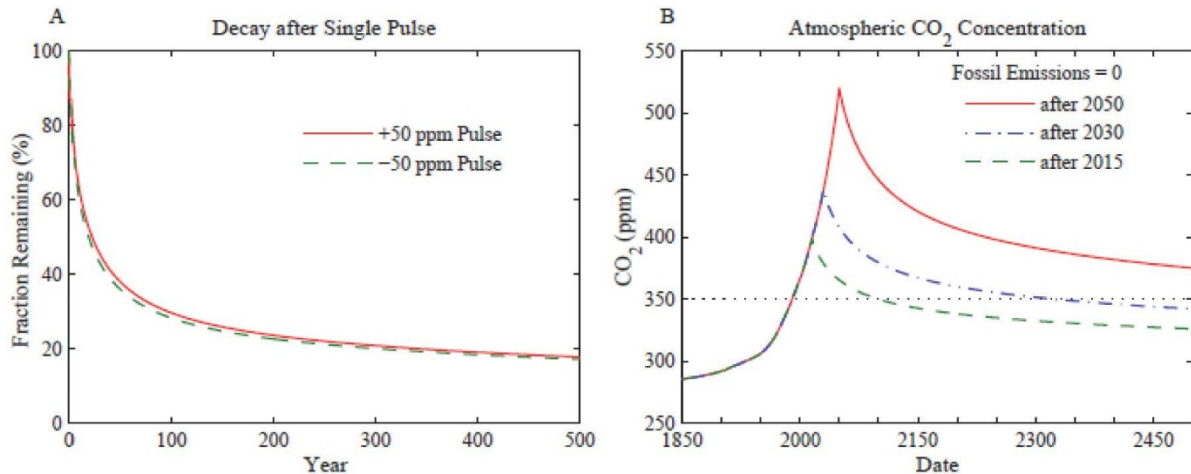


#### Chart 4: Fossil Fuel CO<sub>2</sub> Emissions

Source: *Dangerous Climate Change* (Exhibit 2 to this Declaration at Fig. 11) updated through 2013 at [http://www.columbia.edu/~mhs119/CO2Emissions/Emis\\_moreFigs/](http://www.columbia.edu/~mhs119/CO2Emissions/Emis_moreFigs/).

26. However, in light of the long residence time of CO<sub>2</sub> following its injection into the atmosphere, it is a nation's sum total of its emissions that is the more proper measure of its responsibility for already-realized and latent climate change. See Chart 4 (b) (right side). That chart illustrates that the United States is more responsible than any other for the present dangerously-highly atmospheric CO<sub>2</sub> concentration.

27. Here, I believe that a further word about the atmospheric residence time of CO<sub>2</sub> is in order, and we can do that with the aid of Chart 5 (left side).



### Chart 5: Decay Of Atmospheric CO<sub>2</sub> Perturbations

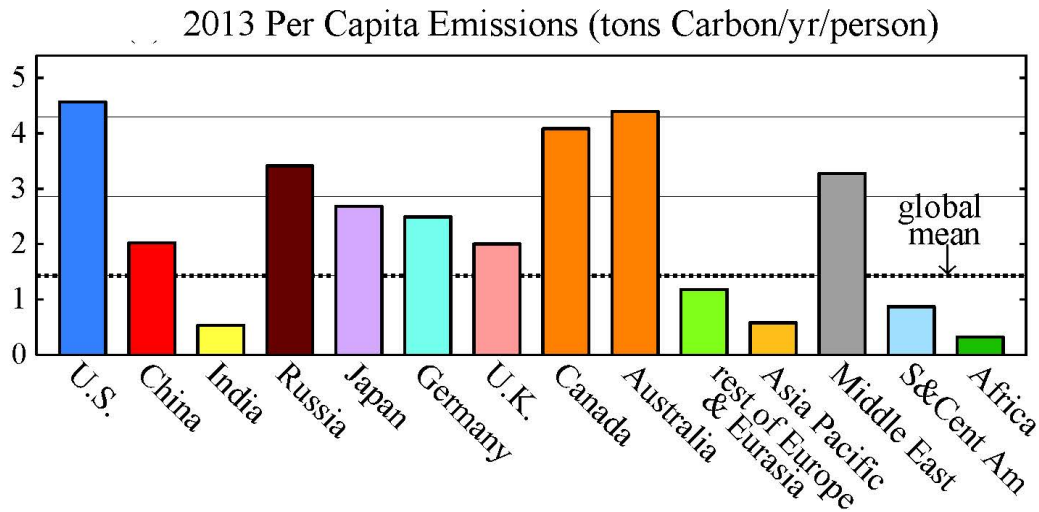
Source: *Dangerous Climate Change* (Exhibit 2 to this Declaration at Fig. 4). (A) Instantaneous injection or extraction of CO<sub>2</sub> with initial conditions at equilibrium. (B) Fossil fuel emissions terminate at the end of 2015, 2030, or 2050 and land use emissions terminate after 2015 in all three cases, i.e., thereafter there is no net deforestation.

28. A pulse of CO<sub>2</sub> injected into the air decays by half in about 25 years, as CO<sub>2</sub> is taken up by the ocean, biosphere and soil, but nearly one-fifth remains in the atmosphere after 500 years. Indeed, that estimate is likely optimistic, in light of the well-known nonlinearity in ocean chemistry and saturation of carbon sinks, implying that the airborne fraction probably will remain larger for a century and more. It requires hundreds of millennia for the chemical weathering of rocks to eventually deposit all of this initial CO<sub>2</sub> pulse on the ocean floor as carbonate sediments.

29. The critical point here is that carbon from fossil fuel burning remains in the climate system, with much of it in the atmosphere, and thus continues to affect the climate system for many millennia.

30. It is in part for this reason – the atmospheric persistence of CO<sub>2</sub> – that our national contribution to the problem is so large. Moreover, we can observe that, as compared with that of other major CO<sub>2</sub>-emitting nations, our national contribution to the global climate crisis is not only

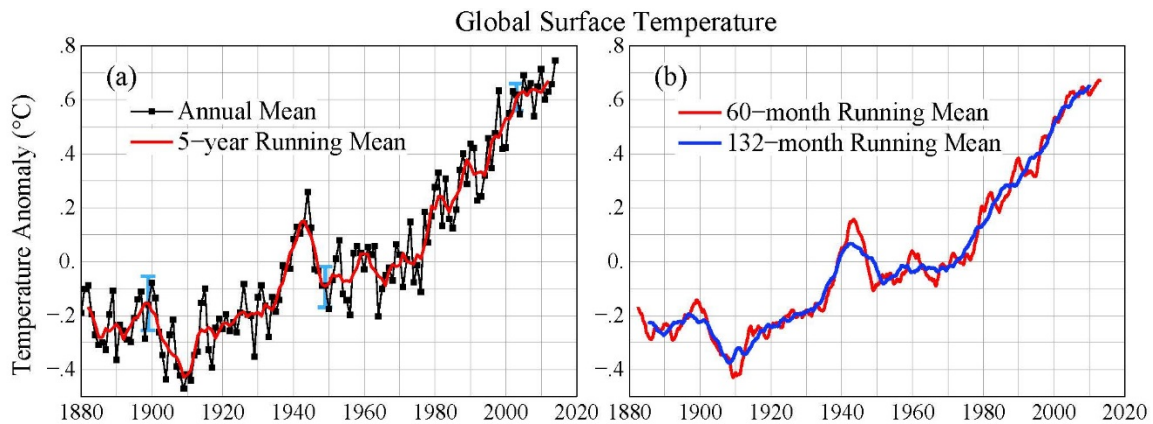
largest in absolute amount (Chart 4b), it dwarfs the contributions of the most populous nations on a per capita basis. Chart 6.



**Chart 6: Cumulative Per Capita Carbon Dioxide Emissions**

Source: [www.columbia.edu/~mhs119/YoungPeople/](http://www.columbia.edu/~mhs119/YoungPeople/).

31. Turning, now to Chart 7, we see the upward march of recent average global surface temperature.



**Chart 7: Global Surface Temperature Anomaly (60-Month And 132-Month Running Means) With A Base Period Of 1951-1980**

Source: *Dangerous Climate Change* (Exhibit 2 to this Declaration at Fig. 3), updated at <http://www.columbia.edu/~mhs119/Temperature/>.

32. Earth has now warmed about 0.9°C above the pre-industrial level. That is now close to, and probably slightly above, the prior maximum of the Holocene era – the period of relatively stable climate over the last 10,000 years that has enabled human civilization to develop.

33. The warming increases Earth’s radiation to space, thus reducing Earth’s energy imbalance. However, because of the ocean’s great thermal inertia, it requires centuries for the climate system to reach a new equilibrium consistent with a changed atmospheric composition. The planet’s energy imbalance confirms that substantial additional warming is “in the pipeline”. That energy imbalance is now measured by an international fleet of more than 3000 submersible floats that plumb the depths of the world’s ocean measuring the increasing heat content.

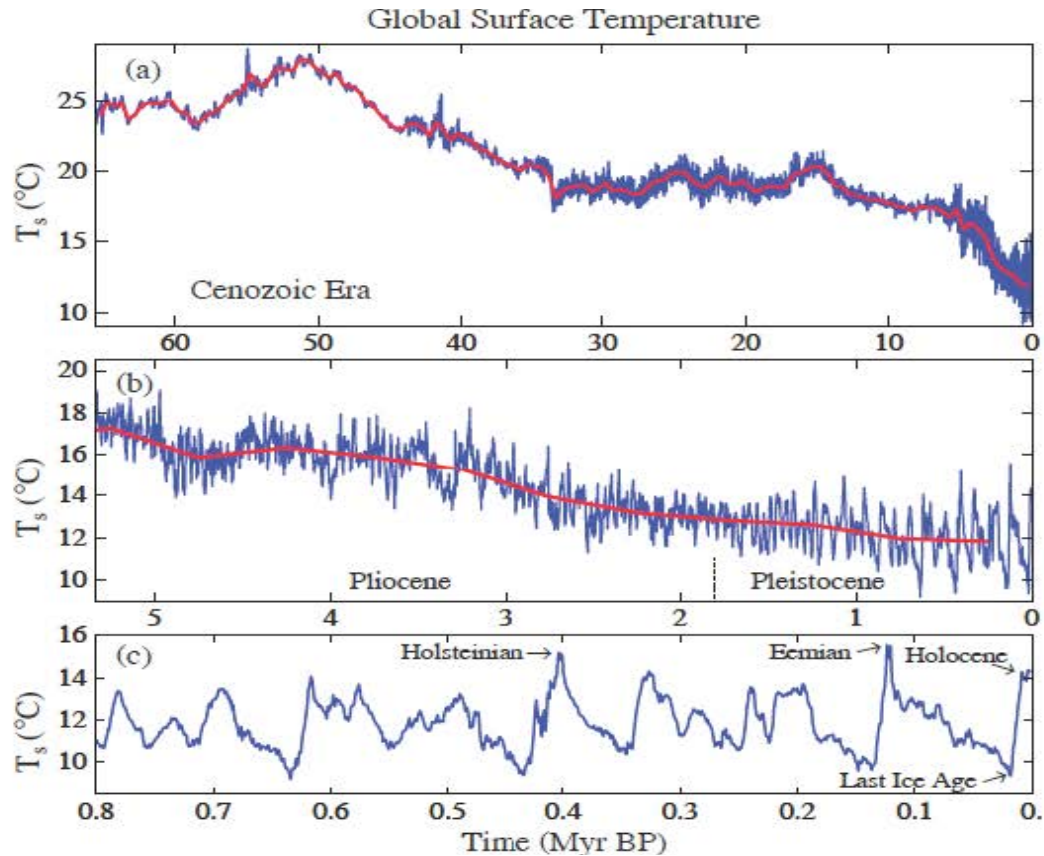
34. Earth’s energy imbalance now averages about 0.6 Watts/m<sup>2</sup> averaged over the entire planet, but I am uncertain whether this conveys to the Court the scale of what is going on. I can note that the total energy surplus is 300 trillion joules per second, but that large number may still be insufficiently evocative. Accordingly, it may be more useful to observe, and with equal validity, that Earth’s energy imbalance is equivalent to exploding more than 400,000 Hiroshima atomic bombs per day, 365 days per year. That is how much extra energy Earth is now gaining each day because of our use of the atmosphere as a waste dump for our carbon pollution.

35. We can turn now to Chart 8.

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**Chart 8: Surface Temperature Estimate for the Past 65.5 Myr, Including An Expanded Time Scale for (B) The Pliocene and Pleistocene and (C) The Past 800 000 Years**

Source: J. Hansen, et al, *Climate Sensitivity, Sea level and Atmospheric Carbon Dioxide*, Phil Trans R Soc A (2013), Fig. 4.

36. Here, we summarize the average global surface temperature record of the last 65 million years. This record is based on high-resolution ice core data covering the most recent several hundred thousand years, and ocean cores on time scales of millions of years. It provides us with insight as to global temperature sensitivity to external forcings such as added  $\text{CO}_2$ , and sea level sensitivity to global temperature. It also provides quantitative information about so-called “slow” feedback processes – such as melting ice sheets and lessened surface reflectivity attributable to darker surfaces resulting from melting ice sheets and reduced area of ice.

37. Several relevant conclusions can be drawn. First, the mechanisms that account for the relatively rapid oscillations between cold and warm climates were the same as those operating today. Those past climate oscillations were initiated not by fossil fuel burning, but by slow insolation changes attributable to perturbations of Earth's orbit and spin axis tilt. However, the mechanisms that caused these historical climate changes to be so large were two powerful amplifying feedbacks: the planet's surface albedo (its reflectivity, literally its whiteness) and atmospheric CO<sub>2</sub>.

38. Second, the longer paleoclimate record shows that warming coincident with atmospheric CO<sub>2</sub> concentrations as low as 450 ppm may have been enough to melt most of Antarctica. Global fossil fuel emissions – towards which, as I noted above, our nation has contributed more than any other – have already driven up the atmospheric CO<sub>2</sub> concentration to approximately 400 ppm – up from 280 ppm of the preindustrial era.

39. I conclude that the present level of CO<sub>2</sub> and its warming, both realized and latent, is already in the dangerous zone. Indeed, we are now in a period of overshoot, with early consequences that are already highly threatening and that will rise to unbearable unless action is taken without delay to restore energy balance at a lower atmospheric CO<sub>2</sub> amount. We can turn now to a brief review of the increasingly unacceptable, but still avoidable, consequences.

### **III. UNABATED EMISSIONS MAY DEVASTATE OUR COASTS, CIVILIZATION AND NATURE AS WE KNOW IT**

40. I will start with the ocean, in light of our most recent research.

41. While I have postulated previously that major ice sheet disintegration and resulting sea level rise is likely to be nonlinear in the event of continued high fossil fuel impacts, my concern had been based largely on heuristic grounds. Now, utilizing multiple lines of evidence – including satellite gravity measurement, surface mass balances, and satellite radar altimetry – it

has become clear, regrettably, that ice mass losses from Greenland, West Antarctica and parts of East Antarctica are growing nonlinearly, with doubling times so far this century of approximately 10 years.

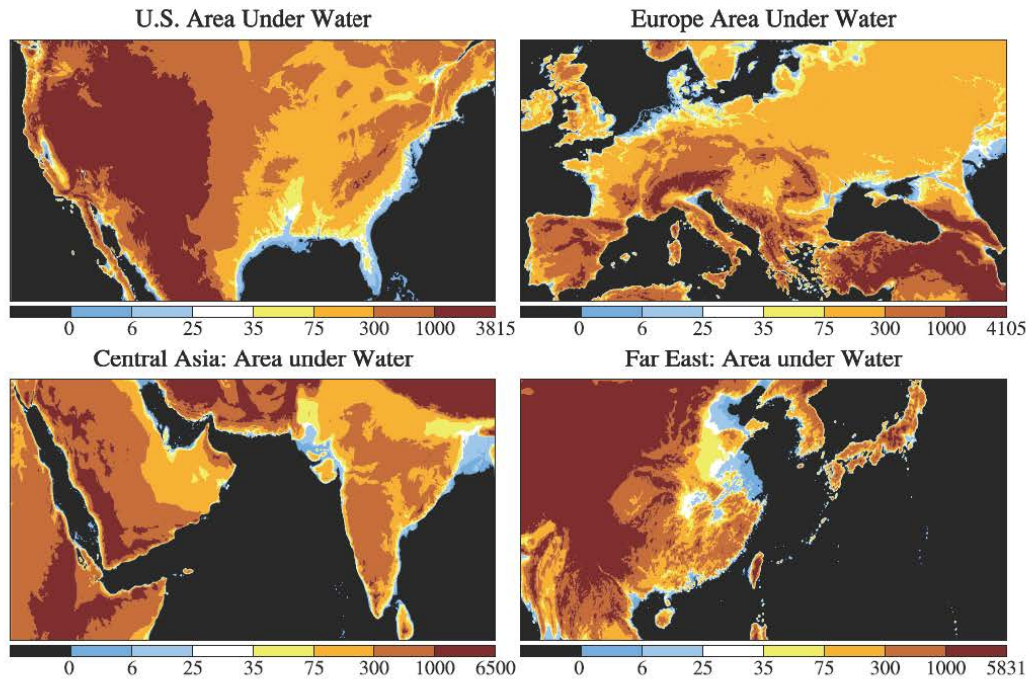
42. My colleagues and I expect the growth rate for ice mass loss in Greenland to slow, based on the most recent few years of data, but because of amplifying feedbacks described in our paper we also think it likely that Antarctic ice mass loss will continue to climb exponentially – again, if fossil fuel emissions are not rapidly abated. This prospect alone cries out for urgent national and international action to constrain carbon pollution, considering that complete disintegration of the Totten glacier in East Antarctica could raise sea levels by approximately 6-7m; that ice fronted by the Cook glacier in East Antarctica could add 3-4m of sea rise; and that West Antarctic ice fronted by Amundsen Sea glaciers have the potential to raise sea level an additional 3-4m. *See Exhibit 3* at 41.

43. In the light of this and related information, we have concluded that humanity faces “nearly certainty of eventual sea level rise of at least . . . 5-9m if fossil fuel emissions continue on a business-as-usual course.” *See Exhibit 3* at PDF page 31. Much of the U.S. eastern seaboard,<sup>6</sup> as well as low-lying areas of Europe, the Indian sub-continent, and the Far East, would then be submerged. *See Chart 9.*

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<sup>6</sup> Western U.S. cities too are vulnerable, to the degree that parts of them are relatively low-lying. It is estimated, for example, that sea level rise of “only” 10 feet (approximately 3 meters) will inundate over 4,000 acres (and over 3,000 homes) in Seattle, nearly 3,000 acres (and over 13,000 homes) in San Francisco, and over 4,000 acres (and nearly 10,000 homes) in San Diego. *See* Climate Central’s “Surging Seas” project at <http://sealevel.climatecentral.org/>.





**Chart 9: Areas (Light And Dark Blue) That Nominally Would Be Under Water For 6 And 25 M Sea Level Rise**

Source: Climate Science, Awareness, and Solutions, Earth Institute, Columbia University (2015).

44. That order of sea level rise would result in the loss of hundreds of historical coastal cities worldwide, with incalculable economic consequences. It would also create hundreds of millions of global warming refugees from highly populated low-lying areas, and thus likely cause or exacerbate major international conflicts.<sup>7</sup>

45. To avoid such a calamity, sea level rise must be recognized as a key limit on any conceivably allowable human-made climate forcing and atmospheric CO<sub>2</sub> concentration, with

<sup>7</sup> In addition, strong temperature gradients caused by ice melt freshening is likely to increase baroclinicity and provide energy for more severe weather events, including in the North Atlantic. This set of circumstances will drive the powerful superstorms of our future. Some of these impacts are beginning to occur sooner in the real world than in our climate model. See **Exhibit 3** at pdf 31.

fossil fuel emissions and land use changes constrained accordingly.<sup>8</sup> As discussed, ice sheet melting has now commenced even though global warming to date measures “only” 0.9°C above the pre-industrial period. This is consistent with the relevant paleoclimate evidence showing a multi-meter rise in sea level in the late Eemian period, approximately 125K years ago, when temperature was at most ~2°C warmer than pre-industrial climate (at most ~1°C warmer than today). This, in itself, and quite apart from the additional harm to terrestrial systems that must also be considered, implies that national and international goals and targets that aim to limit global warming to no more than 2°C run an unacceptably high risk of global catastrophe.

46. An important effect for the coming period of large scale ice sheet melting, in our view, is that the discharge of ice and cold fresh water will expand sea ice cover and result in ocean surface, regional and global cooling effects. *See Exhibit 3* at pdf 3-11. For varying periods, these effects would mask some of the global warming that would otherwise result from projected high CO<sub>2</sub> levels. The temporary surface cooling, however, would be coincident with a further increase in the planet’s energy imbalance, with added energy pumped into the ocean, and there be available, at Antarctica and Greenland, to further melt the subsurface shelves that, at present, restrain several of the planet’s major ice sheets at their grounding lines. *See Exhibit 3* at pdf 18.

47. Upon cessation of ice sheet disintegration and freshwater discharge, global temperature will recover – with the time period for such recovery depending on the amount of ice melt (and sea level rise), and with geographical, geophysical and oceanic circulation factors detailed in our recent study. *See Exhibit 3* at pdf 11.

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<sup>8</sup> This is so, as we wrote in “Ice Melt, Sea Level Rise and Superstorms,” *Exhibit 3* at pdf 32, in light of the “extreme sensitivity of sea level to ocean warming and the devastating economic and humanitarian impacts of a multi-meter sea level rise.”

48. With respect to other important natural and human systems, to which I will now turn, the impacts of global warming – including the renewed warming – will depend in part on the magnitude of Earth’s energy imbalance, and that, in turn, will be controlled by the level of excess atmospheric CO<sub>2</sub>. As I have noted already, global warming to date measures “only” 0.9°C above the pre-industrial period, and yet, that level of warming has already begun to have a widespread effect on natural and human systems.

49. For example, mountain glaciers, the source of fresh water to major world rivers during dry seasons, are receding rapidly all around the world. To cite a close-to-home example, glaciers in iconic Glacier National Park appear to be in full retreat: In 1850, according to the Park Service, Glacier had 150 glaciers measuring larger than twenty-five acres. Today, it has just twenty-five.

50. As well, tropospheric water vapor and heavy precipitation events have increased, as we would expect. A warmer atmosphere holds more moisture, thus enabling precipitation to be heavier and cause more extreme flooding. Higher temperatures, on the other hand, increase evaporation and can intensify droughts when they occur, as can the expansion of the subtropics that occurs as a consequence of global warming.

51. Coral reef ecosystems, harboring more than 1,000,000 species as the “rainforests” of the ocean, are impacted by a combination of ocean warming, acidification from rising atmospheric CO<sub>2</sub>, and other human-caused stresses, resulting in a 0.5-2% per year decline in geographic extent.

52. World health experts have concluded with “very high confidence” that climate change already contributes to the global burden of disease and premature death with expansion of

infectious disease vectors. Increasing climate variability is being examined as a possible contributor to the expansion of Ebola.

53. Subtropical climate belts have expanded, contributing to more intense droughts, summer heat waves, and devastating wildfires. Further, summer mega-heat-waves, such as those in Europe in 2003, the Moscow area in 2010, Texas and Oklahoma in 2011, Greenland in 2012, Australia in 2013, *Australia and California in 2014, and India, France and Spain this year (2015)*, have become more widespread.<sup>9</sup> The probability of such extreme heat events has increased by several times because of global warming, and the probability will increase even further if fossil fuel emissions continue to be permitted, so that global warming becomes locked in or rendered increasingly severe.

54. I have already mentioned the unparalleled calamity that the loss of scores of coastal cities to rapid sea level rise presents to human civilization. But I should mention that many other impacts also will abound.

55. For example, acidification stemming from ocean uptake of a portion of increased atmospheric CO<sub>2</sub> will increasingly disrupt coral reef ecosystem health, with potentially devastating impacts to certain nations and communities. Inland, fresh water security will be compromised, due to the effects of receding mountain glaciers and snowpack on seasonal freshwater availability of major rivers.

56. As to human health: increasing concentrations of CO<sub>2</sub> and associated increased global temperatures will deepen impacts, with children being especially vulnerable. Climate

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<sup>9</sup> Climate researchers in Oregon consider that state's recent heat and dry spell to be consistent with these trends, with the month of June, 2015 being said to be the warmest on record in much of the state. See Oregon Climate Service at <http://ocs.oregonstate.edu/>. In general, however, local observations of climate (heat) extremes are illustrative of what will occur with the increasing atmospheric CO<sub>2</sub> concentration, but I will caution that other, more stochastic, variables usually will be in play as well.

threats to health move through various pathways, including by placing additional stress on the availability of food, clean air, and clean water. Accordingly, unabated climate change will increase malnutrition and consequent disorders, including those related to child growth and development. It will increase death and illness associated with COPD, asthma, and other respiratory distress triggered by worsened allergies. Unabated emissions will also produce other injuries from heat waves; floods, storms, fires and droughts, and it will increase cardio-respiratory morbidity and mortality associated with increased ground-level ozone.

57. With regard to other species, we see that climate zones are already shifting at rates that exceed natural rates of change; this trend will continue as long as the planet is out of energy balance. As the shift of climate zones becomes comparable to the range of some species, the less mobile species will be driven to extinction. According to the UN Panel on Climate Change, with global warming of 1.6°C or more relative to pre-industrial levels, 9-31 percent of species are anticipated to be driven to extinction, while with global warming of 2.9°C, an estimated 21-52 percent of species will be driven to extinction. These temperature/extinction thresholds will not be avoided absent concerted, rational action on carbon emissions.

58. At present, we remain on track to burn a significant fraction of readily available fossil fuels, including coal, oil, natural gas, and tar sands, and so to raise average surface temperature, over time, to far above pre-industrial levels.

59. High global surface temperatures have been recorded previously, in the age of mammals, with some successful adaptation through evolution of higher surface-area-to-mass ratio body types – for example transient dwarfing of mammals and even soil fauna. However, human-made warming is occurring rapidly and will be fully realized in only centuries, as opposed to millennia, thus providing little opportunity for evolutionary dwarfism to alleviate impacts of

global warming. Along with several colleagues, I have been forced to conclude that the large climate change that would result from burning all or most fossil fuels threatens the survival of humanity.

60. All of which brings me to my third point.

**IV. RESTORATION OF OUR CLIMATE SYSTEM, AND SO PROTECTION OF OUR FUTURE, IS STILL POSSIBLE, BUT WE MUST ACT WITH REASON, COURAGE, AND NO FURTHER DELAY**

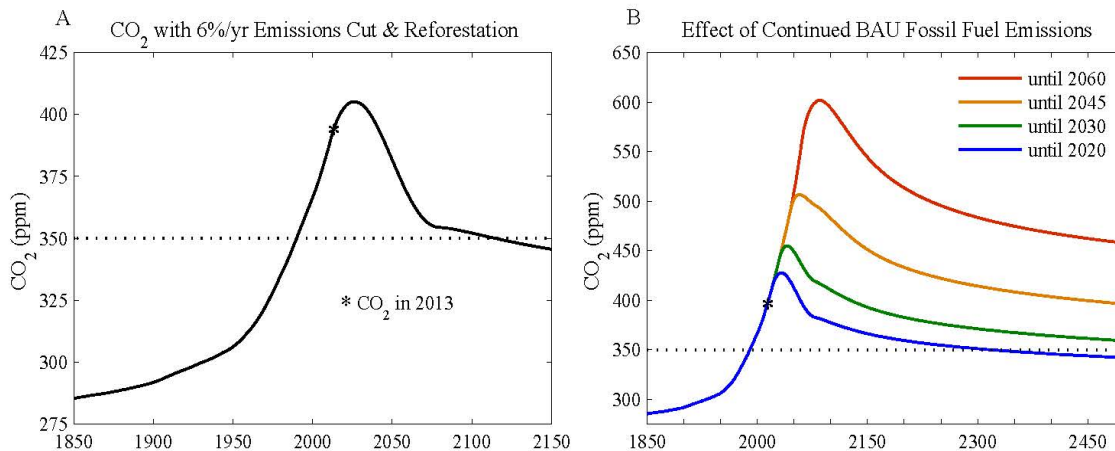
61. As I indicated above, the energy imbalance of Earth is about 0.6 W/m<sup>2</sup>. In the light of that imbalance, colleagues and I have calculated the level to which atmospheric CO<sub>2</sub> must be drawn down in order to increase Earth's heat radiation to space by the same amount and thus restore energy balance – the fundamental requirement to stabilize climate and avoid further dangerous warming.

62. The measured energy imbalance indicates that CO<sub>2</sub> must be reduced to a level below 350 ppm, assuming that the net of other human-made climate forcings remains at today's level. Specification now of a CO<sub>2</sub> target more precise than <350 ppm is difficult due to uncertain future changes of radiative forcing from other gases, aerosols and surface albedo, but greater precision should be feasible during the time that it takes to turn around CO<sub>2</sub> growth and approach the initial 350 ppm target.

63. Let us return, for a moment, to Chart 5, so as to consider again the question of delay. On the left side of the chart, the long-residence time for atmospheric CO<sub>2</sub> is illustrated. It is reflected in the length of time it would take to return CO<sub>2</sub> to lower concentrations even if, as indicated on the right side of the chart, fossil fuel emissions were to cease entirely.

64. Of course, an abrupt cessation of all CO<sub>2</sub> emissions, whether this year or in 2030, is unrealistic. Industry, other business, and consumers all need time to retool and reinvest in emission-free options to fossil fuels.

65. Accordingly, we have evaluated emissions reduction scenarios to devise the path that is both technically and economically feasible, while being sufficiently rigorous to constrain the period of “carbon overshoot” and avoid calamitous consequences (greatly accelerated warming, ecosystem collapse, and widespread species extermination). *See Chart 10.*



**Chart 10: Atmospheric CO<sub>2</sub> If Fossil Fuel Emissions Are Reduced.**

(A) 6% Or 2% Annual Cut Begins In 2013 And 100 GRC Reforestation Drawdown Occurs In 2031-2080, (B) Effect Of Delaying Onset Of Emission Reductions.

Source: *Dangerous Climate Change* (Exhibit 2 to this Declaration at Fig. 5).

66. Our analysis prescribes a glide path towards achieving energy balance by the end of the century. It is characterized by large, long-term global emissions reductions (of approximately 6 percent annually, if commenced this year), coupled with programs to limit and reverse land use emissions via reforestation and improved agricultural and forestry practices (drawing down approximately 100 GtC by the year 2100).

67. These actions could achieve the goal of restoring the atmosphere to approximately 350 ppm within this century if the plan were commenced without delay, and then adhered to. As I have indicated, such action is minimally needed to restore earth's energy balance, preserve the planet's climate system, and avert irretrievable damage to human and natural systems – including agriculture, ocean fisheries, and fresh water supply – on which civilization depends. However, consistent with the abrupt phase out scenarios discussed in the prior paragraph, if rapid annual emissions reductions are delayed until 2030, then the global temperature will remain more than 1°C higher than preindustrial levels for about 400 years. Were the emissions cessation only to commence after 40 years, then the atmosphere would not return to 350 ppm CO<sub>2</sub> for nearly 1000 years. Overshooting the safe level of atmospheric CO<sub>2</sub> and the safe range of global ambient temperature for anything approaching these periods will consign succeeding generations to a vastly different, less hospitable planet.

68. Considered another way, the required rate of emissions reduction would have been about 3.5% per year if reductions had started in 2005 and continued annually thereafter, while the required rate of reduction, if commenced in 2020, will be approximately 15% per year. Accordingly, the dominant factor is the date at which fossil fuel emission phase out begins, again presuming the rate of annual emissions reductions thereafter are sustained.

#### **V. THE FUNDAMENTAL RIGHTS OF MY GRANDDAUGHTER SOPHIE, OTHER CHILDREN, AND FUTURE GENERATIONS TO A HABITABLE PLANET**

69. With all of the above having now been said, and serving as background, I can return, finally, and briefly, to consider the nature of the violations of the rights of my granddaughter and future generations that are properly attributable our government's continued permitting, leasing, and other support for fossil fuel exploitation and expansion projects--



particularly in the absence of any countervailing, coherent, effective government program to rapidly reduce atmospheric CO<sub>2</sub> to a safe level.

70. In this, I include our government's approval of the Jordan Cove project at Coos Bay, Oregon. To be specific, in the context of US emissions to date and the present global climate crisis those emissions have done much to engender, the additional emissions stemming from Jordan Cove will work only to further increase the atmospheric concentrations of CO<sub>2</sub>, and thus to further increase Earth's energy imbalance – *thereby driving our planet towards and potentially beyond irretrievable climate system tipping points.*

71. This is so because, by exacerbating or locking-in Earth's energy imbalance, such government action jeopardizes the signal features of the relatively benign and favorable climate system that, over the last 10,000 years, enabled civilization to develop and nature to thrive, as I have discussed. These features included relatively stable coastlines, moderate weather, fertile soils, and dependable hydrological systems – the natural capital on which the lives of Plaintiffs depend no less than did the lives of their parents and *their* forebears.

72. As well, present and future government action that exacerbates or locks-in Earth's energy imbalance risk economic collapse, social disintegration, and the loss of essential natural and human services, as I have discussed. The resulting diminution of Plaintiffs' life prospects – their compromised ability to earn a living, to meet their basic human needs, to safely raise families, to practice their religious and spiritual beliefs, and otherwise to lead dignified lives – is a predictable if not intended result of the government action.

73. In addition, where such government action exacerbates or locks-in Earth's energy imbalance that, in turn, predictably will lead to the climate change-driven inundation, burning, or other destruction of the value of property in which Plaintiffs hold interests. These will include the

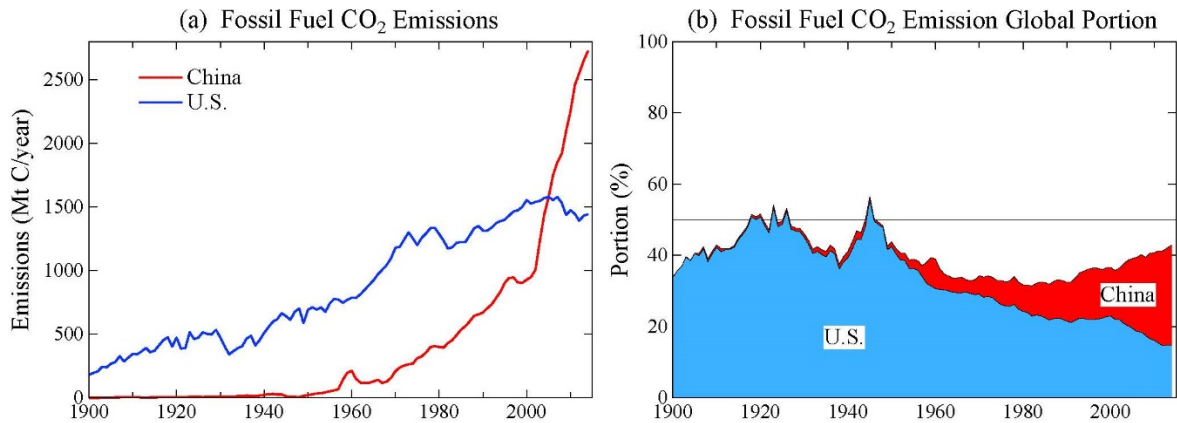
homes, farms and other valuable property that their parents or grandparents own and that Plaintiffs will inherit.

74. Further, these government actions, in consequence of their long-term impacts on Earth's climate system and the thermal inertia of the ocean, will disproportionately impose harsh burdens on Plaintiffs. If fossil fuel emissions are not systematically and rapidly abated, as I have discussed above – including in the materials that I have incorporated by reference – then Youth and Future Generations Plaintiffs will confront what reasonably only can be described as, at best, an inhospitable future. That future may be marked by rising seas, coastal city functionality loss, mass migrations, resource wars, food shortages, heat waves, mega-storms, soil depletion and desiccation, freshwater shortage, public health system collapse, and the extinction of increasing numbers of species. That is to mention only the start of it. At this late stage it is important not to sugarcoat the fundamental assault on their right to equal protection of the law: While prior generations and, to a certain extent, some in our present generation have benefitted and, even, been enriched by the exploitation of fossil fuels, our children and their progeny will not similarly benefit. Indeed, the impact on Plaintiffs' will be nearly completely to the contrary, as I have discussed.

75. Closely-related to the above, our government's continued permitting and promotion of the fossil fuel enterprise now impairs and increasingly will compromise the fundamental natural resources on which Plaintiffs will depend. Again, these are the fundamental resources on which the prior and present generations have relied, and on which Plaintiffs now and in the future must rely. They include the air, freshwater, the oceans and stable shores, the soil and its agronomic capacity, the forests and its wildlife, biodiversity on earth, and the planet's climate system in a form conducive to civilization, humanity and nature as we know it.

76. Furthermore, it is clear to me that Plaintiffs' right to a government that retains any significant capacity to address the climate crisis adequately is violated by prior and present government actions that exacerbate or lock-in our planet's energy imbalance. In time and, as I have argued, likely within the century, such action will irretrievably damage our planet's favorable climate system. Once begun, for example, collapsing and disintegrating ice sheets will not readily be reformulated – certainly not within a timeframe relevant to present and foreseeable generations. The loss of species too is irretrievable. Many are adapted to specific climate zones, so those species adapted to polar and alpine regions will have no place to run. Present and pending actions by our government now must be viewed in the context of a climate crisis that our government to date has done so much to bring about. Action is required to preserve and restore the climate system such as we have known it in order for the planet as we have known it to be able to continue adequately to support the lives and prospects of young people and future generations. But that cannot be done effectively by future governments if ours continues to exacerbate the planet's energy imbalance and press our planet towards irretrievable tipping points from which there can be no practical opportunity to return.

77. To further explain this last point, I will note that earlier in this declaration I discussed our nation's outsized role in creating, through its CO<sub>2</sub> emissions, our present emergency with respect to the planet's climate system. *See supra*, text surrounding Chart 4 and Chart 6. Other nations are keenly aware of this basic fact including, most importantly, China. It is, accordingly, worthwhile here – in the context of considering responsibility to resolve the present crisis and preserve a habitable climate system – to consider further these top two emitters' role.



**Chart 11: Top Two Annual Emitters And Their Cumulative Emissions**

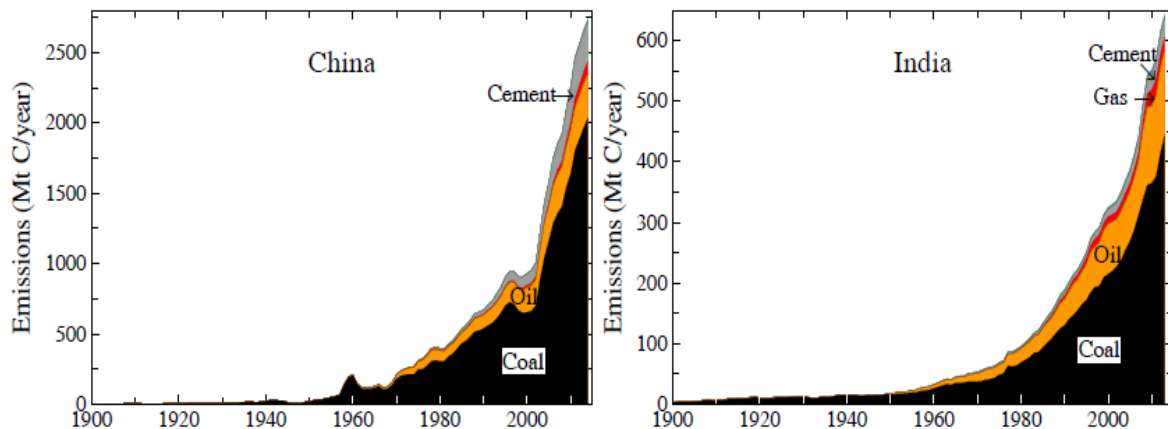
(a) Fossil fuel CO<sub>2</sub> Emissions, 1990 Through 2014, (B) Cumulative Shares: U.S. And China  
 Source: Climate Science, Awareness and Solutions, based on data from ORNL through 2011, updated with BP data through 2014.

78. China's annual CO<sub>2</sub> emissions caught those of the United States in 2005 and then rapidly surpassed U.S. emissions. *See* Chart 11 (a) (left side). However, any nation's contribution to climate change is proportional to its cumulative emissions over time.<sup>10</sup> China's responsibility for global climate change remains a fraction of that of the U.S., despite China's much larger population. *See* Chart 11 (b) (right side). Specifically, China's share of global fossil fuel CO<sub>2</sub> emissions through 2014 is 11.6 percent while the United States share is 25.5 percent.

79. Accordingly, in the light of our preponderant role, the United States has special responsibility for helping to solve the global emissions problem. The remaining carbon "budget" – the amount of emissions that can be tolerated while still allowing the possibility of stabilizing climate – is very small. As we have noted, climate stability requires that global emissions decline by at least 6% per year. In effect, the United States burned not only its fair share of the total (cumulative) carbon budget, it also burned much of China and India's fair shares.

<sup>10</sup> Hansen, J., *et al.*, *Dangerous human-made interference with climate: A GISS modelE study*. *Atmos. Chem. Phys.*, 7, 2287-2312, doi:10.5194/acp-7-2287-2007.

80. It is instructive to examine the emissions of China and India, which are shown in Chart 12. China is the #1 global emitter of CO<sub>2</sub> and India is #3, with the United States being #2. Together the three nations emit about half of global emissions, i.e., the same as the other 190 nations of the world combined. Two conclusions leap out from Chart 12. First, emissions in those nations are accelerating rapidly. Second, most of their emissions are from coal burning. (Note that the scale of the vertical axis is different for China and India. India is in an earlier stage of economic development and its emissions are as yet much smaller than China's.)



**Chart 12: CO<sub>2</sub> Emissions From China (Left Side) And India (Right Side)**

Graphic from Climate Science, Awareness and Solutions, utilizing data from the Carbon Dioxide Information Analysis Center and the [BP Statistical Review of World Energy \(2014\)](#).

81. The rapid growth of coal emissions is both a threat to global climate and a source of hope. If coal can be replaced with carbon-free energy, a huge reduction of global emissions becomes possible. In view of the responsibility of the United States for the excess CO<sub>2</sub> in the air today, as well as the fact that U.S. citizens will suffer the consequences of global emissions, it is incumbent upon the U.S. to vigorously assist China with the technology required to replace coal burning. Yet the U.S. government, and its chief executive, the President have not undertaken such actions, leaving today's young people and future generations extremely vulnerable. Indeed,

U.S. actions to date have been mostly rhetorical.<sup>11</sup> Instead, our government including, especially, the U.S. President, should marshal every available tool, talent, and resource to address and resolve the present crisis with honesty and without further delay.

82. Young people have multiple rights that are guaranteed by our Constitution, including equal protection of the law, equal rights to enjoy life, liberty, property, and the pursuit of happiness – rights that should not be denied without due process. It is the duty of all branches of government to protect those rights. Specifically, it is a duty of the chief executive, the President, to lead and propose and pursue policies that achieve the required ends, as opposed to ineffectual actions that are demonstrably far short of what is needed.

83. The essential step, in my view and that of other experts, including economists,<sup>12</sup> is an accord establishing a growing price on CO<sub>2</sub> emissions, which would lead over time to their phase-out. Agreement upon such a domestic fee by major emitters, most notably the United States and China, with a border duty on products from nations that do not have an equivalent domestic carbon fee, would be expected to lead to widespread global movement toward carbon-free energies.

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<sup>11</sup> EPA’s much-vaunted “Clean Power Plan,” for example, actually allows U.S. coal-fired power plants to continue to operate for decades, and that Agency itself anticipates that, under the rule, power plant emission reductions will proceed at a slower pace than occurred in the ten-year period *prior* to the rule’s enactment.

<sup>12</sup> These include three co-authors of our 2013 PLOS One study. See **Exhibit 2**. The government also has understood the central importance of a rising carbon price, and for at least 25 years. See, e.g., Congressional Office of Technology Assessment, *Changing by Degrees: Steps To Reduce Greenhouse Gases* (1991) at 15 (“a particularly effective way of targeting the heaviest economic sanctions against the worst emitters of CO<sub>2</sub>.”). As colleagues and I noted in 2013, **Exhibit 2** at 19, “[a] rising carbon fee is the *sine qua non* for fossil fuel phase out.”

84. I could go on, but will not so as to show mercy on the Court. Accordingly, I end here with a summary statement, in the light of the foregoing material that I have outlined and referenced, and with the offer to further explain my views and reasoning at the Court's request.

85. Simply put: Our government's persistent permitting and underwriting of fossil fuel projects serves now to further disrupt the favorable climate system that to date enabled human civilization to develop. In order to preserve a viable climate system, our use of fossil fuels must be phased out as rapidly as is feasible. Only government can ensure this will be done. Instead, our government seeks approval for permitting of fossil fuel projects that would slam shut the narrowing window of opportunity to stabilize climate and ensure a hospitable climate and planet for young people and future generations. These projects only allow our government to shirk its duty. Our government's permitting of additional, new, or renewed fossil fuel projects is entirely antithetical to its fundamental responsibility to our children and their posterity. Their fundamental rights now hang in the balance.

I am prepared, as necessary, to further explain or elaborate on any of the points I have made in this declaration, as warranted, for the Court.

I, James E. Hansen, declare under penalty of perjury under the laws of the United States of America that the foregoing constitutes my true and correct written testimony in the matter *Xiuhtezcatl Tonatiuh M. et al. v. the United States of America et al.*, No. \_\_, United States District Court, District of Oregon.

I declare under penalty of perjury under the laws of the State of Oregon that the foregoing is true and correct.

Executed this 11th day of August, 2015 in New York City, New York.

  
**DR. JAMES E. HANSEN**